1-1-2005

Flexibility – Examining an Underappreciated Motivation for Outsourcing with an Optimization Model in a Small E-Product Manufacturer

Asser Fayed
Portland State University

Timothy R. Anderson
Portland State University, tim.anderson@pdx.edu

David Fenwick
Portland State University

Citation Details

Fayed, A., Anderson, T., and Fenwick, D. Flexibility – Examining an Underappreciated Motivation for Outsourcing with an Optimization Model in a Small E-Product Manufacturer. Portland International Conference on Management of Engineering and Technology (PICMET '05)

Flexibility – Examining an Underappreciated Motivation for Outsourcing with an Optimization Model in a Small E-Product Manufacturer

Asser Fayed, Timothy Anderson, Dave Fenwick
Department of Engineering and Technology Management, Portland State University, Portland, OR, USA

Abstract—Technology outsourcing has recently become a politically sensitive issue with proponents emphasizing long-term economic growth opportunities, and opponents pointing out immediate job losses. The underlying reason for outsourcing is often assumed to be the availability of cheaper labor outside the USA but this overlooks the possibility that companies may simply be seeking greater labor flexibility outside of US state and federal labor laws. This paper quantitatively tests a software company's motivation to secure a flexible and adaptable labor pool. Although production lines located at multiple sites provide great flexibility for scheduling and costs because each site has its own local expenses, capacities, and capabilities. This flexibility comes at the cost of added complexity of production planning, hiring and training employees, and quality assurance of finished products. A mixed integer optimization model is introduced to evaluate an outsourcing decision by placing a value on labor flexibility. This model is then used to examine the sensitivity of the outsourcing decision to various parameters.

I. INTRODUCTION

Outsourcing in the information technology industry has increased sharply after the internet bubble with drops in products demand and firm trying to cut production costs. The underlying reason for outsourcing has often been assumed to be cheaper labor offshore [1]. This reasoning has been driving waves of off-shoring with companies outsourcing all possible jobs being under the impression it is cheaper to do so. However this under appreciates other factors behind the outsourcing such as labor flexibility. Outsourcing has been shown to be favorable under some circumstances but this does not mean that it will be favorable under any operating conditions and that we have to outsource all of our production capacity [2]. Labor efficiency, ramp-up capabilities and quality are among some of the factors that need to be considered when making outsourcing decisions.

Fully customized products require more responsive manufacturing capabilities where inventory is not permissible and all the production has to be make-to-order [3]. Multiple production lines provide the flexibility needed to meet that nature of orders but add additional dimensions that increase the complexity of the production planning. Fluctuations in order quantity require continuous adjustments in the production scheduling [4].

Predicting production demand is a critical component of make-to-order production planning success. How well production capacity is capable of responding to orders could spell the difference between profit and loss. In industries such as IT and services where production capacity entails greater labor requirements, labor availability and productivity need to be managed very closely.

The production problem is taken from an actual situation at an e-goods company located in Oregon, USA. The paper quantitatively tests the company's motivation to secure a flexible labor pool. An MIP optimization model is used to evaluate an outsourcing decision by including labor flexibility, integrating labor efficiency, cost and learning curve.

Next section describes the problem environment. Section III presents the research questions. Section IV presents the model followed by the formulation in section V. Section VI discusses results and the final section presents the conclusion.

II. THE CASE DESCRIPTION

ABC, Inc.[1] is a software company that makes custom handwriting fonts from single page handwriting sample forms. These paper forms are scanned and saved in a graphics format, and can be transmitted electronically via Internet to any potential production location in the world.

Once in production, the graphic documents are opened up in a proprietary computer application. A production employee makes changes and adjustments to the form on screen, and then guides the program through the creation of the font. Once a font is created, another employee checks the quality of the finished font, and ships it out also via Internet. Because no additional production parts or supplies are required, and all shipping is done electronically, changes in the employee costs have a tremendous effect on total production costs at ABC, Inc.

Significant ABC employee production considerations include the type of product being produced, the experience of the production employee, the local production employee pay scale, and the month of production ramp-up. Each of these four considerations represents a dimension in the formulation. External considerations include the quantity of orders received, the length of time allowed for processing, the production overhead of the QA and order processing, and the advertising costs.

