AN INVESTIGATION INTO THE SYSTEMATIC USE OF VALUE ENGINEERING IN THE PRODUCT DEVELOPMENT PROCESS

Joyce de Andrade Ruiz[1]; Ariovaldo Denis Granja[2]; Flávio Augusto Picchi[3]; Reymard Sávio Sampaio de Melo[4]

ABSTRACT

Value Engineering (VE) is a methodical technique which aims to achieve the best functional balance between product cost, reliability and performance, and it is the operational tool that facilitates the achievement of the target cost in a product development process (PDP). VE is aligned with recent philosophies for proactive cost management by analyzing cost parameters and drivers in the early stages of the PDP. A typical VE study accomplishes the decomposition of the product’s functions, and the subsequent evaluation of them, in order to pursuit cost reductions without trading-off the product’s functionality, quality and value delivery to clients/users. This research investigates how to use the VE technique in a construction product in a systemized way. VE tools, such as Function Analysis, FAST Diagram, Mudge Technique and Compare Method were combined and applied in a handicap bathroom, as an example of the detailed application of this technique. By means of the VE exercise, a cost reduction in the order of 12% was achieved, even with the addition of two new items, enhancing value delivery to end users.

KEYWORDS:

Value engineering; target costing; product development process; cost management in construction; value delivery.

[1] M.Sc., Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and Urban Design, Department of Architecture and Buildings, State University of Campinas(UNICAMP), joyce.andrade.ruiz@gmail.com

[2] Asst. Professor, Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and Urban Design, Department of Architecture and Buildings, State University of Campinas(UNICAMP), Avenida Albert Einstein, 951, Caixa Postal 6021, Campinas/SP, CEP 13083-852, Brazil, Tel.: +55 19 3788-2082, FAX + 55 19 3788-2411, adgranja@fec.unicamp.br

[3] Asst. Professor, Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and Urban Design, Department of Architecture and Buildings, State University of Campinas(UNICAMP); and Director, Lean Institute Brazil, Rua Topázio 911, São Paulo-SP, Brazil, CEP 04105-063, Tel.: +55 11 5571-6887, Fax:+55 11 5571-0804, fpicchi@lean.org.br.

[4] Ph.D. candidate, Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and Urban Design, Department of Architecture and Buildings, State University of Campinas(UNICAMP), reymardsavio@yahoo.com.br

1. INTRODUCTION

The Lean Thinking, a broad concept of efficiency and productivity in the manufacturer environment, has been adapted to the construction sector to improve its production process, reasoned in the Toyota Production System (TPS) (PICCHI, 2003; MORGAN; LIKER, 2006; WARD, 2007). As basis, the lean orientation has the absolute waste elimination and high efficiency of the production process. Its' proven retrospect of results enhancement is challenged to continue giving good results but now not only in the production process, but also in the development phases (MORGAN; LIKER, 2006; WARD, 2007; BALLARD; RYBKOWSKI, 2009). In this actual context the Value Engineering (VE) is useful to contribute and make part of a lean product development process with the objective of achieving the highest product performance design, focused on the incorporation of clients' values, perspectives, wants and needs since the early design process (WARD, 2007). This is shown as the new frontier of Lean Thinking evolution and VE is a tool that can subscribe in a product development process (MORGAN; LIKER, 2006).

The VE concept was originated too in the industrial environment and has an impressive history of success in product value and quality improvement (DELL'ISOLA, 1997). It facilitates the identification of opportunities to remove unnecessary costs, ensuring product quality, reliability, functionality and performance using as a main target market competitiveness (COOPER; SLAGMULDER, 1997). VE is a part of the target cot strategy that permits the achievement of the target cost through its application in the product development process, by working its functions cross-analyzed with value parameters (COOPER; SLAGMULDER, 1997).

This research addresses this issue, showing results obtained with a systematic application of VE. Its objective is to investigate how to use the VE technique in a construction product, in a systemized way, specifically at the product development phase. In order to identify and analyze the VE possible applications in construction, a literature review of VE was carried out. A handicap bathroom design was analyzed as an example, using a combination of VE tools, identifying opportunities for value enhancing and cost reduction, and calculating the potential results of this systematic approach.

