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A MULTI-STEP DATA ENVELOPMENT ANALYSIS FOR EFFICIENT INDIRECT PROCUREMENT

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Abstract
The paper aims at improving the efficiency of indirect procurement. Though good work is found in supplier evaluation and supplier selection only limited material discusses on the efficiency of complete indirect procurement process. Identifying the right supplier to procure does not completely address the complexity of indirect procurement. One has to identify the number of suppliers to enter into (1) contract (2) discount calling and (3) reduce and/or stop business. We develop a three phase approach for the same. Phase 1: At the commodity level evaluate supplier performance taking into consideration various criteria like, acknowledgment time, delivery time, order quantity fulfillment, number of materials procured by the supplier. A Data Envelopment Analysis (DEA) methodology is adapted for evaluating the suppliers. Phase 2: evaluate the suppliers at material level considering specific criteria e.g.: unit price of the material in addition to criteria set 1. Phase 3: formulate an integer programming problem to identify only those suppliers who are best in the class for a given material based on the phase 1 and phase 2 results. Thus short listed suppliers will be eligible for developing price contract; we refer to them as contracted suppliers. The remaining suppliers are called non-contracted suppliers. These suppliers are classified into different class depending on their slackness in performance with respect to different criteria. The percentage of discount to negotiate is estimated for each class of suppliers. For the non-performing class we recommend reducing and eventually stopping business. The approach was implemented on a sample data set.

Keywords
Supplier Evaluation, Supplier Selection, Data Envelopment Analysis

1.0 Introduction
Supplier evaluation and supplier selection is a well known topic and has prevailed for many years. But, articles discussing the improvement of complete indirect procurement efficiency are very limited. This paper tries to improve the overall improvement in the indirect procurement process by getting closer to reality. We develop a multi phase approach for supplier evaluation and identification on suppliers for price contract, discount calling – negotiate for additional discount understanding the performance level of the supplier. We also identify the non-performers and recommend stopping business with this class.

Data Envelopment Analysis is a well known approach for supplier evaluation. Though the criteria being used to evaluate the supplier differs, most papers discuss on evaluating the supplier and only few take it to the next level of selecting the right supplier for a given material. One of the earliest implementation in field of efficient selection was proposed by Baker and Talluri (1997) based on which Braglia and Petroni (2000) applied DEA to measure efficiencies of the suppliers in a manufacturing domain. Many other works came along the similar lines with Liu et al.(2000) proposing a simplified DEA model to evaluate overall supplier performance, Forker and Mendez (2001) applied DEA to identify most efficient suppliers called as “best peers” and identifying potential supplier that can move into the best peers by following the best peer practices with minimal effort. Narasimhan et al. (2001) proposed a multifactor productivity analysis technique for effective supplier performance evaluation based on DEA. The suppliers were then classified based on their performance efficiency derived from DEA. Talluri and Sarkis (2002) discusses on DEA implementation for evaluating suppliers, monitoring supplier performance and assisting in better customer-supplier relationship. Talluri and Baker (2002) developed a multi-phase approach for effective supply chain management. Talluri and Narasimhan (2004) applied DEA for evaluating and selecting suppliers objectively for strategic long-term partnership. Their models were based on game theory concepts, and linear and integer programming methods. Garfamy (2006) applied DEA to measure the overall performances of suppliers based on the total cost of ownership. Our model takes into consideration multiple aspects and attempts to get closer to reality. We develop a three phase approach to evaluate and identify the right suppliers Phase1: Supplier evaluation at the commodity level of the material hierarchy. A DEA with multiple input and multiple output criteria is adapted for evaluating the suppliers. Phase2: evaluate the suppliers at the material level. Here we adapt the DEA model but with

