Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 105 (2007) 459–474
international journal of production economics
www.elsevier.com/locate/ijpe

Product development process with focus on value engineering and target-costing: A case study in an automotive company

Ugo Ibusuki*, Paulo Carlos Kaminski

Department of Mechanical Engineering, Polytechnic School of the University of Sao Paulo, Av. Prof. Mello Moraes 2231, Cidade Universitaria, 05508-900 Sao Paulo, SP, Brazil

Received 1 October 2004; accepted 1 August 2005
Available online 8 August 2006

Abstract

This research suggests a methodology for the product development process in an automotive company, aiming at the correct systematic approach of Value Engineering (VE) and target-costing in cost management. VE and target-costing are complementary processes, because while one allows the identification of where cost reduction could be achieved, the other shows the target to be achieved to guarantee the long-term profitability plan of a company. In order to do that, work plans were developed, with the application of the VE methodology at three subsequent stages: concept, project and validation. This proposed approach was validated in a case study focused on the engine-starter system of a vehicle, aiming at improved product cost, functionality and quality accomplishment, in accordance with customer needs and the company strategy.

Keywords: Value engineering; Target-costing; Cost management; Cost reduction; Product development

1. Introduction

Since the beginning of the automotive industry's history, the main automotive companies have pursued several of differentiation strategies in the production of passenger cars. Technological and market changes created the potential for Henry Ford to modify the rules of the game by adopting the classic strategy of leadership by cost, based on lower production costs of a standard model sold at low price. Ford dominated the industry quickly at world level. However, by the end of the 1920s, economic growth, growing familiarity with the automobile and technological changes had created the potential for General Motors to change the rules once again, using a strategy of differentiation with a wide range of products and details at premium price. With the growing increase in competition, in the most recent decades, companies sought to create higher value in their products for customers. Japanese companies, like Toyota, succeeded in doing so, with products of higher quality at a lower cost.

Therefore, a program of new product development must include projects designed to lower product cost and to enhance the value to the customer, because due to growing competitiveness, customers always demand new products with better quality and functionality, without an increase in price (Roy et al., 2004).

*Corresponding author. Tel.: +81 44 330 7196; fax: +81 44 330 5812.
E-mail address: ugo.ibusuki@poli.usp.br (U. Ibusuki).

0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2005.08.009

Many studies are being undertaken in the field of Product Development Process (PDP), because it is one of the main ways to gain competitive advantage for a company. The performance of a product and a good part of its cost are defined in its development (Dekker and Smidt, 2003) and for that reason, in order to optimize these two parameters, a correct approach of cost management in the PDP is necessary.

This research demonstrates the importance of developing products not only with quality, but also with cost and functionality in conformity with customer values. These three characteristics, denominated as the "survival tripod" by Cooper (1995) and Cooper and Slagmulder (1997), are related as a rule for the success of companies, which should balance this tripod in accordance with market requirements and the company strategy. Also, according to Cooper and Slagmulder (1997), the correct term should be "cost management" and not "cost reduction", because the latter simply implies the reduction in functionality and quality of products, while the real task would be to provide exactly the same function with better quality, but at lesser cost.

2. Theory of target-costing

At the beginning of the project phase, the knowledge of the product's technical features by the development team is as important as the definition of the product cost. Therefore, it is at this moment that the product target-cost should be defined (Ferreira, 2000).

According to Monden (1995), a target-costing system has two objectives:

1. Reduce the cost of new products so that the level of required profit could be guaranteed, simultaneously satisfying the levels of quality, development time and price demanded by the market
2. Motivate all the employees to achieve the target-profit during the new product development, turning target-costing into an activity of profit administration for the whole company, using the creativity of employees from several departments to draw up alternative plans that allow higher cost reductions.

The definition of target-costing involves, basically, product planning so as to satisfy customer attributes and the profit generation to the company, given the market requirements (Yoshikawa et al., 1994). This information is essential so that the product cost can be considered an active variable of the project.

2.1. Stages to determine the target-cost

The implementation of a target-costing approach and the determination of the product target-cost involve the ten steps described below, which were based on the research of Crow (1999).