2. VALUE ENGINEERING (VE)

VE, first called 'Value Analysis', was created by Lawrence D. Miles in 1947 (CSILLAG, 1995), in the period during and immediately after the Second World War (SPAULDING et.al, 2005). Miles was commissioned to explore methods of substituting materials, construction techniques, reducing manufacturing times and costs without reducing the products' functions and quality (MILES, 1989). Lessons learned in this process were evolved and applied by Miles in his later VA work.

According to Cooper, Slagmulder (1997) VE consists of a systematic and multidisciplinary examination of factors that decomposes the product cost to identify reasonable ways to reduce costs without jeopardizing its functionality and quality. It is a fundamental part of the target costing strategy, as the tool that provides costs reductions by analyzing and working the product's functions. One could say that it is an intelligent cost reduction technique trough "best value for money" concept (LIN; SHEN, 2007; SHEN; LIU, 2003). This guarantees that products will perform their basic functions and essential characteristics with quality and an acceptable cost, or a target cost, from the client's perspective of value.

VE methodology can be applied in various fields, especially at the product development process and project design. The ideal phase for VE use is the design phase, maximizing results, due to the fact that 95% of the product costs are already committed at the design phase (COOPER; SLAGMULDER, 1997).

It is a technique that provides cost reduction (measurable parameters) and guaranteed value (immeasurable parameters), the performance evaluation must consider both aspects. According to Lin, Shen (2007) the difficulty in evaluating value is one of the reasons why VE is still less utilized in construction.

Another point of concern is the moment when VE is used. The later VE is incorporated in the product development cycle, the lower are the results and benefits it can provide (DELL"ISOLA, 1997). Consequently, this kind of use leads to a bad use of the technique, tending to reduce specifications, quality and even profit (BALLARD, RYBKOWSKI, 2009).

2.1 VALUE

It is important to conceptualize the clients' value, which encompass basically two perspectives in this context. Thinking of a construction enterprising there are in resume two clients whose perspectives must be fulfilled; the first is the one that represents the company that is making profit from the enterprising (that will be called company) and the second one are the users that effectively are going to use the space under construction (that will be called users). This both perspectives are most of the time contradictory because the company wants to reduce costs to make more money and to have a commercial and marketable product, and, on the other hand, the users want a space as better as possible with all comfort, benefits and equipments that usually leads to an excessive spending of money. In Brazil, some research efforts have been recently carried out on this subject focusing on social housing provision, e.g., Bonatto; Miron and Formoso (2011), and Kowaltowski and Granja, 2011.

To reach the balance between these two different perspectives the VE is used to allow the company design team to analyze and modify the project reducing costs, but oriented by the users' value. This provides a balance between the two different values perspectives, as shown in Figure 1.

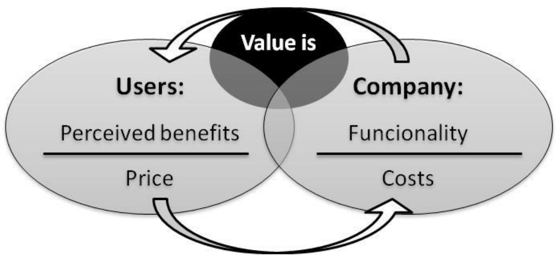

Figure 1 – Value concept: Context perspectives. Adapted from Cooper e Slagmulder (1997)

The "perceived benefits" comprehended the clients' factors of desire and need and the "necessary sacrifices" refer to the purchase costs and use of the product. It is important to clarify what point of view is going to be focused on the work, who is the real client, the stockers, the users, the company. Because their expectations are usually different, a solid VE work that considers both aspects, function and value, is relevant to achieve the balance and best result for the evolved stakeholders (players).

2.2 VE'S TOOLS

The practical VE operation is attained with the use of various tools to provide a detailed analysis of the product under study. In this work, the following VE tools were adopted following consideration of their potential for construction detailed analysis: Function Analysis, the FAST Diagram, the Mudge Technique and the "Compare" Method.

2.2.1 Function Analysis

The function analysis is the most important VE technique. (DELL'ISOLA, 1997; COOPER; SLAGMULDER, 1997). It consists of detailing the product under study to identify functions, classify them and associate their costs under the adopted component level criteria (SPAULDING *et.al*, 2005). The functions are characterized by two words, a verb plus a substantive, for example, the function of a wall can be "to limit area". The VE concept in manufacturing, according to Miles (1989), classifies functions in two parts: i) Basic Functions (BF) - those that represents the specific function of the product and, ii) Secondary Functions (SF), those that are part of the product but are not directly related with the basic function (COOPER; SLAGMULDER, 1997; CSILLAG, 1995).

