

USING DATA ENVELOPMENT ANALYSIS (DEA) AS A TOOL FOR PURCHASING CONTROL

Corina Pop-Sitar and Luitzen de Boer
University of Twente, Faculty of Technology & Management,
PO Box 217 - 7500AE, Enschede, The Netherlands

ABSTRACT

Today we observe an continuing challenge to develop performance measures that evaluate purchasing effectiveness relative to the organization's objectives and to extend conventional measurement systems to an enterprise-wide purchasing control function that detects the 'weak spots' in the purchasing function. In this paper we address the observed challenge by presenting a conceptual framework for purchasing control that identifies different possible control-configurations. Furthermore, we show how Data Envelopment (DEA), can be used as a supporting tool in purchasing control by explicitly relating the resources employed in purchasing to the goals achieved.

INTRODUCTION

In this paper we aim to investigate the potential of Data Envelopment Analysis (DEA) in Purchasing Control. The remainder of this introduction serves to define Purchasing Control and to position this instrument in relation to performance measurement approaches in Purchasing. An important challenge in both Purchasing Control and performance measurement is to relate purchasing effectiveness to purchasing efficiency in a sensible way. This challenge is addressed in the subsequent sections. First, we show a framework that distinguishes different Control configurations in purchasing and thereby aids in identifying appropriate sets of variables measuring efficiency and effectiveness for each configuration. Next, we illustrate the possibilities of using DEA as a tool for simultaneously measuring these variables in practice and drawing useful conclusions from them.

Following Telgen (1998) Purchasing Control can be defined as an instrument for supporting the regulating or managing the entire purchasing function. In particular, it contributes in two ways:

1. Providing quantitative insight in purchasing 'flows' through the organisation. Basically, it provides answers to questions like:
 - What is the total purchase volume?
 - How much of that is spent on BOM and Non-BOM related items and services?
 - How much do the different departments buy? In total as well as broken down into different commodities etc.
 - How many active suppliers do we have?
 - etc.
2. Based on the quantitative data, identifying and detecting the apparent 'weak spots' in the purchasing function. Purchasing Control is on the outlook for 'suspicious' situations, e.g. an extremely large

number of suppliers for a minor non-Bom commodity. Further investigation is always necessary to assess whether the suspicion was justified.

It is important to note the broad and explorative nature of Purchasing Control. In that respect, Purchasing Control is different from the often much more focused and dedicated purchasing performance measurement systems, like e.g. a particular vendor rating application. In practice approaches for purchasing performance measurement and control are grouped by Lysons (1996, pp.393-408) under four main categories:

1. Accounting approaches:
 - profit centres
 - activity based costing
 - standard costing and budgetary control
2. Comparative approaches:
 - benchmarking
 - ratios
3. The purchasing management audit approach
4. Management by objectives.

The profit centre approach involves establishing a centralized purchasing organization that controls assets and is responsible not only for expenditures but also for income. The profitability of the purchasing function is generated by an internal accounting transfer of items and services procured by purchasing to other functions at a price above their actual direct cost. In effect purchasing sells to other functions at a transfer price. The performance is measured by the profits generated by the purchasing function. This approach is more theoretical than practical due to its weaknesses:

- decentralization of control increases administrative costs;
- an equitable transfer price is quite difficult to determine;
- transfer charges may lead to inter-functional conflicts.

The activity based costing approach makes a distinction between value adding and non-adding activities and tries to reduce or eliminate if possible the non-adding activities. Also, an analysis of cost drivers is made and potential cost savings are identified.

Standard costing is used in many organizations to evaluate the purchasing department's pricing performance. Standard costs monitor performance by comparing the effective costs with the standard costs and analyzing the variances. One of the traditional control and evaluation tools used in organizations of all types is the budgetary process. Budgets are derived from objectives. A figure is given which is the estimated expenditure required to meet the desire objective. This budget figure is then used as a control comparing actual expenditure with projected. If the materials purchase, MRO, capital, and purchasing administrative budgets are carefully prepared, based on realistic assumptions about the future, they provide a reasonable standard against which actual expenditures can be compared. These budgets only include the direct and production materials and the departmental expenses, whereas indirect materials and other items remain out of focus. They indicate only the maximum spending but they can not control the quality of purchasing: what is purchased?; at what price?; from which supplier?