1. *Re-orient culture and attitudes*. The first and most important stage is to re-orient thinking toward market-driven pricing, prioritizing customer attributes as a basis for product development. This is an essential change of attitude in most organizations, where cost is the result of design rather than one of the project requirements.
2. *Establish a market-driven target-price*. A target-price needs to be established based on market factors such as the company positioning in the market place (market-share), the market penetration strategy, competitors and competitive price, the targeted market-niche and the elasticity of demand.
3. *Determine the target-cost*. Once the target-price is established, the target-cost should be calculated by subtracting the target-profit and any uncontrollable allocations, such as taxes and some indirect fixed costs. It can be summarized in a margin-denominated Mark-up.
4. *Balance target-cost with requirements*. Before the target-cost is concluded, product requirements must be considered. The greatest opportunity to control product costs is through proper setting of requirements and specifications. This requires a careful understanding of customer needs, the use of conjoint analysis to understand the value that customers place in particular product functions and the use of techniques such as quality function deployment (QFD) to help make these tradeoffs among various product requirements, including target-cost.
5. *Establish a target-costing process and a team-based organization*. A well-defined process must integrate activities and tasks to support the target-cost, be based on early and roactive consideration of target-cost, and incorporate the tools and methodologies described subsequently. Furthermore, a team-based

organization is required that integrates essential disciplines such as Marketing, Engineering, Manufacturing, Purchase and Finance.

6. *Generate ideas and analyze alternatives*: The greatest opportunities for cost reduction lie in the multiple alternatives of product concept and design, its manufacturing and support processes at each stage of the development cycle. They can be seized when there is creative consideration of the alternatives coupled with structured analysis and decision-making.
7. *Establish product cost models to support decision-making*. Product cost models and cost tables provide the tools to evaluate the implications of multiple concept and design alternatives. At the early stages of development, these models are based on parametric estimation or analogy techniques. As product and process become more defined, these models are based on industrial engineering or bottom-up estimation techniques (reverse engineering). They need to be comprehensive to address all of the proposed materials and production processes, assuring reasonable accuracy.
8. *Use tools to reduce costs*. Tools and methodologies related to design for manufacturing and assembly (DFMA), design for inspection and test, modularity and part standardization, and VE or function analysis are employed in the development of guidelines, databases, training and procedures supporting the analytic tools.
9. *Reduce indirect cost application*. Since a significant portion of a product's costs is indirect, the company should also address it by examining these costs, re-engineering indirect business processes and minimizing non-value-added costs. But apart from these steps, development personnel generally lack an understanding of the relationship of these costs to the product and process design decisions they make.
10. *Measure results and maintain management focus*. Current estimated cost needs to be tracked against the target-cost throughout the whole development. Management needs to focus on the target-cost achievement during project and phase-gate reviews to convey the importance of target-costing to the organization.

3. Developed research

According to the research of Ibusuki and Kaminski (2002, 2003), the technique of VE is known by the company of the automotive industry where the study was developed, being applied by a department, integrated into Engineering, which takes the same name. This technique is circulated in the company in a 40-h training designed and conducted by employees of the VE department. Even so, in spite of the training being led towards a functional view for the application of VE, as suggested in the work-plan by ABEAV (1989), VE is not employed systematically in the cost reduction process. Functional analyses are hardly ever developed in products and their components; VE is applied only to the physical structure of the product/component, and then to raw material, labor and general expenses through the tear-down process.

Therefore, in the way that VE is implemented in the company, it is unlikely that an eventual technical solution will change the basic characteristic of a product. Fig. 1 (Ibusuki and Kaminski, 2003) shows the restriction.

A systematized methodology was developed for the application of VE, based on the training course of the company and on the theory presented by several specialists and organizations, such as ABEAV (1989), SAVE (1998), ECS (1996) and Park (1999), attempting to solve the aforementioned restriction.

4. Proposed methodology

To reach the target-cost with the calculated cost during the PDP, a methodology focused on the technique of VE was proposed with an approach in three different steps:

- Concept-VE: focused on the conceptual stage of product development, aiming at functional innovations;
- Project-VE: focused on the design stage of the product and process, aiming at improvements during their development stage;
- Validation-VE: focused on the validation stage of the product and process, and also already at the production stage, aiming at improvements mainly in the production process.

Through this systematic VE application, the maximization of potential cost reduction and quality (function) improvement was aimed at.