A. Product Type

Three different product types are considered, with each varying in complexity and time to complete. They will be referred to as T1, T2, and T3 to protect the company's identity. Each type of product is tailored to a specific customer.

[1] Data is aggregated to protect company confidentiality.

B. Employee Experience

Beginning production employees in training may take days to produce their first T3 that would pass quality assurance testing, while an experienced employee may take only 30 minutes. On average, the T1 takes approximately 5 minutes of production time to produce, the T2 averages 10 minutes, and the T3 takes about 30 minutes to produce.

Four different levels of experience will considered for the ILP model:

- Entry Level trainees with less than a month of experience;
- Production employees with between 1 month and 2 months;
- Production Level employees with between 3 month and 6 months of experience; and
- Senior Level production employees with more than 6 months of experience.

Table 1 shows the relative times required for the production of the three different products from the domestic employees with differing levels of experience.

TABLE 1. PRODUCTION EXPERIENCE EFFICIENCY

Employee Experience	T1	T2	T3
< 1 month	40 min.	60 min.	150 min.
1-2 months	15 min.	30 min.	90 min.
3-6 months	10 min.	20 min.	60 min.
> 6 months	5 min.	10 min.	30 min.

C. Local Pay Scales

Two different site locations are considered for pay scales: one in USA, and one in China.

Production pay is a fixed pay based on the skill level plus a compensation determined on a price per piece basis for only completed products that have passed QA. More experienced employees make considerably more pay than inexperienced trainees due to the additional number of products that more experienced employee may produce and a higher fixed monthly pay.

D. Monthly Production Ramp-up

New employees require training. An existing employee can't have more than one trainee at a month. Thus the capacity ramp up is constrained by the previous month capacity at that location. Two locations are considered. With training and experience, employees' productivity improvement follows a skill-level improvement curve which differs from one location to another.

III. THE RESEARCH QUESTIONS

The research questions raised by this study is intended to provide a more understanding of the drivers behind outsourcing and to what extent it should pursued. Three hypothesis are built around the company common believe to be investigated by the model.

In the last recession many companies have started exploring outsourcing as an option to reduce manufacturing cost [5]. ABC, Inc. wasn't in much different than other companies and there was an immediate need for cost reductions. Outsourcing was considered as an option. The common belief was that outsourcing would be favorable only because of the cheaper labor overseas.

H1: Cheaper labor overseas is can fully explain outsourcing practices of ABC.

After the recession came to an end, demand quickly increased. Overseas was believed to provide better ramp-up capabilities because of the cheaper labor.

H2: Outsourced production volume ramp-up is preferable than domestic ramp-up.

H3: All production should be outsourced.

IV. THE MODEL

After studying the case, a model has been developed by determining the needed data and collecting them, recognizing the company objective, identifying the decision variables that are under decision makers control and need to be optimized and mapping the constraints on the different aspects of the problem that can't be violated. Below is the description of the data, variables, objective function, and the constraints.

The goal of the formulation is to maximize profit, which is defined here as being gross revenue minus labor cost and cost of goods and advertising. Other fixed and variable corporate operating costs will not be considered in the objective for simplicity.

A. Data

The data is categorized into product related and labor related.

1. The product related data consists of:

- The amount of orders of each product type received each month.
- The grace period within which the product demand must be met.
- The time required to produce a unit of each product type by each labor skill level at each location.
- The advertisement cost each month.
- The unit cost of each product type at each location.
- The selling price of each product type.

2. The labor related data consists of:

A wide variety of information is needed about labor to provide a meaningful model for testing. Employees experience is significant in the production time and hence the product cost as well as the available production capacity. The modeling of this problem accommodates a novel labor skill scale presenting the labor productivity improvement with training and experience. The starting number of employees at each location is necessary to set initial starting conditions. Working schedules may by country and therefore the available working time for an employee for each month at

each location excluding holidays needs to be modeled.

An appropriate overhead cost for each labor skill level at each location which includes the fixed pay, office space cost, and equipment and software license costs was used.