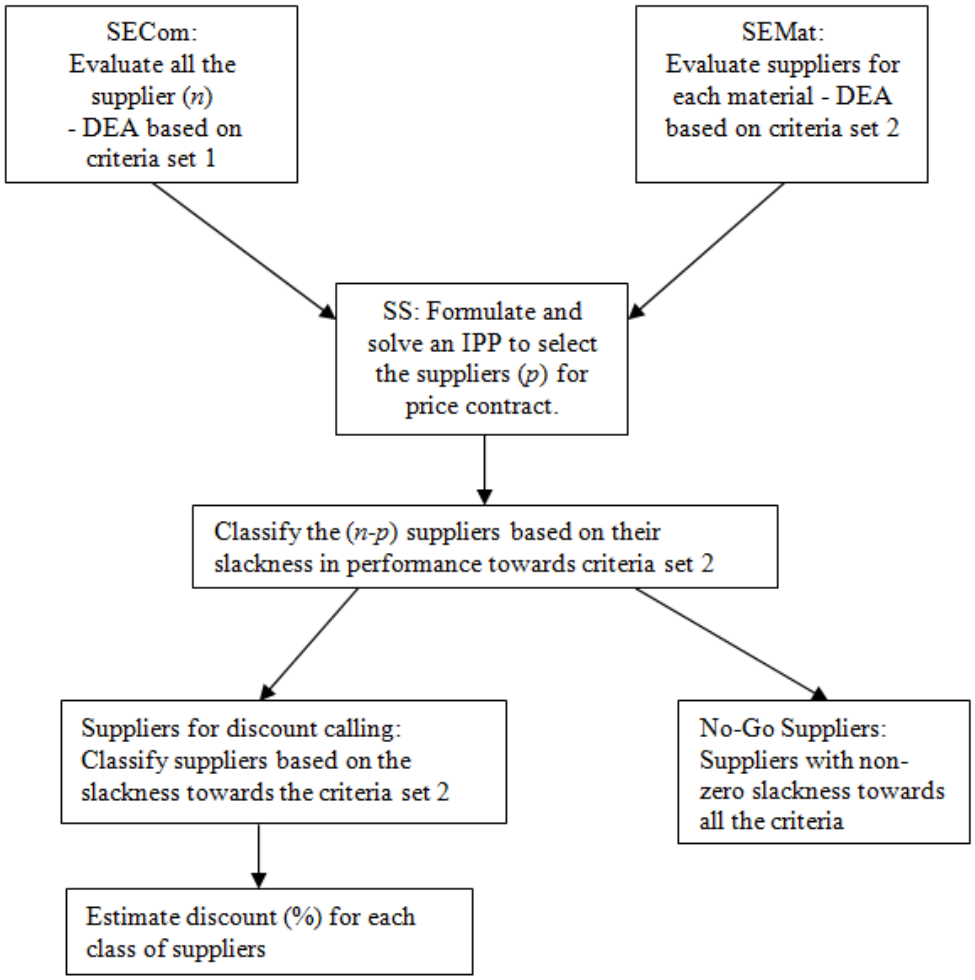
different set of input and output criteria. Phase 3: the results from phase 1 and phase 2 are combined and an Integer Programming Problem (IIP) is formulated to (a) identify the suppliers for price contract. It is essential to have the right number of suppliers for a material, as too many or too few a number of suppliers are not correct and have their own pros and cons to the manufacturer. Hence, only the best in class suppliers are selected for (a) developing long term price contract to supply one or more materials (b) to negotiate for additional discount based on their performance. These are the next best suppliers. The better the performance the lower is the discount rate. (c) Identify suppliers to reduce or stop business. These are the poor performing suppliers.

The paper is organized as follows: Section 2 describes the methodology with subsection 2.1, 2.2 and 2.3 describing phase 1, 2 and 3 respectively. In Section 3 a case study for implementing our approach along with the analysis and results is provided. The conclusion and future scope of work is discussed in Section 4.

2.0 Our Approach

We developed a three phase approach. Phase 1- SECom: Supplier Evaluation at Commodity level by adapting DEA with supplier evaluation criteria set 1. The criteria set 1 includes delivery time, delivery quantity, and responsiveness to purchase order etc. which are common across material. Phase 2- SEMat: Supplier Evaluation at Material level with supplier evaluation criteria set 2, the criteria set 2 is more specific to each material e.g. the unit price of the material. Phase 3- SS: Supplier Selection based the integration of the results of Phase1 and 2. The flowchart explaining the three phases is provided in Exhibit1.