In the following items, each one of the proposed VE techniques is detailed, as well as how they could

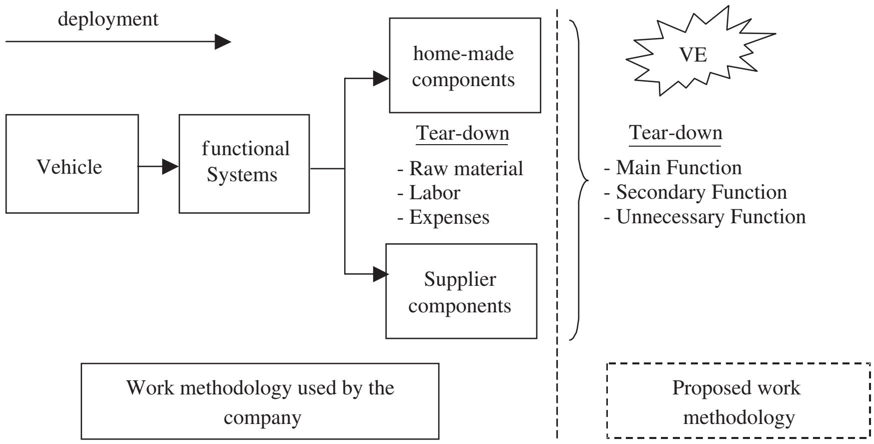

Fig. 1. Scope of the proposed methodology at the company.

be implemented, seeking integration in the PDP stages of the company.

4.1. Concept-VE

The proposal of Concept-VE consists in the search of possible innovation at the conceptual level of a product, still at the conceptual stage of development, before the requirements of quality, cost and investment are set. It represents the logical extension of the VE methodology focused on improvements at an early stage.

Unlike the conventional proposal of VE, which acts to increase the value of a product through the improvement in existent functions without increasing their costs, the proposition of Concept-VE lies in the introduction of some concept that had not been previously identified. Therefore, it proposes a stage of innovation search as a constituent phase of the PDP, increasing the chances of developing revolutionary products.

In order to do that, ideas, independent of the moment of their generation, should be managed for future use in the process of Concept-VE.

4.2. Project-VE

The proposal of Project-VE consists in the search for functional improvement of a product still at the design stage. This is the most traditional form of the VE methodology, which acts to increase the value of a product by improving existent functions without increasing their costs. In order to do that, a work plan was proposed based on SAVE's (1998) framework and divided in six steps with the following objectives:

- Preparatory: to choose the product, determine targets, form a work group and plan activities
- Information: to obtain general information about the product under study, such as its details, costs and values
- Analytic: to identify functions and their costs, relate function and cost, determine critical functions and formulate the problem
- Creative: to obtain ideas, select and grade them
- Judgment: to formulate and develop alternatives, propose technical and economical solutions and, finally, decide which is the best alternative
- Planning: to present the proposal, plan implementation and apply it.

4.3. Validation-VE

The proposal of Validation-VE consists in the search for functional improvement of a product at its validation stage. At this stage, the components of the main functions are identified and prototypes are assembled, acting to increase the value through the functional improvement of physically existent components, and not creating new components. Consequently, the results are poorer than in the proposals of Concept-VE and Project-VE.

The work flow should follow a cycle of five stages, according to Fig. 2 (Ibusuki and Kaminski, 2003), functional analysis/target-cost–initial project–prototype construction–quality and cost estimation–VE study, which is repeated until quality and target-cost have been achieved.

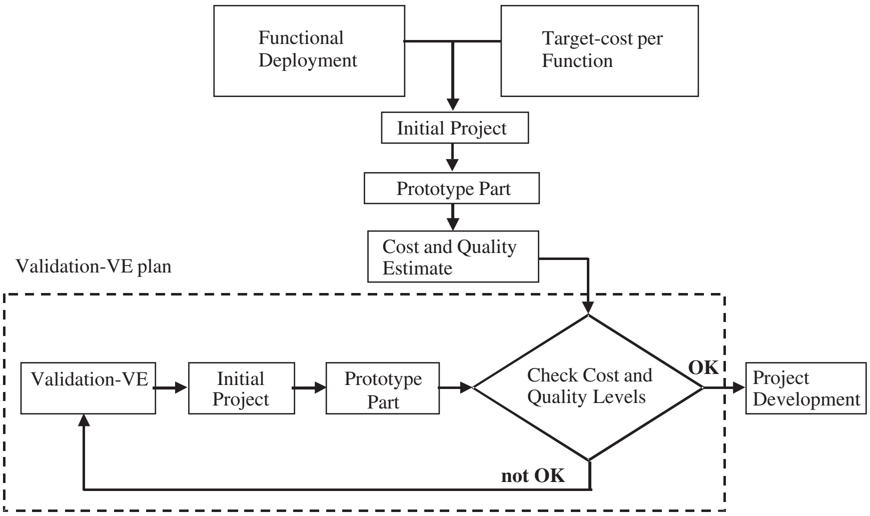

Fig. 2. Flow chart for Validation-VE.