Benchmarking approach aims to discover 'best practice' wherever it might be found. The idea is to identify key characteristics of best practice and adopt them. Benchmarking of the purchasing department is seen as increasingly important factor in maximizing overall company performance. This process is becoming easier for many companies as a result of objective industry standards of performance being established through high-powered research conducted by CAPS into key purchasing areas. The purchasing performance

benchmarking permits an answer to the question 'how is the firm doing, compared to other firms?' by providing averages for measures of purchasing performance. But this comparison is not so relevant, it can only indicate if the purchasing performance measures are under or over the average. It can not indicate the causes for poor performance and what correction actions have to be done in order to obtain superior performance.

Ratios show the relation between two variables and can be used to indicate trends, set standards and control costs. Some of the ratios that are used to measure and control purchasing performance are: purchase dollars as percent of corporate sales; average purchasing order cycle time; percent of total goods purchased handled by purchasing department; average cost of orders placed, etc. Most of the ratios serve primarily as indicators or warning-signals. They do not explain why certain problems occur and additional research is needed to identify their cause.

The purchasing management audit approach assesses the extent to which goals and objectives of the purchasing department are balanced with its resources. Scheuing (1989, pp.137) has defined the purchasing management audit as "a comprehensive, systematic, independent and periodic examination of a company's purchasing environment, objectives, strategies and tactics to identify problems and opportunities and facilitate the development of appropriate action plans". A purchasing management audit usually analyzes the following issues: purchasing personnel; purchasing organization; purchasing policies and procedures; purchases, suppliers and prices; inventory; purchasing reports; purchasing problems and opportunities. Purchasing management audits are little used because of the time and costs involved.

Management by objectives approach aims to identify the objectives that a manager or function should be expected to achieve within a given period. At the end of the period the actual performance and will be compared with the desired results. Management by objectives approach entails goal setting, participation, periodic reviews and evaluation. There are three main types of objectives: improvement objectives, personal development objectives and maintenance objectives. This approach can be used for assessing the effectiveness of the purchasing function.

We observe a growing dissatisfaction with actual performance measurement and control systems. In particular, we point out three problems:

- Measurement and control systems have failed to keep up with changes in functions, task-skills and expectations;
- Most of the performance measurement systems concentrate only on purchasing activities that are performed in the purchasing department, while the purchasing performance outside the purchasing department remains out of focus;
- Performance measurement and control systems described in the Purchasing and Supply literature seem to show a gap in linking efficiency-measures with effectiveness-measures in Purchasing. Most systems concentrate on controlling and measuring only purchasing efficiency based on the assumption that an excellent purchasing organization leads to high purchasing performance (purchasing effectiveness).

In the following sections we specifically address the latter two problems. First, we identify different Control configurations in purchasing which may serve as a basis for identifying appropriate sets of variables measuring efficiency and effectiveness. Next, we discuss the possibilities of using DEA as a tool for simultaneously measuring these variables in practice and drawing useful conclusions from them.

A FRAMEWORK FOR PURCHASING CONTROL

Based on the control paradigm by De Leeuw's (1974), we propose a framework for identifying different levels of analysis (configurations) in Purchasing Control and performance measurement. The control paradigm contains three basic elements: a controlling system, a system that is subject to control (controlled system) and an environment which can impact the two other systems both positively and negatively (see figure number 1). Using this paradigm, and taking the viewpoint of the controlling system, Kramer (1978) defines four conditions for effective control of the controlled system:

- the controlling system must define a goal, which serves as a guide in deciding on which control-actions to take;
- the controlling system must have an adequate model of the controlled system;
- the controlling system must have sufficient information on the environment and the system under control;
- the controlling system must have a sufficiently rich set of alternative courses of action to choose from.