Exhibit1: The flowchart explaining the three phases



2. 1 Step 1: SECom - Supplier Evaluation at Commodity Level

A list of suppliers, encompassing of all the suppliers supplying one or more material of the commodity are considered. This is basically the union of the suppliers of the various materials belonging to a commodity. The suppliers are evaluated based on the criteria set 1. The criteria identified at the commodity level are common at a higher level e.g.: total number of materials supplied by the supplier, delivery time, delivery quantity, responsiveness to PO acknowledgement etc. The DEA methodology is adapted for evaluating the suppliers. The output oriented Charnes Cooper Rhodes Model is implemented to obtain the desired results.

The DEA evaluates the peer entities called Decision Making Units (DMUs). The DEA can take multiple input and output criteria for evaluation. A DMU is efficient if it lies on the frontier and less efficient otherwise. The methodology deals with the relative efficiency of the DMUs. Hence, a DMU is efficient only with respect to the other DMUs under evaluation. In the Charnes, Cooper, Rhodes (CCR) model of the DEA the relative efficiency of a DMU is calculated as a ratio of outputs to inputs and then compared to the ratios of other DMUs. The result of the DEA is in the form of objective values for each DMU. These objective values vary between 0 to 1 where, 1 refers to efficient performance, these suppliers lie on the frontier and values closer to zero indicate poor performance. The results obtained from the DEA analysis enable ranking the suppliers based on their performance towards the criteria defined.

2.2 Phase 2: SEMat - Supplier Evaluation at Material Level

In this Phase the list of suppliers supplying a given material are evaluated. The evaluation criteria at the material level are more specific e.g.: unit price of the material. The output oriented Charnes Cooper Rhodes DEA Model is adapted for evaluating the suppliers. Understanding suppliers supplying more than one material may not have the same level of performance towards each of the material supplied, we evaluate suppliers for each material independently. The results obtained from the DEA model will help rank order the suppliers supplying a given material.

2.3 Phase 3: SS - Supplier Selection

There need to be only a right number of suppliers for a given material. Too many suppliers or too few suppliers for a material have both pros and cons e.g. too many suppliers: - Cons (1) the manufacturer must ensure sufficient business is provided to all the suppliers (2) it is difficult to manage huge number of suppliers. Pros - the manufacturer will be able to meet their demand from one or the other supplier; too few suppliers: Cons - the suppliers may not be able to support the manufacturer with all their demand. Pros – easy to manage small group of suppliers. Therefore, it is essential to have the right suppliers for a material. Identifying the right number of suppliers is a challenge. Hence, in this paper, we propose an approach which provides the manufacturer the right combination of suppliers essential for smooth running of the organization. We propose three steps (1) Contract: to develop price contract only with the best in class suppliers with respect to the criteria defined. (2) Discount: to negotiate for additional discounts with good performing suppliers but they may not be the best in class (3) No go: to reduce or discontinue business with poor performing suppliers.

2.3.1 Step 1 - To identify suppliers for contracting: Based on the Phase 1 and Phase 2 results, we formulate an IIP to select the best in class suppliers for a given material and also ensure the selected suppliers are among the top list of the commodity suppliers.

Suppose there are a total of n suppliers and m materials. Note that a supplier can supply more than one material. Let s_i represent the i^{th} supplier where $i \in (1,\ldots,n)$ and $s_i = 1$, if the supplier is selected and $s_i = 0$, if the supplier is not selected. Let r_{ij} be an indicator variable of i^{th} supplier providing j^{th} material. $r_{ij} = 1$, if i^{th} supplier is an efficient supplier at material level for j^{th} material and $r_{ij} = 0$, otherwise. Let η_i represent efficiency of i^{th} supplier at commodity level and k the minimum number of suppliers that are required to be selected for each material. The problem is formulated as below.

$$Minimize: \sum_{i=1}^{n} s_i$$

$$Subject \quad to: \sum_{i=1}^{n} r_{ij} \times s_i \times \eta_i \geq k \quad j \in (1,\ldots,m)$$

$$r_{i,j} \in \{0,1\}$$
$$s_i \in \{0,1\}$$
$$\eta_i \in \{0,1\} \quad (1)$$

The solution to the above IPP provides the list of suppliers to enter into contract. Let *p* be the total number of suppliers identified for contracting. The remaining *n-p* numbers of suppliers are input to the next step.

