DATA ENVELOPMENT ANALYSIS AND THE QUEST FOR TARGETS – A CASE STUDY IN CONNECTION TO WASTE REDUCTION ON SITE

Aerson Moreira Barreto[1], Luiz Fernando Mählmann Heineck[2], Luiz Antonio Freire Pinto Silveira[3] and Thais Moreira de Vasconcelos[4]

ABSTRACT

Target costing is addressed in this research work based on statistics and data collection on building developments. Contrary to standard practices that claim target costing should not be based on any distracting previous cost experiences, this paper introduces DEA - Data Envelopment Analysis – a linear programming technique capable of drawing an efficient frontier for a set of performance data (site waste reduction in this research paper). Such performance frontier departs from standard cost estimating practices that deal with average or percentile performance: target values are now obtained according with the best performances a set of observations is capable of displaying: what in normal circumstances is taken as an outlier is now investigated in connection to the causes underneath such outstanding performance. DEA's efficient frontier is akin to the concept of opportunity costs as fundamental to microeconomics. Target setting is exemplified through a site waste evaluation of a number of building sites, each one conducted according to different levels of managerial effort geared to improve this aspect of lean production goal. Results point to the range of management actions that might be chosen by administrative site personnel, in different sets, employing a parsimonious number of them, according to the specific circumstances of each building site.

KEYWORDS

Target Costing, DEA, Efficiency Frontier, Waste construction

INTRODUCTION

This paper introduces the discussion on Target Cost (TC) but a within a view that targets are not absolute values, but best possible performance that might be achieved in a group of organizations that have similarities in their activities. Moreover, targets

[1] Professor, Civil Engineering., Rural Federal University of Semi-arid , Rua Gamaliel Martins Bezerra, SN, Alto da alegria, University campus, Angicos/RN, CEP: 59.515-000, Brazil, Phone +55 (84) 98379811, aersonbarreto@ufersa.edu.br

[2] Professor, Civil Engineering. Department of Mechanical Engineering and Operations, Campus do Pici, Federal University of Ceará, Brazil, Phone +55 (85) 97152754, freitas8@terra.com.br

[3] Graduate Student in Civil Engineering, Rural Federal University of Semi-arid , Rua Gamaliel Martins Bezerra, SN, Alto da Alegria, Unievrsity Campus, Angicos/RN, CEP: 59.515-000, Brazil, Phone +55 (84) 99587475, luizinhuu00@hotmail.com

[4] Architect, University of Fortaleza, Rua Vicente Leite, 497, Apto 500, Meireles, Fortaleza, CEP: 60170-150, Brazil, Phone +55 (85) 91999069, thaismor@gmail.com

are related to independent variables that might cause them, that is,targets cannot be set without hinting on how they can be achieved. Moreover, maximum efficiency in the use a restricted number of input variables is linked to target performance.

The objective of this research is to show how Data Envelopment Analysis, an operations research mathematical technique, is suited to produce rational targets. An example is taken from the field of waste reduction on site, as documented by data extracted from a group of building companies acquainted with lean construction principles. These building companies operate in Fortaleza, a 3 million inhabitants city in the northeast of Brazil.

Based on the experience of applying of DEA (Data Envelopment Analysis), this study seeks to contribute to theoretical discussions on Target Costing and Waste Management. It is structured as follows. The first section describes succinctly TC as addressed in construction research literature. The second section introduces the concept of DEA and shows how it deals with maximum possible efficiency in the use of a restricted number of input variables. The third section provides the obvious link between TC and DEA. The fourth section deals with an example of setting targets for waste reduction on site. Finally conclusions are draw on the use of DEA for targets on overall cost reduction, taken into account not only output variables but also the minimization of cost associated with input variables.

TARGET COSTING IN CONSTRUCTION RESEARCH

The concept of Cost Target refers to a business management strategy and a process to arrive at the optimal value of obtaining production costs, ensuring product profitability and meeting the needs of a competitive market (Wiwnhage et al, 2012). These authors show that the principles of TC are related to aligning cost of production with market prices. De Melo e Granja (2013) showed that not only internal processes should be scrutinized in order to achieve target costs, but also interorganizational ones. In short, target costs are established as a mediation of inputs and outputs that an extended production process is capable of producing at its best performance. Ballard (2012) proposes rules for cost estimating in order to arrive at TCs. One of such rules is the comparison of fixed prices set by the market with a range of probability costs that producers might experience. Once more, targets are not freely dreamed off, but supported by some sort of statics.