Company experience has shown that employees in different countries vary in their ability to develop skills for producing their products. Therefore, both locations had different employee's skill-level improvement curves and new employee training capacity.

B. Decision Variables

Two types of decision variables were used in this problem. The first type of decision variable is the amount of each product to be produced. We are only considering three products types, six months of production, four labors skill levels for each location and two production sites. While discrete products need to be shipped and fractional values are not possible, on a monthly level, the production levels are high enough to allow continuous variables to be used for these decision variables.

The second sort of decision variables is the number of employees to be available with three dimensions presenting month they are available in, their skill level and the production site where they work. Since allowing fractions of employees in the decision variables is not meaningful, these variables were constrained to be integers.

C. Objective

The objective function has four dimensions presenting the production location, month of production, labor skill-level used for production and the product type produced. The objective of the model is to maximize profit or in other words maximize the positive difference between the total revenue and the total production cost by changing the production decision variables without violating any of model constraints. The total revenue is the sum of the selling price multiplied by the amount of products across the four dimensions. The total production cost is the sum of the unit cost multiplied by the amount of production, labor overhead cost multiplied by the number employees and advertisement cost.

D. Constraints

The constraints are built on the model data and can be categorized into product oriented constraints, labor oriented constraints, and joint product and labor oriented constraints.

Product oriented constraints are:

- The amount of products across the four dimensions has to be non-negative.
- The production amount of a product type at any month can not exceed the sum of the orders at that month and the carry over orders from previous months of that product type.
- Orders of any product have to be met within a month or otherwise to be brought to the customer at no cost.

Labor oriented constraints are:

- The number of employees at any location has to be non-negative.
- The number of employees at any location has to be integer.
- The number of start-up employees with a skill-level at a location has to be equal to the number of available employees with same skill-level in the first month of production planning at that location.
- The number of new employees at a location in any month after the first can not exceed the number of existing employees at that location.
- Every domestic employee grows up on the productivity scale one level every month.
- Not all employees at the outsourcing location grow up in productivity scale every month.

Joint Product and labor oriented constraints are:

- For each month and location the total amount of production multiplied by the corresponding production times has to be less than or equal to the total available employees working time at that month and location.

V. THE FORMULATION

A. Notations

The following notations are used for the formulation of the optimization model

Subscripts:

$l \in \{1,2,...,L\}$, where (l) is the location, and (L) is the number of locations.

$m \in \{1,2,...,M\}$, where (m) is the month, and (M) is the number of months.

$n \in \{1,2,...,M\}$, where (n) is a month, and (M) is the number of months.

$s \in \{1,2,...,S\}$, where (s) is the Worker skill-level, and (S) is the number of skill levels.

$t \in \{1,2,...,T\}$, where (t) is the product type, and (T) is the number of product types.

Sets of data:

SP_t : Selling Price of product type (t)

$UC_{t,l}$: Unit Cost of product type (t) produced at location (l)

$OHC_{s,l}$: Over Head Cost of labor skill-level (s) at location (l)

ADC_m : Advertisement Cost for month (m)

$O_{t,m}$: Number of Orders of product type (t) at month (m)

$TP_{t,s,l}$: Time (min) to produce product type (t) by labor skill-level (s) at location (l)

$LWT_{m,l}$: Labor Working Time (min) in month (m) at location (l)

$STL_{s,l}$: Start-Up labor (number of labors at the first month with skill-level (S) at location (l)

$SL_{t,m,s,l}$: Slack; Amount of orders of product type (t) by Worker skill level (s) at location (l) that are carried over for an additional month

$X_{t,m,s,l}$: Amount of product type (t) produced in month (m) by Worker skill level (s) at location (l)

$Y_{m,s,l}$: Number of Workers in month (m) with skill level (s) at location (l)

B. Mathematical model

1. Objective function

Decision variables:

$$Max \quad \sum_{l=1}^{L}\left(\sum_{m=1}^{M}\left(\sum_{s=1}^{S}\left(\sum_{t=1}^{T} X_{t,m,s,l} * (SP_t - UC_{t,l}) - SL_{t,m,s,l} * SP_t\right) - OHC_{s,l} * Y_{m,s,l}\right) - ADC_m\right)$$