2.3.2 Step 2- To identify suppliers for discount calling and estimate the percentage of discount to be negotiated: These suppliers are of relatively equal or low performance compared to the suppliers set *p* selected in step1. These *n-p* suppliers are classified based on their slackness towards each of the criteria. Note that some of the supplier's slack value can be equal to zero. Suppliers with slack values equal to zero for all the criteria are classified as class 1; suppliers with a non-zero slack value for only one of the criteria are classified as class 2; suppliers with non-zero slack values for two criteria are classified as class 3 and so on. The suppliers are thus classified for discount calling. The last class of suppliers which encompasses the poor performing suppliers, *b*, is not considered for discounting. The list of *b* suppliers will be moved to the next phase of analysis.

The percentage of discount to negotiate is a function of the class of the supplier. The higher the class, the better is the performance of the supplier towards the various criteria listed and hence, the lesser is the discount percentage negotiated. The percentage of discount is estimated using equation (2). Let *D* denote the maximum discount and *d* the minimum discount that can be negotiated. Let *c* represent the classes of suppliers, where c = {1,2,..*C*}. Then the discount allocated for the c^{th} class is given in eqn. (2). Note that *C* is not the last class of supplier in the classification and the last class is moved to the next step.

$$D_c = (c(D-d))/C \quad (2)$$

2.3.3 Step 3 –To identify the no-go suppliers: The last class of suppliers as classified in Phase two, encompassing of *b* suppliers. We suggest reducing and attempt to eventually stop business with these set of suppliers due to their poor performance in all the criteria. We thereby classify them as the no-go suppliers.

3. Sample Case Study

A sample data for an indirect commodity is considered for analysis. The commodity encompasses of ten different materials. A total of 92 different suppliers supplied the commodity. The number of suppliers for each material varies. Each material has a minimum of 10 suppliers and some of the suppliers supplied more than one material. The list of materials and the number of suppliers supplying each material is provided in Exhibit 2.

Phase 1: The 92 suppliers were evaluated based on the criteria set 1, provided in Exhibit 3. Exhibit 3 provides the input and output criteria considered for the implementation of the DEA. On implementation, 66 efficient suppliers were identified. Phase 2: The suppliers supplying a given material are evaluated based on the criteria set 2 defined in Exhibit 4. On implementing the Phase 2 approach the results provided in Exhibit 5 are obtained.

Solving the IPP as formulated in Sub-subsection 2.3.1 with maximum number of suppliers *k*=3 the below result was generated. Exhibit 6 provides the suppliers selected for contract towards each of the material. It can be observed that some of the suppliers selected supply more than one material. Thereby, only 19 suppliers of the 92 suppliers at the commodity level were selected for contract and the split with respect to each material is shown in Exhibit 6.

The list of suppliers was classified based on the slackness towards each of the criteria defined and the class with non- zero slackness towards all the criteria is identified as the no-go supplier class. The remaining class of suppliers was chosen for discount calling. Exhibit 7 provides the classification of suppliers into different classes and the percentage of discount to be negotiated. Exhibit 8 summarizes the discount calling and no-go suppliers for each of the materials.

Exhibit 2: Material and the number of suppliers supplying the corresponding material.

Material Code	Total number of suppliers
M100	11
M200	18
M300	17
M400	18
M500	10
M600	12
M700	42
M800	20
M900	11
M1000	13

Exhibit 3: Criteria Set 1- The list of criteria for evaluating the suppliers at commodity level

Output Criteria:
1. Time taken to acknowledge the purchase orders 2. Delivery time 3. Order quantity fulfillment 4. Number of different materials supplied by the supplier
Input Criteria:
1. Total number of purchase orders and 2. Quantity ordered

Exhibit 4: Criteria Set 2- The list of criteria for evaluating the suppliers at material level