DATA ENVELOPMENT ANALYSIS

DEA was developed by Charnes, Cooper and Rhodes (1978) to evaluate the relative efficiency of Decision Making Units (DMU). DMU is a fancy acronym to describe organizations, individuals, that is, any sort of decision making agent that might choose a set of inputs to obtain desired outputs. These authors claim that DEA defines a boundary (a frontier) as a reference to measure the relative efficiency of a particular group of DMUs involved in a study. Within such group, some DMUs are found efficient and hence situated in a graphical efficiency frontier and others are deemed less efficient. Zhu (2003) highlights some features of the DEA, including the fact that it considers the possibility of different combinations of inputs and outputs to set the border. Every efficient unit is efficient at its own combination of inputs, most of them making use of a restricted set of inputs. Efficient units might discard inputs that are not making them any better. Less efficient units not only might discard their own non-contributing inputs, but primarily imitated their neighboroughs efficient units in the quest for efficiency, using a restricted number of proper inputs. As the technique uses mathematical programming to evaluate rows of output and input variables, neighboroughs are defined by graphical distance between such rows of coordinates. Lin and Okudan (2009) state that the degree of inefficiency of any DMU can be measured as the distance of its vector of inputs/outputs to the envelope. Figure 01 locates the efficient and inefficient units. For the sake of simplicity DEA graphically disposes as an example a special case with one output and one input variables

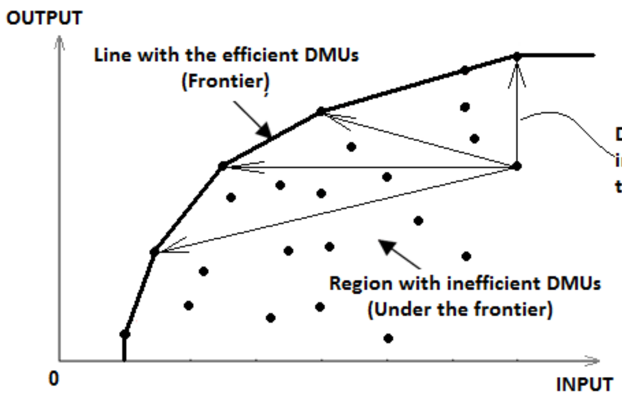

Figure 1: Efficiency frontier and location of DMUs

Macedo e Silva (2004) emphasize that the basic idea is the comparison of inputs and outputs. Talluri (2000) and Eilat, Golany and Shtub (2006) corroborate these authors arguing that in the presence of multiple performance measures and factors of production, weighted sums of outputs and inputs are employed. Weighting procedures are established by operations research, maximizing combined outputs and minimizing the use of a selected number of inputs. It is interesting to note that outputs are taken as a whole, with all possible performance measures taken into consideration: they represent value, and cannot be disregarded; on the other hand, for each DMU only a set of possible inputs that are known to be under operation are taken into account: they represent costs, and hence should be minimized. In practical terms, management should avoid using such inputs in the future, as they do not add to output but represent costs.

Going a step further, the technique evaluates the best ratios of output to input. That is, efficiency is not measured by the larger weighted outputs or the minimum weighted restricted set of inputs, but by a relative measure of outputs and inputs. In actual fact, this is the standard concept of efficiency, a relative measure of benefits and costs. Dalmas (2005) describes the benefit/cost ratios as a percentage index. Each DMU situated at the efficient frontier has a 100% efficiency ratio, which is the weighted output is the maximum the minimized set of inputs can achieve. Maximum efficiency is set to 1 (100%) and minimum efficiency is set to zero (0%). Such efficiency ratios are valid for the group of DMUs under examination. Different groups of DMUs will have a different efficient frontier, different DMUs with efficiency set to 100% and different set of DMUs with efficiency set to less than 100%.

REJOINING TC AND DEA CONCEPTS

Last paragraph discussion allows one to understand that TCs established though the use of DEA will always be a relative figure. It is not possible to arrive at an absolute maximum TC, hopefully obtained by examining different sets of DMUs combinations, taking the largest of them all and setting it to 100%. Weights for input variables can be associated with opportunity costs, a well established concept in microeconomics.