In general, the effort of Validation-VE to achieve the target-cost is oriented towards two directions: reduction in material and process costs. The methods used to diminish the direct material cost include reducing the number of parts, designing smaller and lighter parts, using cheaper parts and designing parts that do not require special high-precision or very expensive production processes. The methods used to decrease process costs could be raising tolerances, reducing investments in plant, increasing productivity and implementing the process with focus on cost reduction.

4.4. Flow chart of the proposed methodology

The flow chart identifies the summary of the proposed methodology, segmented as a function of the PDP stages, also highlighting the departments in charge of each activity (Fig. 3 (Ibusuki and Kaminski, 2003)). The application of VE techniques depends on the PDP stage in which product improvements will be searched for. Better results are obtained at earlier stages of the PDP.

5. Case study

The case study was developed based on an idea proposed by an employee of the VE department of applying new technology concepts to the existent systems of the product/vehicle, aiming at a break of paradigm that could lead to great innovations.

5.1. Concept-VE

An attempt was made to develop a new concept for the function "start engine" in diesel engines of the company's product/vehicle, according to the proposal of Concept-VE of introducing some concept that had not been previously identified.

A market research was carried out, through the Internet and contact with suppliers, in search of concept alternatives on the market for the function under analysis. It was verified that, besides the currently used electric drive system, hydraulic, spring and pneumatic engine-starters were also available. The analysis was conducted on an engine-starter with a pneumatic drive due to the availability of this system in commercial vehicles. Therefore, the following advantages of the pneumatic drive have been listed, as pointed out by the supplier and by specialists in the company.

- *Longer useful life*: unlike what occurs with the electric starter, over heating and burning problems do not happen
- *Low maintenance cost*: a longer useful life reduces cost and time, with maintenance associated with change and repair
- *More force and less weight*: it has more torque with less weight
- *Safe operation*: the cold operation of the pneumatic starter eliminates the danger associated with electric systems, such as sparks, shocks and heating