From the regular classification of functions, Dell'Isola (1997) proposed a differentiation to make a better adaptation to construction. He created the "Necessary Secondary Function" that corresponds to those required by regulations, laws and technical standards. Adopting this definition, the functions classifications are: i) Basic Functions (BF); ii) Secondary Necessary Functions (SNF); iii) Secondary Functions (SF).

2.2.2 FAST Diagram

Charles Bytheway developed the Function Analysis System Technique, known as FAST Diagram, in 1964, about 17 years after the beginning of VE. The objective was to introduce a visual tool that could depict a schematic relationship of dependencies between the functions that were previously classified by Function Analysis (ABREU, 1996; CSILLAG, 1995).

Based on VE principles, a multidisciplinary group is formed with representatives of different areas that will discuss and analyze the product and its functions from different points of views, developing a logical representation (ABREU, 1996). These special meetings are called "charrets" (SPENCER; WINCH, 2002). The main objective is to obtain detailed information from different perspectives by stimulating problem solving and creative activity on the part of the participants. An experienced VE facilitator is usually required to guide the process. A flow chart is created during the process to show inter-relationships between functions and solutions.

This phase generates a large number of ideas, some of them innovative, useful, and some others irrelevant (MAO; ZHANG; ABOURIZK, 2009). Because of this, they recommend being careful and critical in this intense brainstorming phase and to pay special attention to the objectivity and focus on the outcome of these meetings. Rozenfeld *et.al* (2003) highlights the increasing use of FAST in the product development process (PDP) of new products.

2.2.3 Mudge Technique

The technique of numerical function relations evaluation, known as Mudge Technique, consists in the pair to pair comparison of the functions that compose the product (CSILLAG, 1995). In this tool, scores are assigned by the comparison of importance between two pairs of functions (CSILLAG, 1995; MORAES et.al., 2008). The weight scale used is: i) 1 to a less important function; ii) 2 to a significantly important function; and iii) 3 to a very important function (CSILLAG, 1995).

The objective of this technique is to show the relative percentage that is obtained from the total points weight of each function divided by the total sum of all products functions weights. Based on the obtained results, it is possible to prioritize the functions relevance in order to enable the analysis of their inter-relationships.

2.2.4 "Compare" Method

The "Compare" method, name created by joining the initials of the words compare, parameters and resources (CSILLAG; 1995), results in a chart and a graphic based on the Function Analysis, the FAST diagram and the Mudge Technique, with the inclusion of cost parameters. All information obtained from the cited tools is gathered and the results are synthesized into a graphic known as "Compare Graphic". This graphic is formed of two data series, the first, called "relative needs" comes from the relative results obtained from the Mudge Technique and the second comes from the chart that has the costs of the product's functions, and it is called "resource consumption". Cost, time or material consumption units can be used for the resources (CSILLAG, 1995). From this graphic evaluation it is possible to analyze the functions and to consider those that have higher potential for achieving cost reductions, without trading-off the basic functions of the product and the value perceived by the customer.

3. RESEARCH METHOD

The method used in this study consists of two parts; the first one is the literature review identifying applicable tools, and the second one is the simulation of the techniques using a handicap bathroom as an example.

From the literature review, a sequence for VE tools application on a construction product is proposed. The chosen tools were those more recognized and used for VE work analysis in the manufacture, such as the Function Analysis and FAST Diagram. The "Compare" Method has also been used, because of the systematic way in which it incorporates costs parameters, combined with client's perspective of value obtained by the Mudge Technique. A proposed flowchart for the whole construction process (MESQUITA; FABRICIO; MELHADO, 2003) and for the VE application in a systematic way is depicted in Figure 2.

4. HANDICAP BATHROOM VE SIMULATION

A handicap bathroom was used to simulate the use of VE technique and tools in a systematic way, in order to identify opportunities of costs reductions and, at the same time, to guarantee end-users needs. This handicap bathroom is a project of a Brazilian energy provider company that is replicated among its facilities buildings in order to make then accessible for the use of handicap people. In this study, the perspective of value to the end-user is given by the Brazilian standard recommendation, NBR 9050:2004, for accessibility of buildings, furniture, spaces and urban facilities.