According to Vasconcelos and Oliveira (2008) opportunity cost for an input variable corresponds to the best possible use of such variable among alternative uses. As such variable is capable of producing in the most efficient way in one of its alternative uses, someone will want to pay higher to secure such resource. This is the true cost of maintaining this input, which is the monetary gain lost for not hiring it for someone else at its best price. In this sense, microeconomics theory already contemplates the idea of a best possible use of resources among alternatives. It might be taken that such alternatives should be feasible, should be experienceable, that is, opportunity costs exists in a set of known production arrangements.

Weights for output variables follow the same reasoning. Output is set as its highest by a combination of weights for each individual output variable. Consider for example that output is measured in terms of material's waste and safety records. For a particular 100% efficient DMU this special combination is the best because someone values it that way. If someone finds value in this combination of records, he is willing to pay for this output, that is, this is the maximum value someone finds in this combined performance on waste and safety. In this case, target cost is best view as target value. Maximum efficiency is set to 1 (or 100%). It means that the sum of outputs divided by the sum of inputs is equal to 1. Thus output equals input, and it is irrelevant if someone is searching for target costs or target values, since in micro economical terms they are the same.

SETTING TARGETS USING DEA

For the 100% efficient DMUs amongst a set of other not that much efficient, performance targets are set according to what they are already achieving. By definition, they cannot produce any better. Management should strive to reproduce the use of relevant inputs, disregard the irrelevant ones and maintain the successful modus operandi. It remains an open question how to introduce Kaizen efforts in these already efficient circumstances.

Hopefully, the majority of DMUs in such a group are in search of ways to improve their performance, as they are not in the efficient frontier. Ghosh (2008) maintain that, the use of best practices identified by the efficient units can be used by inefficient units in a benchmarking process, resulting in increased efficiency. Higher costs due to the use of different set of inputs will be more than compensated by better output. It might also occur that smaller costs can also be obtained, with diminishing outputs, but still with favorable benefit/cost ratios.

Langroudi and Jandaghi (2008) show in the Figure 2 various DMUs (A, B, C, D, E, F, G and H) where the efficient frontier contains A, B, C and D. As an example, DMU G can be made more efficient by taking steps either by reducing the use of inputs (X1 to X2) or increasing output (Y1 to Y2) maintaining the same amount of input (X2). They describe horizontal or vertical movements, but it should be added that any combination of movements leading to the efficient frontier is possible. As to the right of point D, the efficient frontier becomes a line parallel to the x axis: there is no logical reason to employ more resources that D does, as no output benefit will accrue.

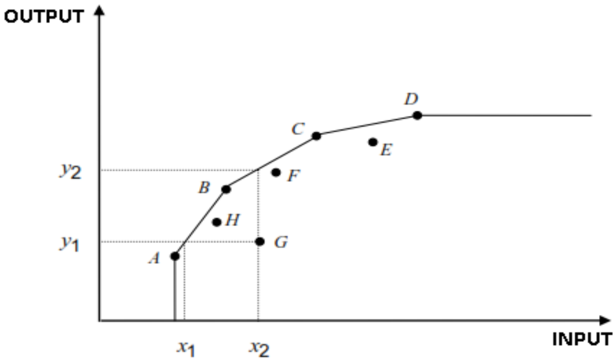

Figure 2: Decisions for efficiency (Adapted from Langroudi and Jandaghi, 2008)

Cooper, Seiford and Zhu (2004) discuss the allocation of costs and weights assigned to inputs by DEA and state that the variation in costs of production may lead inefficient units to the level of efficiency. Movements either to increase costs or more than proportionally increase output, or decrease costs and less than proportionally decrease output are always rational. They argue that very little information is required to make such moves: DMU G might study how DMUs H and F operate in such a way to take advantage of their particular set of resources, almost reaching the efficient frontier. Going one step further, it might envisage imitating B and C that already are on the efficient boundary. In mathematical terms A and D are also possible targets, although not situated in G vicinities. They operate with a significant difference in terms of input variables, and might not be straightforwardly imitated. Figure 3 by Sttavrinides and Soteriou (2000) adds to this discussion.