2. Constraints

$X_{t,m,s,l}, Y_{m,s,l} \geq 0 \qquad \forall \quad t,m,s,l$ Non-Negativity Constraint

$Y_{m,s,l} = Integer \qquad \forall \quad m,s,l$ Labor Integer Constraint

$\sum_{m=1}^{n}\sum_{l=1}^{L}\sum_{s=1}^{S} X_{t,m,s,l} \leq \sum_{m=1}^{n} O_{t,m} \qquad \forall \quad t,n$ Production constraint

$\sum_{m=1}^{n}\sum_{l=1}^{L}\sum_{s=1}^{S} (X_{t,m,s,l} + SL_{t,m,s,l}) \geq \sum_{m=1}^{n-1} O_{t,m} \qquad \forall \quad n>1,t$ Carry over constraint

$\sum_{s=1}^{S}\sum_{t=1}^{T} X_{t,m,s,l} * TP_{t,s,l} \leq \sum_{s=1}^{S} Y_{m,s,l} * LWT_{m,l} \qquad \forall \quad m,l$ Available Worker-Time Constraint

$Y_{1,s,l} = STL_{s,l} \qquad \forall \quad s,l$ Available Start-Up Labor Constraint

$Y_{m,1,l} \leq \sum_{s=1}^{S} Y_{m-1,s,l} \qquad \forall \quad m>1,l$ Labor Ramp-Up Constraint

$Y_{m,s+1,1} = Y_{m-1,s,1} \qquad \forall \quad m>1, s<S$ Domestic Labor Skill-Level Improvement Curve

$Y_{m,s+1,2} < Y_{m-1,s,2} \qquad \forall \quad m>1, s<S$ Outsourcing Labor Skill-Level Improvement Curve

$Y_{m,S,l} = Y_{m-1,S,l} + Y_{m-1,S-1,l} \qquad \forall \quad m>1,l$ High Skilled Labor Constraint

VI. RESULTS AND ANALYSIS

An algebraic integer programming optimization tool was used. The optimization model is built based on the formulation provided in the previous section. Data was provided by ABC, inc. and was entered into the optimization model.

ABC, inc. has experienced fluctuations in demand in 2000 that threatened the company financial position. Running the model with only domestic capacity and under similar demand levels as shown in fig.1 revealed that in addition to the higher labor salaries and related taxes, the inflexibility in reducing work force in response to dwindling demand has been a major cause for the losses the company experienced. As defined by the company the inflexibility is caused by the state and federal law in addition of the difficulty associated with ramping-up the production capacity again if demand is to rise. In this paper we are not discussing specific state and federal labor laws neither are we judging their suitability but rather we are describing this company experience.

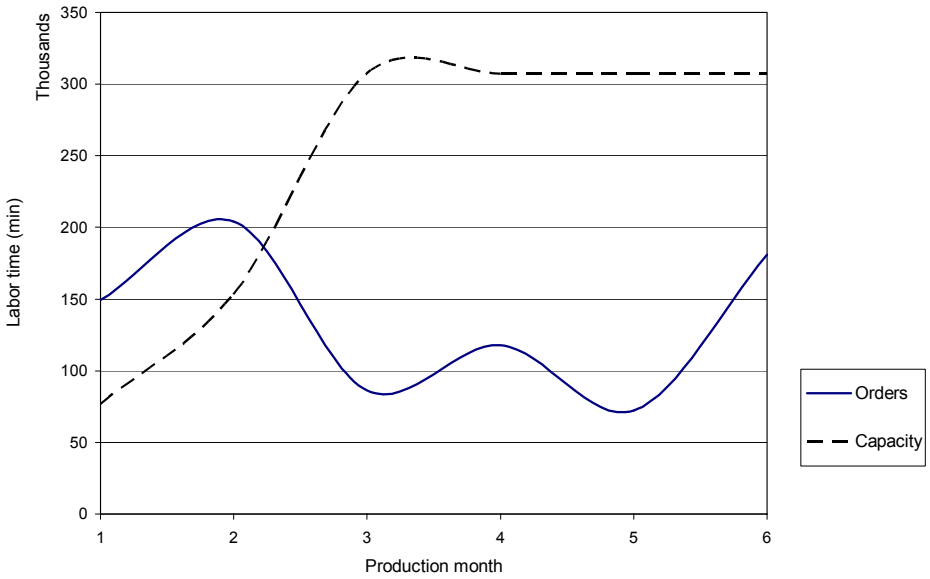

Fig.1. Domestic labor capacity and products demand over the months of production.