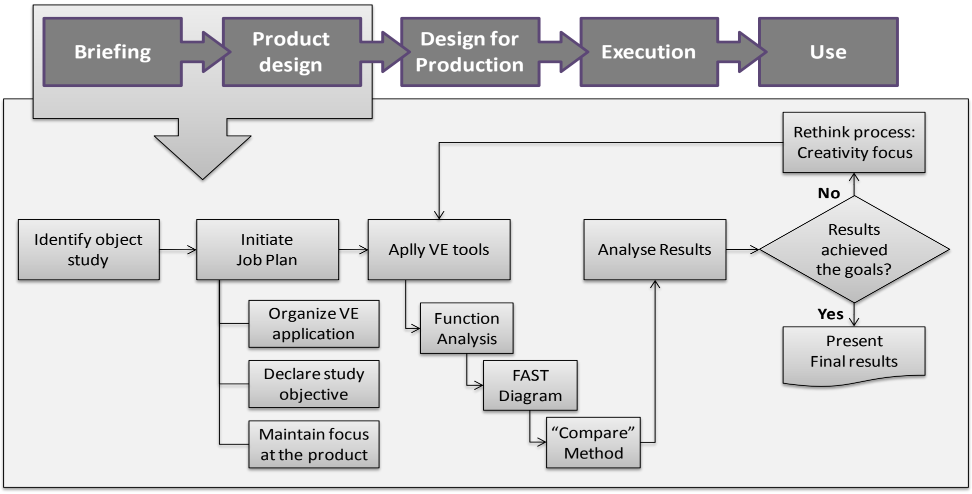

Figure 2 – Proposed sequence for VE systemic application – Process flowchart

4.1 HANDICAP BATHROOM CHARACTERIZATION

Figure 3 (A) and (B) shows the handicap bathroom in a broad representation (A) and in its detailed form (B).The bathroom area was chosen for the simulation of the VE application. This micro space was chosen to concentrate and initiate the understanding of VE use and to provide elements for future studies.

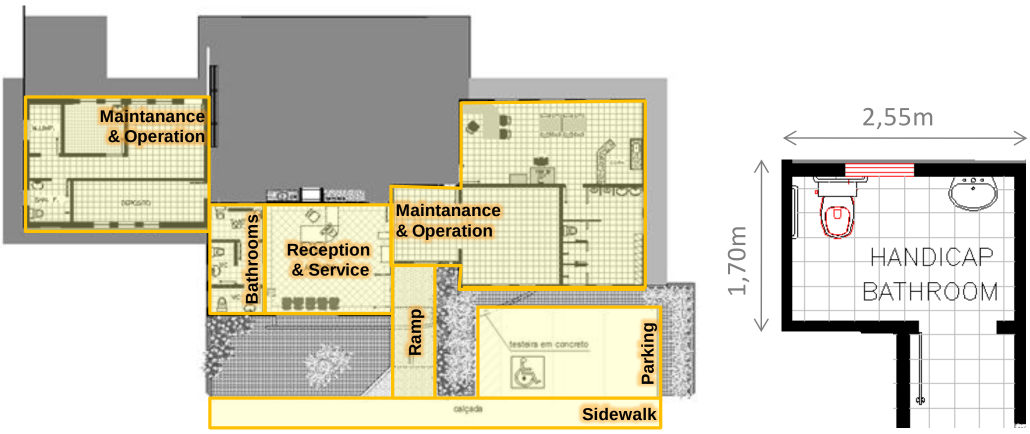

Figure 3 (A): Building design and activities in each area. (B): Handicap bathroom design and dimensions. (ENERGY PROVIDER COMPANY, 2005).

4.2 SIMULATION OF THE VE APPLICATION

The simulation was oriented through the proposed sequence on Figure 1, having as first steps product identification and job plan preparation, objectives, participants, availability and needed resources. The next step was to prepare the Function Analysis. This tool was used to guide the decomposition suggested by the Brazilian Standard Norm “NBR 15575:2010” that comprises building performance. This Standard divides the building in five macro systems: i) Structural systems; ii) Internal floors; iii) Vertical closures; iv) Roofing; and v) Sanitary Installations. Besides these five systems, it was necessary to add two more systems: Electrical and Handicap Accessories (Table 1).

The next steps were to prepare the FAST diagram and the Mudge technique (Figure 3). The “Compare” Method synergizes the three tools applied previously. The component chart provides the costs’ identification of each function, enabling a calculation of total cost per function (this chart could not be presented in this article due to lack of space). These totals divided by the total cost of the product, generates the second data series necessary to make the “Compare Graphic” that will be presented in the next section.