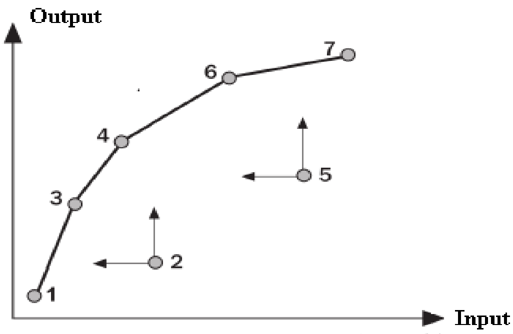

Figure 3: Efficient and inefficient unit within an envelope surface (Adapted from Sttavrinides and Soteriou, 2000)

Soteriou and Sttavrinides (2000) propose a slightly different example. DMUs 1, 3, 4, 6, and 7 are efficient, while 2 and 5 are not. Instead of moving to their neighbouroughs as for G above, it could be done a comprehensive qualitative evaluation on how the efficient units employ their resources. Lessons learned from the efficient DMUs might be applied to the whole group to make them all 100%

efficient. Alternatively, any target setting comprising horizontal moves to the left and vertical upward moves by DMUs 2 and 5 will increase their efficiency, as graphically they get nearer to the efficient frontier.

SETTING TARGETS FOR WASTE REDUCTION ON SITE – A METHDOLOGICAL APPROACH

Data obtained in a survey conducted by Barreto (2010) on the study of management effectiveness to reduce waste on 29 different building sites in the city of Fortaleza (Brazil) was used to produce an example of target cost setting. A simple exercise was conducted with just one output variable (a proxy for the amount of waste produced on site) and one input variable (a geometric combination of management actions deemed to be connected to best practices in terms of waste reduction). Output is represented by the floor area footage that produces one cubic meter of site debris. It is the inverse of a common Key Performance Indicator (KPI) that relates the number of cubic meters of debris per floor area footage. Typical values are in the range of 0,03 m^3/m^2 at its best to $0{,}20^3/m^2$ at its worst, what corresponds to output values of $5m^2/m^3$ at its worst to 33,33 m^2/m^3 at its best. The latter illustrates the range of values that are set for the y axis in the following figures.

Input variables are obtained as follows. A set of 16 managerial actions were selected by respondents as the more powerful ones to help reduce waste on site. A score ranging from 1 to 10 was assigned to them in accordance with respondent's feelings on their relative importance for that matter. The four better scored where taken as representative of each site managerial effort to reduce waste. Their scores were multiplied in order to get an x axis figure. Therefore, maximum x values would be 10000 (10x10x10x10). For a particular DMU, if the four major managerial actions scored 8 each, corresponding x value would be 4096. Table 1 shows y and x values for the didactic example hereinafter put forward. From an initial set of 31 DMUs 29 were deemed appropriate for analysis: this is the reason why the list of DMUs starts with n°3 and ends with n° 31.

Table 1: Inputs and Outputs from Barreto (2010) research.

DMU	Input	Output	DMU	Input	Output	DMU	Input	Output
DMU 3	4.200	33,38	DMU 13	2.700	10,58	DMU 23	5.600	4,89
DMU 4	3.969	32,38	DMU 14	5.040	9,33	DMU 24	3.402	4,76
DMU 5	1.120	23,87	DMU 15	3.360	8,26	DMU 25	3.024	4,63
DMU 6	7.200	20,28	DMU 16	448	8,24	DMU 26	8.000	4,56
DMU 7	4.320	18,07	DMU 17	800	8,02	DMU 27	5.600	4,35
DMU 8	3.200	17,52	DMU 18	4.480	7,78	DMU 28	2.160	4,25
DMU 9	360	17,43	DMU 19	3.780	7,22	DMU 29	10.000	4,12
DMU 10	3.240	16,51	DMU 20	2.800	6,12	DMU 30	8.000	3,47
DMU 11	7.200	13,20	DMU 21	6.300	5,69	DMU 31	4.200	2,94
DMU 12	4.320	11,21	DMU 22	2.400	5,37			

RESULTS AND DISCUSSION

Figure 4 shows that DMUs 3, 5 and 9 are 100% efficient: the remaining 26 are ineficient, occupying different positions within the data envelope graphic produced by DEA software. This envelope might also be obtained graphically just by searching the DMUs x,y coordinates that are able to produce the highest piecewise convex boundary for the set of 29 data points. DMUs 9 and 3 are specially efficient units in this example as they set the minimum and maximum 100% efficient reduction of waste for the set: they are associated respectively with vertical and horizontal lines that are drawn in order complete the data envelope that encompass all remaining inefficient DMUs.