For example, the controlling system could be the general management in an organization and the controlled system could consist of the purchasing department. Naturally, the boundaries of the controlling and controlled systems may be fixed in other ways. For example, the controlling system can be the purchasing department in an organization and the controlled system can consist of all the buyers within the entire organization. In this case the environment consists of all internal customers. Another possibility is when the purchasing department is the controlling system, while the controlled system consists of all the active suppliers and the environment consists of the internal customers. The examples can continue but the general idea is the same (see Table 1). We emphasize that Table 1 is not exhaustive.

Given a specific control configuration has been decided upon, appropriate measures have to be taken in order to comply with the conditions for effective control. For example, the general goal of 'achieving optimal purchasing performance' must be specified in more detail according to the particular control configuration under consideration.

Purchasing performance is a relation between the purchasing output or results (purchasing effectiveness) and the purchasing input or resources (purchasing efficiency) through which the purchasing objectives are realized (Van Weele 1994). On a general level, Purchasing effectiveness can be evaluated along four main dimensions:

- contribution to cost reduction;
- contribution to product and process quality;
- contribution to logistical performance;
- contribution to customer satisfaction.

However, depending on the definition of the controlled system, these general effectiveness dimensions may require different measures. If we want to investigate the effectiveness of the buyers in the organization we may need other measures of cost reduction compared to the cost effectiveness of say suppliers. The same applies to Purchasing efficiency: depending on the controlled system (buyers, departments, commodities, suppliers etc) the kinds of input (resources) employed will differ and hence need different measures.

Once appropriate measures for effectiveness and efficiency have been identified, the problem remains how to draw useful conclusions from a control perspective. In other words: how can 'suspicious' departments, buyers, suppliers, commodities etc be identified? Some may seem more effective, other more efficient. In the next sections we investigate the possibilities of using DEA for this purpose.

INTRODUCTION OF DEA

Data Envelopment Analysis (DEA) originally developed by Charnes et al (1978) has been applied to a wide range of evaluation and decision problems in both public and private organisations (see e.g. Seiford 1990). In qualitative terms, DEA may be described as a technique which provides a means of calculating efficiency levels within a group of basically comparable objects of interest. In terms of controlled systems in a purchasing setting, these objects could be buyers, suppliers, commodities, departments and so on.

In DEA, the efficiency of each object is calculated relative to the group's best practice. An object is said to be 'efficient' if it yields the same overall output as the group, while using at most the same amount of input. This explicit and direct connection of input and output is one of the strong points compared to many other control systems that focus on either output or input. Furthermore, in DEA, input and output may be defined in different dimensions. One way of formally defining a DEA model is as follows:

$$\begin{aligned}
 & \text{Min } E_n \\
 & \text{subject to} \\
 & \sum_{j=1}^N w_j y_{ij} - y_{in} \geq 0 \quad i = 1, \dots, I \\
 & \sum_{j=1}^N w_j x_{kj} - E_n x_{kn} \leq 0 \quad k = 1, \dots, K \\
 & w_j \geq 0 \quad j = 1, \dots, N
 \end{aligned}$$

Where there are N objects producing I different outputs y_{in} for $i=1, \dots, I$ using K different inputs x_{kn} for $k=1, \dots, K$. Furthermore, w_j denote the weights that are applied across the N objects, while E_n is the so-called efficiency score of object n . An intuitive explanation of the model reads as follows. The objective function Minimise E_n represents the attempt to find the most advantageous representation possible for the efficiency of the group relative to object n , hence the objective to minimise the efficiency factor of n . The first restriction makes sure that the weighted output of the group, i.e. $\sum w_j y_{ij}$, is at least equal to the output of object n , while the second restriction does not allow the weighted input of the group to exceed the input of object n . It follows easily that if E_n takes values below 1, the group is more efficient than the single object n . However, if E_n lowest possible value is 1, it means that it is not possible to represent the groups best practice in such a way that it yields the same output as object n and using less input. In that case, object n is efficient.

Based on AGPS (1997) successful implementation of DEA in Purchasing Control would follow the following steps:

1. Setting the scope of the DEA model. In terms of Purchasing Control this means defining the controlling system and the controlled system. For possible configurations in Purchasing, again see Table 1.
2. Defining relevant input and output variables. Given the particular control configuration, the objectives of the controlling system will vary and hence different input and output variables will apply. In Table 2

possible input and output variables for DEA models are shown for a number of different control configurations.