5. RESULTS

The results obtained from the simulation of the VE application are mainly the functions’ methodic evaluation and their parameters of value, end-user needs and related costs. Table 1 brings the Function Analysis that provides the start of VE application, which makes it possible to prepare the FAST diagram, and the Mudge Technique. Figure 4 shows the Mudge Technique, whereas is possible to find each function relative need, for example, “F” function is obtained through the division of the sum of all “F” weights (highlighted column and line: 2+2+3+2=9) by the total sum of all functions weights (140), leading this specific function to have a relative need of 6%.

The “E” function (Table 1) was the first one to be focused in order to reduce costs because it presented the lowest relative needs (Figure 4). By changing the construction technique used, that is reducing the number of mortar layers, a cost reduction from R$3,042.43[5] to R$1,327.19, (- 56% (R$1,715.24)) was achieved.

The cost savings enabled the incorporation of new components with high "relative needs", which had equal or lower costs than the savings made. Thus, two elements that are indicated by NBR9050:2004, but are not mandatory, can be added to the final product, increasing the end-users’ value perception. Those elements are a hygienic shower and a storage rack, corresponding respectively to the functions: "I – Provide sanitary use", and "K –Provide ease of use". The modifications added up to a total of R$334.03, and still provided a reduction of R$ 1,381.21 on the total costs, representing cost reductions of 23% over the initial three functions total cost. The changing of the functions "E", "I" and "K" resulted in handicap bathroom total cost reductions from R$11,847.84 to R$10,466.62, which means 11,7% of savings, but delivering more value to the end-users.

[5] Exchange rate as March/2011: 1US$ = 1,70R$; 1€=2,31R$

Table 1– Function Analysis of the handicap bathroom under study

FUNCTION ANALYSIS: HANDICAP BATHROOM (Provide sanitary and accessible use)				
Components		**Functions (verb + substantive) (*)**	**Function's classification BF / SNF / SF**	**Construction's subcomponents Handicap Bathroom**
STRUCTURE	A	Transmit vertical loads	SNF	Foundation's beams, structural masonry
	B	Transmit horizontal loads	SNF	Floor and Ceiling slabs
INTERNAL FLOORS	C	Plaster horizontal surfaces	SF	Ceramics, painting
VERTICAL SEALS (PARTITION WALLS)	D	Limit area	SNF	Masonry
	E	Plaster vertical surfaces	SF	Tile
	F	Grant ventilation	SNF	Miter (window)
	G	Allow access	SNF	Miter (door)
ROOFING	H	Protect from weather	SNF	Cobertura
SANITARY INSTALLATIONS	I	Provide sanitary use	BF	Hydraulics, drainage, sanitary wares and metals fittings
ELECTRICAL SYSTEMS (**)	J	Provide illumination	SNF	Electrical installations
HANDICAP ACCESSORIES (**)	K	Provide ease of use	BF	Handicap accessories

(*) Two additional necessary subsystems (**) beyond those appointed by the NBR 15575

Legend:	
BF	Basic Function
SNF	Secondary Necessary Function
SF	Secondary Function

	A	B	C	D	E	F	G	H	I	J	K	Σi i=Ai→Ki	Somatory of points of each function (Σi ; i=Ai→Ki)	Relative needs (%) *
A	-	A2	C2	D3	A3	F2	G3	H2	I3	A2	K3	AΣ =	7	**5%**
B		-	C2	D3	B3	F2	G3	H2	I3	J2	K3	ΣB =	3	**2%**
C			-	D3	C3	C2	G3	H2	I3	J2	K3	ΣC =	9	**6%**
D				-	D3	D2	D2	D2	I3	D2	K3	ΣD =	20	**14%**
E					-	F3	G2	H2	I3	J2	K3	ΣE =	0	**0%**
F						-	G2	H2	I3	F2	K3	ΣF =	9	**6%**
G							-	G2	I3	G2	K3	ΣG =	17	**12%**
H								-	I3	H2	K3	ΣH =	12	**9%**
I									-	I3	K3	ΣI =	27	**19%**
J										-	K3	ΣJ =	6	**4%**
K											-	ΣK =	30	**21%**
Total points of the crossfunction's analysis Σ (Σ i=A → K):													**140**	**100%**

* Relative result of the somatory of points of each function divided by the total points of the product under study. Σi / Σ

Figure 4 – Mudge Technique results for the handicap bathroom

Table 2 depicts the results obtained from the simulation of the VE application on the handicap bathroom, and Figure 5 shows the “Compare” graphic, a visual tool that helps designers to identify cost intervention opportunities by considering the relative consequences on the value delivery effectiveness for end-users.