It might be observed that waste reduction is scattered along the graph and one cannot conclude that increased managerial effort, as depicted in x axis, is associated with better performance. On the other hand, DMUs 17, 16, 13, 10, 8, 7 and 6 tell a different and more positive story: managerial effort pays off, as performance increases almost linearly with increasing x values, what could be corroborated by a linear regression analysis drawn through such points. Moreover, DMUs 9, 5, 4 and 3 produce a still better performance, even if they use less managerial effort. This is the reason why they are efficient: they produce higher outputs with fewer inputs. It should be noted that DMU 4 is almost 100% efficient, as it is situated just below the efficient frontier.

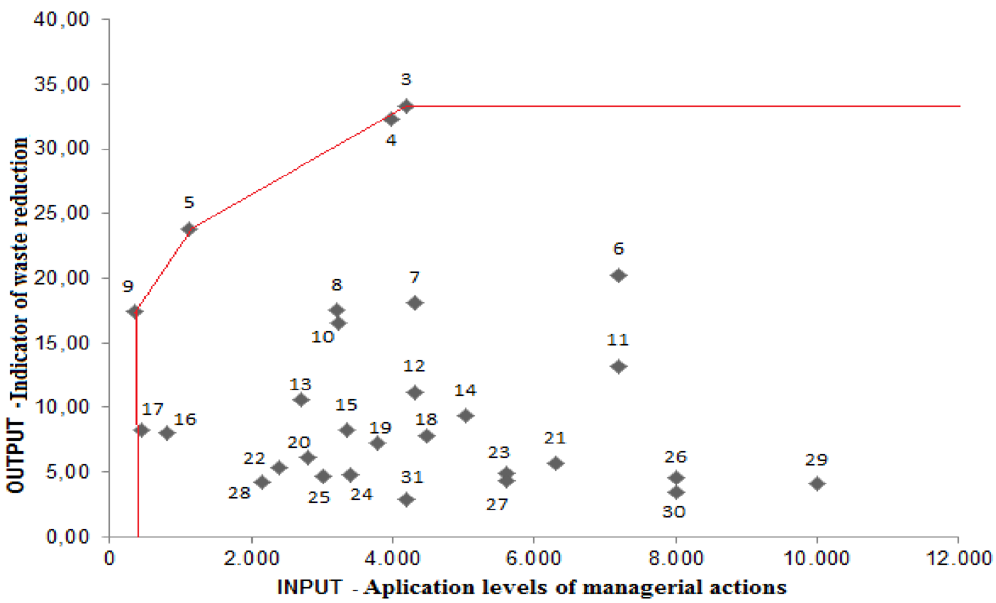

Figure 4: The efficient frontier for the group of 29 DMUs.

There are two possibilities for setting DEA targets for the 26 remaining DMUs, (including DMU 4 that needs just a small improvement to become efficient). Either they improve their output (waste performance) still using the same amount of resources (managerial effort) or they deliberately reduce their performance using a positive cost/beneficial reduction of management effort. Simultaneous changes to both output and input variables are also possible, provided that DMUs coordinates get nearer to the efficient frontier. The aim is to become one of the 100% efficient frontier data points, moving just closer to the external boundary is a suboptimal possibility. Neighboroughs might be benchmarked on how they relate output and inputs. For example, DMU 11 might take advice with DMU 6, while DMU 12 could appreciate how DMUs 8, 10, 7 and 6 work.

In this didactic example total cost are made up of waste and management effort. DMU 11 move towards the external boundary maintains the same management cost, but produces an improvement of 60,42% in connection to wastage. It produces 0,0758 m^3/m^2 (13,20 m^2/m^3) while the horizontal frontier line drawn(taking DMU3 as a cornerstone for the piecewise convex boundary line) is associated with 0,0300 m^3/m^2 (33,38m^2/m^3). Waste reduction is thus (0.0758 – 0,0300)/ 0,0758 = 0,6042.