3. In addition, it should be noted that a high number of input and/or output variables reduced the effectiveness of the DEA model as more controlled systems will appear efficient. Furthermore, the output should preferably contain variables that show actual achievement of an objective as well as variables that indicate future results (proactive).
4. Performing a pilot-run of the model for a subset of the controlled systems and subsequently discussing the outcomes with the people involved or responsible. This may give rise to adaptations of input and/or output variables and the way these are measured. In addition, it is imperative that there is widespread agreement on the comparability of the input and output variables.
5. Running of the adjusted DEA model and subsequently analyzing the results.

The application of DEA in purchasing is still limited and has so far been confined to supplier selection (see e.g. Holt 1998, Weber et al, 1993; and Papagapiou et al, 1997). In those publications DEA was used to evaluate actual bids from (potential) suppliers rather than to analyse existing practices within the (purchasing) function. Control configurations as shown in Table 2 have as far as we know, not been reported in the literature so far. In the next subsections we illustrate how DEA may be used in such a Purchasing control fashion.

CASE DESCRIPTION AND ANALYSIS

We study the application of DEA in a large service organisation in the Netherlands which in addition to its headquarters runs more than 20 local service units all over the country. Although all local units basically perform similar services they differ considerably in terms of the number of employees. In the case study we take the perspective of a corporate purchasing department (CPD) operating from the headquarters (the controlling system in this case) and the local units (LU) as the controlled systems. More specifically, the CPD is interested in the way the LUs have organised the purchasing of their catering services. Based on control-data obtained from the LUs it is clear that all LUs use external suppliers to deliver catering services but also that there are many differences in terms of operating hours of canteens, breadth and width of assortment, availability of automat(s) and so on. Table 3 shows some of these figures for a selection of 10 LUs.

The service level in Table 3 is defined on a scale from 1 to 7 and covers the width and breadth of the assortment offered in the canteen and automat(s). The 'net costs per employee' represents the total purchased value of ingredients and manpower minus the turnover of the canteen and automat(s) divided by the number of employees that work at the specific LU.

From the perspective of the CPD, a few immediate conclusions can be drawn, e.g. LU no 7 seems to perform rather poorly compared to LU no 10. The latter operates under substantially lower purchasing costs while offering more service. However, for most LUs it seems not that easy to immediately draw firm conclusions as each low performance of a certain LU can be 'explained' or 'justified' by a higher performance on at least on other aspect. Therefore, DEA was applied to shed more light on the relative purchasing performance of the various LUs, using the following parameters:

- Input: Net costs per employee;
- Output: Number of time units the canteen is open per week
- Number of time units automat(s) are available per day
- Service level provided by supplier

Using these input and output parameters, the simple input-oriented DEA-model as defined previously was used and solved in a Microsoft Excel spreadsheet application. The basis worksheet used is shown in Figure 2.

Figure 2 shows the efficiency-score in cell B15 that was calculated for Location 1 using the built-in Solver module. Similarly, the efficiency scores for the other 9 locations were calculated. This required only minor changes in the formulas already programmed for the first location. The resulting efficiency scores are shown in Table 4.

As becomes clear from table 4 location 6 and location 7 are efficient, while in particular locations 3, 5, 7 and 8 seems inefficient. These results provide CPD with the following leads:

1. Where to focus further 'control-effort': in this case CPD might contact and/or visit locations 3, 5, 7 and 8 in order to obtain additional information and discuss their specific situation. Individual circumstances may account for the supposed inefficiency. Still, corporate resources are utilised for the most promising areas within the organisation.
2. Provide local purchase teams with specific and clear improvement targets. In this case for example, location 5 could be advised to investigate how it could move towards the performance achieved by location 10. Various improvement scenarios can be derived. If the provided output of the suppliers of location 5 is to remain unchanged, a drastic cost reduction of 56% (1.00-0.44) should be aimed at. However, many combinations of improved service and lower cost can easily be calculated by means of 'what-if' analyses in Excel. Efficient target values can be derived by combining the output and input values of the existing efficient locations. For example, suppose the manager responsible for location 5 believes the actual costs per employee could be reduced by 20% to index-figure 0.49, an efficient set of output variables can be calculated by finding a linear combination of the input and output variables of locations 6 and 10 that yields an input equal to 0.49. One such set is $w_1 = 1$ and $w_2 = 0,497$. Subsequently, using these weights the appropriate target values for the output variables can be calculated, resulting in 'Time units canteen open' = 42, 'Time units automat available' = 14 and 'Servicelevel' = 4,5.
3. More fundamentally, it enables CPD to initiate a focussed discussion within the organisation, but especially on management level, as to possible preferences for certain efficient solutions, combinations of service and costlevels. Top-management can be asked to unambiguously specify whether certain baseline levels of service (output) and/or costs (input) should not be exceeded. Within these absolute boundaries, the DEA model enables CPD to suggest a limited number of different but efficient set of cost/service combinations. Purchasers at the locations are free to choose which of these combinations to aim at.

Summarised, in this case-study DEA supported the control activity of detecting *relative weaknesses* in the initial purchasing of a certain commodity at different locations of the organisation. However, in the same way, DEA might prove useful in other Purchasing Control configurations, as shown in Table 2. Table also indicates possible input and output variables for DEA applications.

FURTHER RESEARCH

The case presented in this article has shown that DEA provides a good basis for purchasing control and performance measurement. But this method can only serve as a indicator or warning-signal. Additional effort is needed in order to find out what is wrong and why certain problems occur. Also we did not fully

implement this method in practice, and maybe the implementation gives rise to some problems in the organization. However, this method can be used as a supporting tool in purchasing control when measuring both purchasing efficiency and effectiveness on different levels of analysis.

REFERENCES

Books

- Lysons, K. (1996) Purchasing, Pitman Publishing, London
Kramer, N. T. J. A. (1978) Systeem in probleem, Leiden
Leeuw, A. C. J. de (1974) Systeemleer en organisatiekunde, Leiden
Scheuing, E. E. (1989) Purchasing Management, Prentice Hall, New Jersey

Articles

- Dumond, E. J. (1991) 'Performance measurement and decision making in a purchasing environment' International Journal of Purchasing Management, Spring, pp. 21-31
Charnes, A., Cooper, W.W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units' European Journal of Operational Research, 2, pp. 429-444
Holt, G. D. (1998) 'Which contractor selection methodology?' International Journal of Project Management, vol. 16, pp. 153-164
Papagapiou, A., Mingers, J. and Thanassoulis, E. (1997) 'Would you buy a used car with DEA?' Operational Research Insight, January-March, pp. 13-19
Seiford, L. M. and Thrall, R. M. (1990) 'Recent developments in DEA: the mathematical programming approach to frontier analysis' Journal of Econometrics, Vol. 46, pp. 7-38
Steering Committee for the Review of Commonwealth/ State Service Provision (1997) 'Data envelopment analysis: a technique for measuring the efficiency of government service delivery' AGPS, Canberra
Telgen, J. (1998) 'Inkoopcontrol is essentieel voor de inkoopfunctie' Tijdschrift voor Inkoop & Logistiek, October, pp. 19-21
Weber, C.A. and Current, J. R. (1993) 'A multi-objective approach to vendor selection' European Journal of Operational Research, Vol. 68, pp. 173-184, Weele, A. J. van (1984) 'Purchasing performance measurement and evaluation' International Journal of Purchasing and Materials Management, Fall, pp.16-22.