Output Criteria:
1. Unit price 2. Time taken to acknowledge the purchase orders 3. Delivery time and 4. Order quantity fulfillment
Input Criteria:
1. Number of purchase orders and 2. Order quantity

Exhibit 5: Number of efficient suppliers for each material

Material	Total Number of Suppliers	Efficient Suppliers
M100	11	5
M200	18	15
M300	17	14
M400	18	14
M500	10	7
M600	12	10
M700	42	30
M800	20	15
M900	11	9
M1000	13	10

Exhibit 6: Suppliers selected for price contract

Material Code	Supplier 1 Code	Supplier 2 Code	Supplier 3 Code
M900	S51234	S66662	S88456
M1000	S55123	S73456	S88845
M300	S55512	S77345	S88884
M100	S55551	S77734	S95678
M800	S62345	S77773	S99567
M200	S55512	S77345	S88884
M500	S66234	S84567	S99956
M400	S55512	S77345	S88884
M700	S66234	S55551	S55123
M600	S66623	S55551	S51234

Exhibit 7: Classification of suppliers into different classes and the percentage of discount considered for negotiation based on the class

Class	1	2	3	4	5
Number of Suppliers	1	1	1	3	6
Discount (%)	2	4	6	8	10

Exhibit 8: Summary of the number of suppliers for discount calling and the no-go suppliers for each material

Material Code	Total Number of Suppliers (*n*)	Suppliers for Discount calling	No-go Suppliers
M100	11	2	6
M200	18	12	3
M300	17	11	3
M400	18	11	4
M500	10	4	3
M600	12	7	2
M700	42	27	12
M800	20	12	5
M900	11	6	2
M1000	13	7	3

4.0 Conclusion and Future Scope

Evaluating suppliers to improve the efficiency of procurement in terms of quality, delivery time, price etc. is essential and has prevailed for a long time. There are more aspects for efficiency improvement in the indirect procurement along with supplier evaluation. This paper tries to address a few more aspects that will help in (1) cost saving by availing any opportunity in price discount. The buyer is provided with required information to negotiate with the supplier and avail additional discounts (2) identifying the right set and number of suppliers at different material hierarchy. Our approach enables multiple input and output criteria and the criteria list varies with the hierarchy of material. As a future scope one can identify the optimal number of suppliers for a material. Also, estimation of the discount percentage for each class of suppliers can be more detailed.

References

Baker, R.C., Talluri, S., 1997. A Closer Look at the Use of DEA for Technology Selection, *Computers and Industrial Engineering*, 32 (1), 101–108.

Braglia, M., Petroni, A., 2000. A Quality Assurance-Oriented Methodology for Handling Trade-Offs in Supplier Selection. *International Journal of Physical Distribution and Logistics Management*. 30 (2), 96–111.

Forker, L.B., Mendez, D., 2001. An Analytical Method for Benchmarking Best Peer Suppliers. *International Journal of Operations and Production Management* 21 (1–2), 195–209.

Ho William, Xu Xiaowei, Dey Prasanta K., 2010, Multi-Criteria Decision Making Approaches for Supplier Evaluation and Selection: Literature Review, *European Journal of Operational Research*, 202, 16-24.

Liu, J., Ding, F.Y., Lall, V., 2000. Using Data Envelopment Analysis to Compare Suppliers for Supplier Selection and Performance Improvement. *Supply Chain Management: An International Journal* 5(3), 143–150.

Narasimhan, R., Talluri, S., Mendez, D., 2001. Supplier Evaluation and Rationalization via Data Envelopment Analysis: An Empirical Examination. *Journal of Supply Chain Management* 37 (3), 28–37.

Talluri, S., Baker, R.C., 2002. A Multi-Phase Mathematical Programming Approach for Effective Supply Chain Design. *European Journal of Operational Research* 141 (3), 544–558.

Talluri, S., Narasimhan, R., 2005. A Methodology for Strategic Sourcing. *European Journal of Operational Research* 154(1), 236-250.

Talluri, S., Sarkis, J., 2002. A Model for Performance Monitoring of Suppliers. *International Journal of Production Research* 40 (16), 4257–4269