A still better approach is to move directly towards DMU 3. Waste reduction is again 60,42%, but managerial cost can be reduced according to how much it cost to perform each of the 4 managerial actions that where scored and multiplied in order to obtain x values. Suppose cost are directly associated with scores; better management costs proportionally more. DMU 3 has an x value of 4200, that is, on average their four action scores were 8.0503. Management cost is 4 * 8.0503 = 32.2012. DMU 11 has an x value of 7200, four action scores with an average of 9.2116 and 36.8462 management cost. Total target costs for DMU would be a reduction of 60.42% in waste and 12.61% in management costs ((36.8462-32.2012)/36.8462).

Following the same steps and reasoning above, DMU 8 is now addressed in is quest for target performance. Its x, y coordinates are (3200,17.52), a relatively efficient building site. It might improve its performance by approaching the efficient boundary in a multitude of ways. Any move towards such frontier will do, provide it does not get below DMU 9 or to the right of DMU 3. Possible moves are to imitate its neighboroughs 9, 5 and 3. Their x,y coordinates are respectively (360,17.43), (1120,23.87) and (4200,33.38). Moving towards DMU 9 maintains almost the same waste performance (17.52 vs. 17.43) but with a reduction in management costs of (((30.0848-17.4236)/30.0848)=0.4209) = 42.09%. Moving towards DMU 5 improves waste performance and decreases managerial costs, what is a positive move.

Moving towards DMU 3 improves waste by (((0.0571-0.0300)/0.0571)=0.4747) 47.47 % but increases management costs by (((32.2012-30.0848)/30.0848)=0.0703) 7.03 %. Depending on the relative costs of management and waste this move might be worthwhile or not, in terms of target performance.

Figure 5 shows a suggested move towards the efficient boundary for the 26 DMUs. Observe that it indicates a vertical move for all building sites, except the ones like 7, 12, 18, 31, 14, 23, 27, 21, 6, 11, 26, 30, and 29 that are using more than 4200 units of management input. This amount corresponds to an average score of 8.0503 for each of the four management actions that were associated with waste reduction. The inclined move paths towards DMU 3 means that it is not interesting to excel on management efforts on site, if no better performance is obtained compared to a site like 3. For the remaining inefficient sites, target waste performance would be obtained by maintaining their management effort but making better use of it. Vertical lines indicate the path for improvement, till a supreme target performance is obtained.

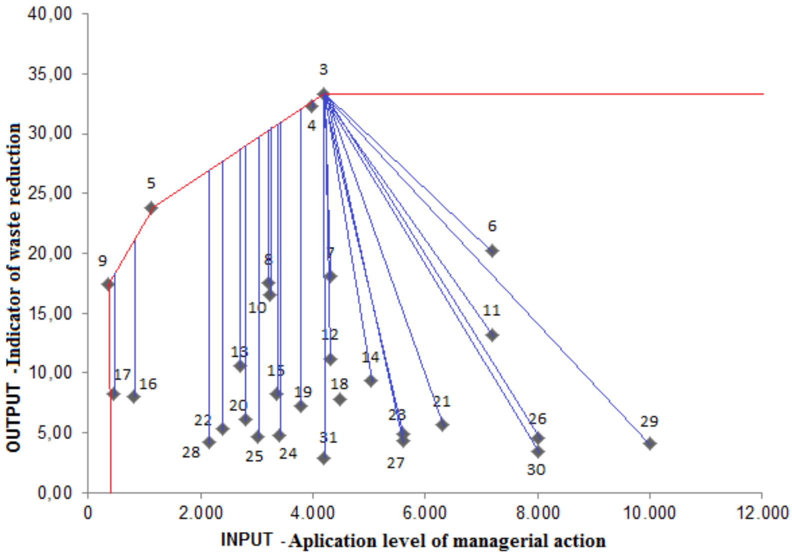

Figure 5: Efficiency frontier for the group of 29 DMUs.

FINAL COMMENTS

This study aimed to contribute to the debate around target costing and performance. It introduces the concept of cost benefit analysis in the setting of targets based on the best possible performance achieved by building construction enterprises. While acknowledging that anchoring on past performance detracts from target cost philosophy of breaking free from traditional form of behavior, it allows construction agents to choose the sort of resources, their amounts and combinations in circumstantial suited to them. Each agent has only one aim: to point out how efficient they can be as compared to a reduced set of 100% efficient DMUs. Those were allowed to be efficient in their own way, runners up should also have such freedom of action on order to arrive at their targets.