Tables 1 — Examples of Controlling and Controlled Systems

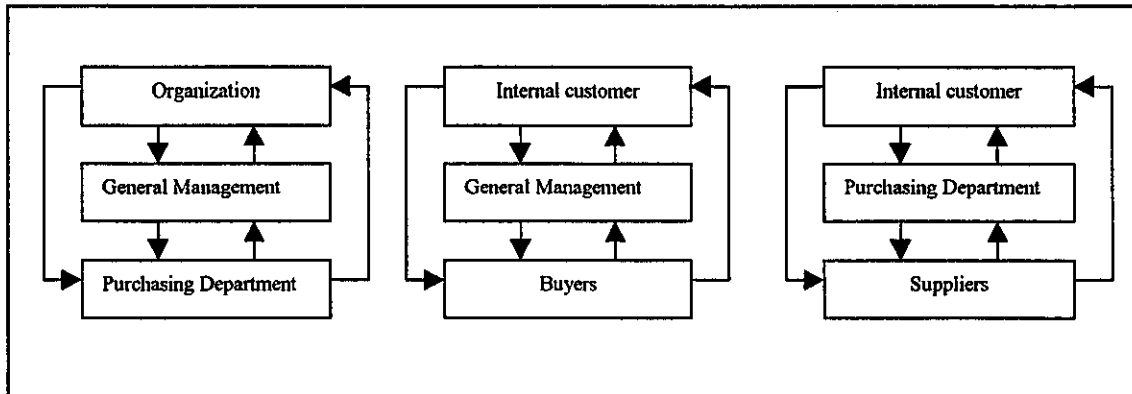


Table 2 — Possible control configurations and matching DEA variables

Control System:		General management controlling Purchasing departments	Purchasing dept. controlling all commodities (and related suppliers)	Corporate Purchasing dept controlling local purchasing of same commodity	Purchasing manager controlling purchasing officers
DEA input variables		<ul style="list-style-type: none"> • Headcount; • Dept. budget 	<i>Transaction costs:</i> <ul style="list-style-type: none"> • Initial: #suppliers; operational; # invoices below 250\$; <i>Failure costs:</i> <ul style="list-style-type: none"> • Supply failure rate <i>Relationship costs:</i>	<i>Transaction costs:</i> <i>Failure costs:</i> <i>Relationship costs:</i> <ul style="list-style-type: none"> • purchase volume 	<ul style="list-style-type: none"> • salary; • expenses; • training and education costs;
DEA Output-variables	Costsaving	<i>Realised:</i> <ul style="list-style-type: none"> • savings; • improvement in rejection rate; • # requisitions handled in time; • rating in customer survey 	<i>Realised:</i> <ul style="list-style-type: none"> • purchase volume (saving potential); • # competitive tenders 	<i>Realised:</i> <ul style="list-style-type: none"> • savings; • # flawless deliveries; • # on-time deliveries; • score in customer survey; • service level 	<i>Realised:</i> <ul style="list-style-type: none"> • Savings; • # contracts closed • rating in customer survey
	Quality improvement	<i>Proactive:</i> <ul style="list-style-type: none"> • # cost reduction programs; • # quality projects with suppliers 	<i>Proactive:</i> <ul style="list-style-type: none"> • # years supply assurance; • consignment stock days 	<i>Proactive:</i>	<i>Proactive:</i> <ul style="list-style-type: none"> • # cost reduction proposals; • # training hrs;
	Logistical performance				
	Customer satisfaction				

Table 3 — Available control data from LUs

Location	Time units canteen	Time units automat	Service level	Net costs per employee (index figures)
1	12	4	3	0.47
2	12	1.5	1	0.18
3	12	6	1	0.34
4	22.5	2.5	2	0.28
5	16	3.5	3	0.61
6	25	5.5	2	0.27
7	17.5	7	2	0.83
8	18	5	2	0.54
9	37	2.5	5	1.00
10	33	17	5	0.46

Table 4 — DEA efficiency scores for 10 local service outlets

Location	Efficiency score
1	0.58
2	0.71
3	0.48
4	0.88
5	0.44
6	1.00
7	0.26
8	0.40
9	0.48
10	1.00

Figure 1 — Control paradigm (De Leeuw, 1974)

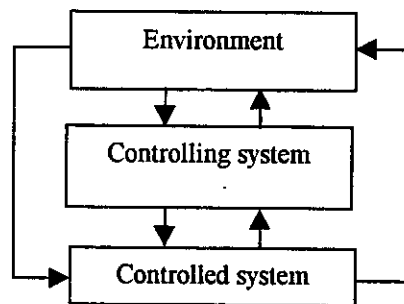


Figure 2 — Worksheet used in DEA application