Figure 2 shows how the outsourcing provides work force flexibility in responding to fluctuations in demand. Typically the labor cost is more emphasized in outsourcing decisions but this under estimate the impact of the labor flexibility which is a major criterion especially in services and intensive labor industries.

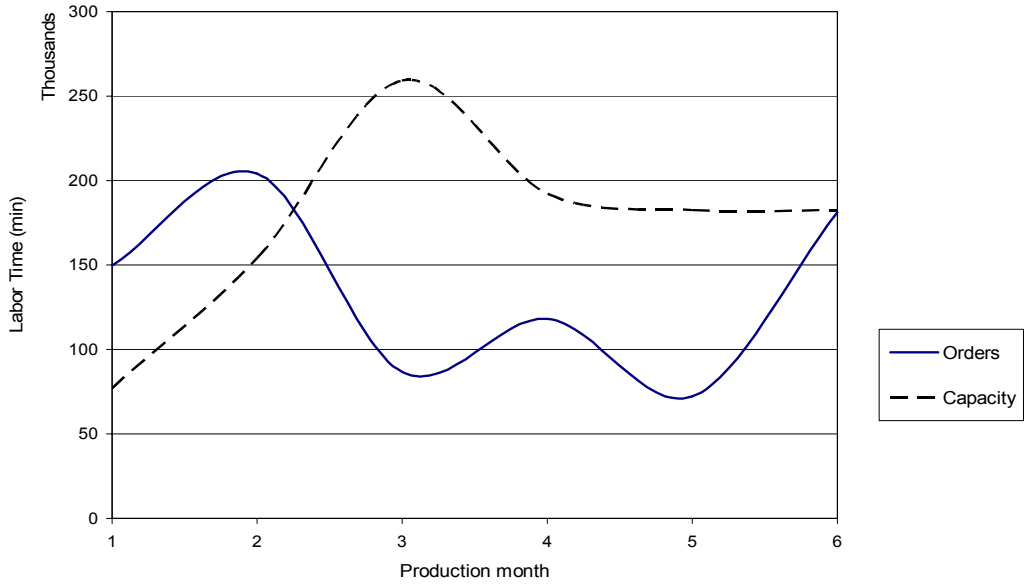

Fig.2. Outsourcing labor capacity and products demand over the months of production.

Figure 3 shows the percentage of domestic capacity out of the total production capacity to maximize the profit while outsourcing option is open across different demand variability indexes. It shows that there are characteristics other than labor cost and flexibility that should be considered when making the outsourcing decision.

Overhead cost is one of the less considered factors; outsourcing production site would typically have higher overhead costs resulting from communication and quality issues. Outsourcing communication costs results from traveling, shipping products and communicating to deliver information or transfer knowledge. Increase in quality cost is associated with needing to have a larger sample for inspection due to having more defective products in addition to reproducing the defective products.

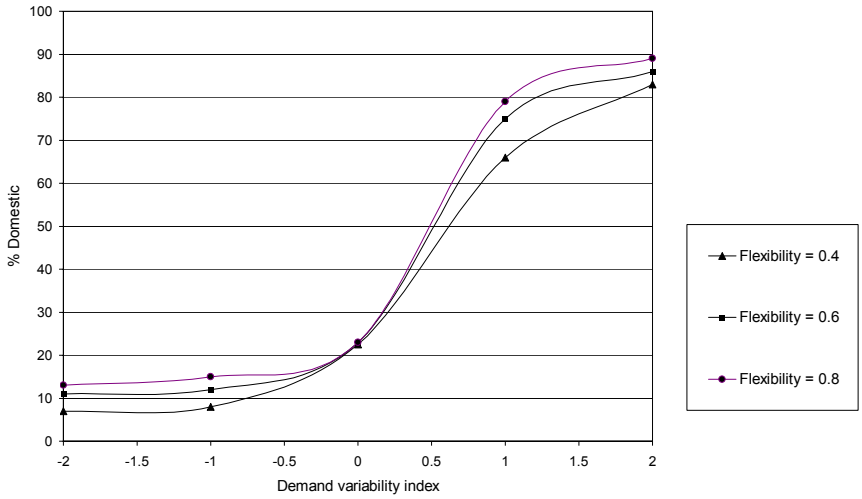

Fig.3. % Domestic production with different labor flexibility at different demand variability indexes.