Moreover, Data Envelopment Analysis, an operations research technique, provides another concept that is akin to lean construction, which is selecting a parsimonious number of different types of resources, amongst a more liberal set of them, suffice to provide maximum performance. Not only performance is explained by a restricted set of inputs, but also target performance is linked to an input-output model. If targets are to be achieved, inputs should be enacted upon. In this research work, management actions are to be set into operation, avoiding the establishment of targets as an exercise of wishful thinking.

A waste management example is given, what allows the introduction of a powerful concept difficult to grasp as first: best performance is what can be achieved in relative terms, comparing benefits and cost (respectively reduction of waste and management effort, as in this case) and not an absolute level of performance, as normally taken for granted in target cost propositions. Moreover, in line of opportunity costs derived from macroeconomics, the best use of resources can only be measured as far as their best possible known use is taken into account. This is again a relative concept that helps bring light to the discussion set forward in this paper: target cost cannot be set at will, with no connections to reality – if they are experienceable they should have been experienced.

REFERENCES

Ballard, G., Pennanen, A. (2013) "Conceptual estimating and target costing", *Proceedings for the 21st Annual Conference of the International Group for Lean Construction*. Fortaleza, Brazil, July/August, 2013.

Barreto, A.M. (2010). *Application of Data Envelopment Analysis (DEA) on the avaliation of effectiveness of management Actions to reduce waste in construction works.* Dissertation. Department of Civil Engineering, Federal University of Ceará, Fortaleza, BR, 156 pp.

Charnes, A., Cooper, W. W.; Rhodes, E. (1978). "Measuring the efficiency of decision making units". *European Journal of Operational Research*, v.2, n.6, p. 429-444.

Cooper, W. W., Seiford, L.M., Zhu, J. (editor) (2011). Handbook on Data Envelopment Analysis, Kluwer Academic Publishers. Boston, MA, 497 pp.

Dalmas, J. C. (2005). "Aplicação da análise estatística multivariada e da análise de envelopamento de dados (DEA) no estudo da eficiência de cursos de graduação". Proceeding 50st *Annual Meeting of RBRAS,* and 50st SEAGRO Conference, Londrina, PR, Brazil.

De Melo, R.S.S, and Granja, A. D. (2013). "Interorganizational cost management and its implications for target costing in construction". *Proceedings of the 22th Annual Conference of the International Group for lean Construction,* Fortaleza, Brazil, July/August, 2013.

Eilat, H.; Golany, B.; Shtub, A. (2006). "Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology." European Journal of Operational Research. v172, n 1, 1018-1039

Grosh, n. (2008). "Data Envelopment Analysis: A new horizon in measuring technical efficiency and benchmarking". TIG Research Journal, v 1, n 1, p. 49-56.

Langroudi, M. Z. A., and Jandaghi, G. (2008). "Validity examination of EFQM's results by DEA models". Journal of Apllied Quantitative Methods, v 3, n 3, p. 207-214.

Lin, C. Y.; Okudan, G. E. (2009). "An exploration on the use of data envelopment analysis". *Journal of Industrial Engineering Management System - IEMS*. v. 8, n. 1, p. 47-53.

Macedo, M.; Silva, F. (2004). "Análise de desempenho organizacional: utilizando indicadores financeiros e não-financeiros na avaliação de performance empresarial". Proceeding 28st ENANPAD Conference. Curitiba, PR, Brazil.

Stavrinides, Y.; Soteriou, A. C. (2000). "An internal customer service quality data envelopment analysis model for bank ranches". *Internacional Journal of Bank Marketing. MCB University Press*. p. 246 – 252.

Talluri, S. (2000). Data Envelopment Analysis: Models and Extensions. Hollys S. Lewis, Feature Editor, Pennsylvania state University, p. 8-11.

Vasconcelos, M. A. S., Oliveira, R. G. (editor) (2008). Manual de microeconomia, Atlas, São Paulo, SP, Brazil, 317pp.

Wienhage, P., Rocha, I., Scarpin J. E. (2012). "Aplicação do Target Costing e Engenharia do Valor na Precificação de Curso de Pós-Graduação." *ABCustos Associação Brasileira de Custos*, v 7, n 1, p. 85-129.

Zhu, J. (editor) (2009). Quantitative models for performance evaluation and benchmarking. Springer, New York, NY, 88 pp.