Table 2 –Results obtained from the VE study on the handicap bathroom

Systems		Functions	Relative needs (%)	Total Initial Costs (R$)	Initial Resource consumption (%)	Total Modified Costs (R$)	Modified Resource consumption (%)
ESTRUCTURE	A	Transmit vertical loads	5%	1.567,25	13%	1.567,25	15%
	B	Transmit horizontal loads	2%	477,48	4%	477,48	5%
INTERNAL FLOORS	C	Plaster horizontal surfaces	6%	1.234,70	10%	1.234,70	12%
VERTICAL SEALS (PARTITION WALLS)	D	Limit area	14%	673,84	6%	673,84	6%
	E	Plaster vertical surfaces	0%	3.042,43	26%	1.327,19	13%
	F	Grant ventilation	6%	316,35	3%	316,35	3%
	G	Aloow access	12%	767,04	6%	767,04	7%
ROOFING	H	Protect from weather	9%	268,68	2%	268,68	3%
SANITARY INSTALLATIONS	I	Provide sanitary use	19%	1.103,11	9%	1.237,29	12%
ELECTRICAL SYSTEMS	J	Provide illumination	4%	540,83	5%	540,83	5%
HANDICAP ACCESSORIES	K	Provide ease of use	21%	1.856,13	16%	2.055,98	20%
		Totals:	100%	11.847,84	100%	10.466,62	100%

Modified Functions

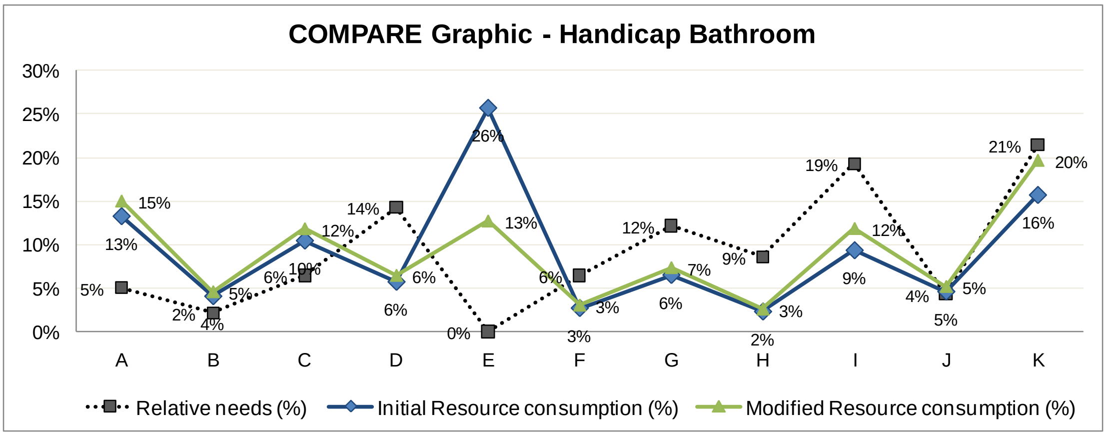

Figure 5 – "Compare" Graphic for the initial and the modified project

6. CONCLUSIONS

The VE simulation exercise used in the previous example of a handicap bathroom has achieved a cost reduction around 12% with enhancement of delivered value. This systematic VE exercise showed that it is possible to incorporate the perception of end-users' value and, at the same time, to reduce costs considering both perspectives of value as shown in Figure 1. This exercise can contribute to answering the question of how to assess cost issues in the early stages of project definition, without trading-off the value delivery proposal to end-users. The "Compare" Graphic provided a clear path for establishing cost reduction interventions priorities focusing on functions with higher contrast between resource consumption (cost) and relative needs.

The research has limitations however, as the chosen context was deliberately restricted to a facility's single room, in order to better understand and evaluate the VE use in a construction product development process. As further research suggestions, it is recommended the VE simulation to be used in broader construction context and in a whole projects.