Introduction of new products or services necessitate new labors training and labor would go over this product learning curve while ramping-up the production of this product to meet the demand. Ramping-up production capacity is dependent on the labor effectiveness in the climbing learning curve, flexibility in hiring new employees as needed. Labor efficiency is another advantage of domestic labors over outsourcing especially in services industries where English proficiency plays a major rule. Efficiency can be compensated by the cheaper labor cost when demand level is below capacity. But when ramping up production to meet increase in demand, labor efficiency tends to play a major rule.

In contrast to the common belief of the ABC company and public perception of outsourcing motivation, the model results have shown that the first hypothesis (H1: Cheaper labor overseas is can fully explain outsourcing practices of ABC) is not supported by this company's application. In other words, cheaper labor is not the only reason behind outsourcing as the labor flexibility is playing a role in favoring outsourcing.

The model results shows that the second hypothesis (H2: Overseas ramp-up is preferable than domestic ramp-up) is also null. Fig.3 shows that with positive variability in demand, domestic labor is highly favorable.

The results also show that the third hypothesis (H3: All production capacity should be outsourced) is not supported. Fig.3 shows that in steady market demand, about a quarter of the labor force should be domestic while this percentage highly increases with positive variation in demand index and decreases with negative increase in the demand variation index.

In summary, the model shows that under different demand conditions, having a multiple productions sites is favorable. When introducing new products and ramping-up production, then having a large domestic work force is favorable while at times of recessions and when products mature and demand decline then having a larger outsourcing work force is favorable.

VII. CONCLUSION AND FUTURE WORK

The model has drawn more emphasize to the importance of some factors in considering outsourcing decisions such as labor learning curves and flexibility. It has also drawn attention to some of the advantages of domestic labor such as effectiveness, ramping up capabilities and lower overhead costs.

The results has shown to counter the traditional believes by some companies that outsourcing is favorable because of cheaper labor, perform better in ramp-up and all production capacity should be outsourced.

The formulation of the optimization model presents an approach to solve multi-dimensions problems that contains large number of variables. This model can easily accommodate any changes in any of the design parameters and can be used to solve similar parameters with some small customization.

The model determined the number of employees needed to keep up with the production levels under the constraints, and it also determined the lowest cost way to increase employees in order to maximize profit.

The model has already proven useful to the company in determining production feasibility for a large influx of orders, and will help provide production assurance in negotiations for larger orders. The model give detailed production planning by providing information on what product type to produce at which location by which labor and when.

Future work can include applying this model to more complex and larger problems in software and services industries. Consider the relation between production planning and market such as when to run promotional and discounts and on what products and how to set the product pricing.

ACKNOWLEDGMENT

Thanks to ABC, inc. for providing us with the data and introduce us to this interesting problem.

REFERENCES

[1] E. Lundquist, "Recovering technology OUTSOURCING HURTS NOW, BUT THE PAIN NEEDN'T LAST FOREVER.," *eWeek*, vol. 21, pp. 26, 2004.

[2] "There's More to Consider Than Cheaper Labor," *Computerworld*, vol. 37, pp. 42, 2003.

[3] G. Dobson and C. A. Yano, "Product offering, pricing, and make-to-stock/make-to-order decisions with shared capacity," Production and Operations Management, vol. 11, pp. 293-312, 2002.

[4] B. Pine and J. II, "Mass Customization, a New Frontier in Business Competition," in Harvard Business School Press, Boston, Mass., 1993.

[5] C. Devonshire-Ellis, "Outsourcing Manufacturing Operations to China," *Beijing Review*, vol. 48, pp. 38, 2005.