7. REFERENCES

ABREU, R.C.L. (1996). *Análise de Valor – Um caminho criativo para a otimização dos custos e do uso dos recursos*. Qualitymark. Rio de Janeiro. (in Portuguese)

BALLARD, G.; RYBKOWSKI, Z. (2009).Overcoming the Hurdle of first cost: Action Research in Target Costing. Construction Research Congress.

BONATTO, F.S.; MIRON, L.I.; FORMOSO, C.T. (2011). Avaliação de empreendimentos habitacionais de interesse social com base na hierarquia de valor percebido pelo usuário. *Ambiente Construído*, 11 (1) 67-83. (in Portuguese).

COOPER, R.; SLAGMULDER, R. (1997).*Target Costing and Value Engineering*.Productivity.Institution of Management Accountants. IMA – Foundation for Applied Research. Portland OR.

CSILLAG, J.M. (1995). *Análise do Valor. 4ª Edição ampliada e atualizada com novas tendências gerenciais.* Atlas. São Paulo - SP. (in Portuguese)

DELL'ISOLA, A.P.E. (1997). *Value Engineering: Practical Applications for Design, Construction, Maintenance & Operations*. RS Means. Kingstone MA.

ENERGY PROVIDER COMPANY. (2005). Design documents.

KOWALTOWSKI, D.C.C.K.; GRANJA, A.D. The concept of desired value as a stimulus for change in social housing in Brazil. *Habitat International*, 35 435-446.

LIN, G.; SHEN, Q. (2007).Measuring Performance of Value Management Studies in Construction: Critical Review. *ASCE, Journal of Management in Engineering*, 23 (2) 2-9.

MAO, X.; ZHANG, X.; ABOURIZK, S. (2009).Enhancing Value Engineering Process by Incorporating Inventive Problem-Solving Techniques. *ASCE, Journal of Construction Engineering and Management*, 135 416-424.

MESQUITA, M. J. M.; FABRICIO, M. M.; MELHADO, S. B. (2003). Concurrent Engineering in Construction: Studies of Brief-Design Integration. *Proceedings* IGLC-10, Aug. 2002, Gramado, Brazil.

MORAES, A.G.; PANDOLFO, A.; ROJAS, J.W.J.; SALLES, M.; PANDOLFO, L.; GUIMARÃES, J; REINEHR, R. (2008). Avaliação e Comparação de obras de habitação de interesse social auxiliado por ferramenta computacional. *Estudos Tecnológicos*- Vol. 4, nº 2: 105-123. Rio Grande do Sul. May/August. (in Portuguese)

MORGAN, J. M., LIKER, J. K. (2006). *The Toyota product development system: integrating people, process, and technology*. Productivity press. New York, NY.

MILES, L.D. (1989). *Techniques of Value Analysis and Engineering*. Eleanor Miles Walker, 3rd edition.

NBR 15575-1:2010. (2010). *Edifícios habitacionais de até cinco pavimentos - Desempenho Parte 1: Requisitos gerais*. ABNT - Associação Brasileira de Normas Técnicas. (in Portuguese)

NBR 9050:2004.(2004). *Acessibilidade a edificações, mobiliário, espaços e equipamentos urbanos*. ABNT - Associação Brasileira de Normas Técnicas. (in Portuguese)

PICCHI, F.A.. (2003). Oportunidades de aplicação do Lean Thinking na construção. *Ambiente construído*, jan/mar 2003, Porto Alegre – RS. (in Portuguese)

ROZENFELD, H.; AMARAL, D.C., TOLEDO, J.C., CARVALHO, J. (2003). *O processo de desenvolvimento de produtos*. Fábrica do Futuro. Capítulo 6. v.13, n.2. (in Portuguese)

SAVE. (2009). SaveInternational. http://www.value-eng.org/. Acess: 22/11/2009.

SHEN, Q.; LIU, G. (2003).Critical Success Factors for Value Management Studies in Construction. ASCE, Journal of Construction Engineering and Management, 129 (485), 2003.

SPAULDING, W.M.; BRIDGE, A.; SKITMORE, M. (2005).The use of function analysis as the basis of value, management in the Australian construction industry. *Construction Management and Economics*, 23 (7) 723-731.

SPENCER, N.C.; WINCH, G.M. (2002). *How buildings add Value for Clients*. Reston, USA: Thomas Telford, 61p.

WARD, A. C. (2007). *Lean Product and Process Development*. The Lean Enterprise Institute Inc. Cambridge MA.