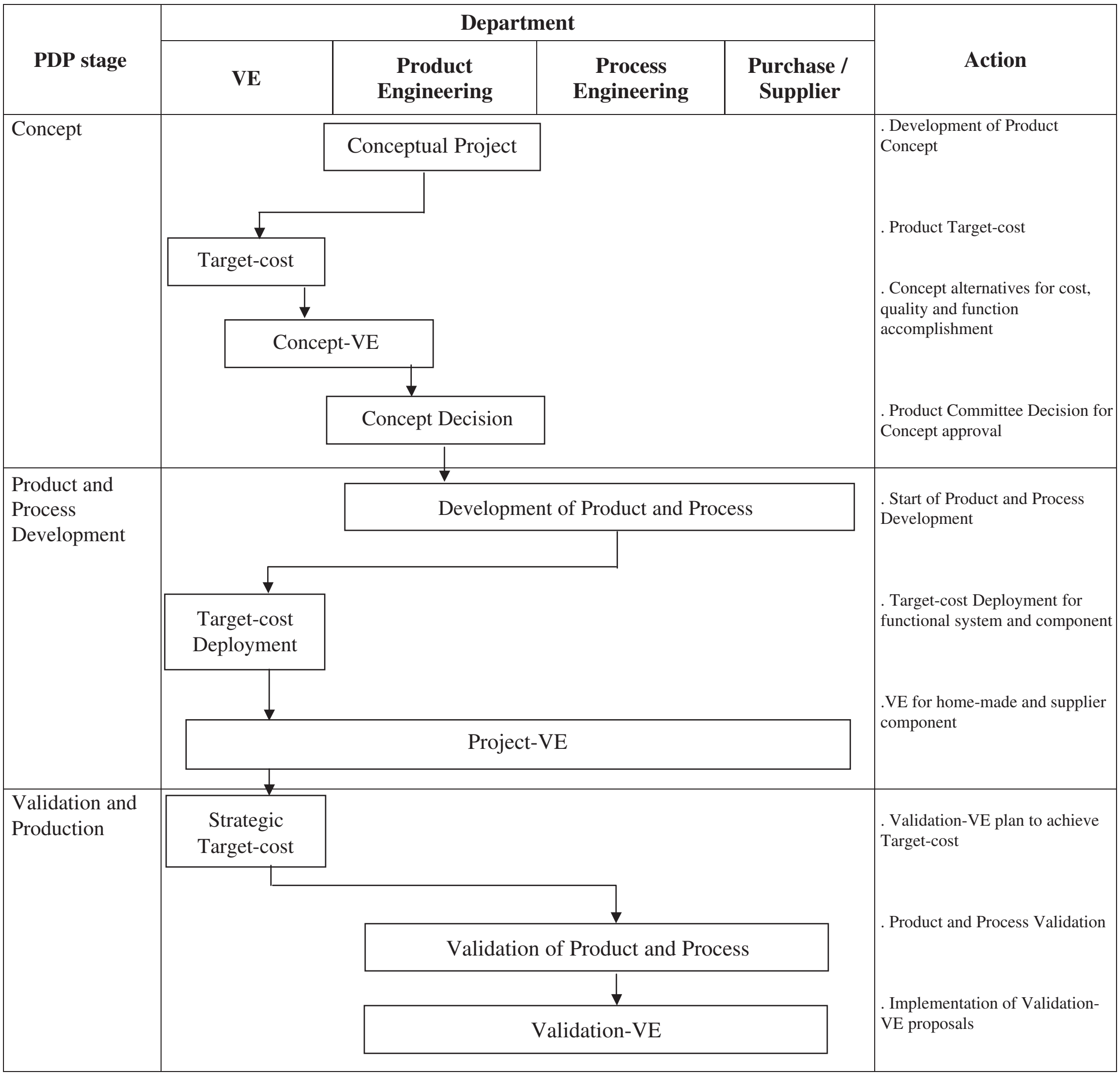

Fig. 3. Flow chart of the proposed methodology.

- *Potential cost reduction*: at system level, a potential of cost reduction is verified, mainly due to the possibility of using the already existent compressed air tank (to drive the brake system).

The possible disadvantages in comparison with the current product are as follows.

- *Increase in cost and weight*: with possible need to adapt a new compressed air tank, and to develop a specific engine-starter for the diesel engine of the company
- *Failure in drive*: lack of pressure due to possible leaks in compressed air systems
- *Increase in maintenance cost*: due to leaks in the compressed air system becoming unacceptable.

Because this component is acquired from suppliers, the target-price to the supplier was defined as being the acquisition price of the electric starter, the system currently in use. Therefore, the target-cost consists of the target-price minus the mark-up of the supplier. Later on, at the stage of Project-VE, the target-costing study will be detailed for the product under analysis.

5.2. Project-VE

At this stage of VE application, the six steps suggested in the proposed methodology were carried out.

5.2.1. Preparatory

As a primary source of information, specialists in the company, such as cost analysts, electrical and mechanical engineers, as well as technical documentation about electric starters were consulted. As a secondary source, customers were inquired in a market research, and the supplier of pneumatic starter brought technical information about the imported pneumatic starter, such as catalogs, drawings and the product itself, besides commercial information such as a comparison with competitors, test results with customers and price quotation.

Fig. 4 (Ibusuki and Kaminski, 2003) shows the drawing of the pneumatic starter of the contacted supplier, to be developed in this case study.

It was defined that the scope of the study would center around the engine-starter, even though additional studies should be carried out at the level of the engine-starter system due to change in the drive system. Table 1 (Ibusuki and Kaminski, 2003) shows a comparative of the two concepts of electric and pneumatic starters, for a better understanding of the scope on the product.

A work group was formed, composed of two cost analysts (electric and mechanical specialists) of the VE department, supported by people from other departments such as Engineering, Marketing and Manufacturing.

The group was led by the author of the study (at that time an employee of the VE department), who was in charge of the coordination of the study, contact with the specialists and suppliers, and the promotion of specific studies according to the work schedule plan.

5.2.2. Information

At this stage, the study of QFD and cost calculation was developed.

Through Matrix QFD (Fig. 5 (Ibusuki and Kaminski, 2003)), it was possible to identify the specification of larger impact on customer attributes, in the evaluation as a function of their relationships (Han et al., 2004). It was the drive system, in this case, the pneumatic engine-starter. Once the priority had been identified, the development was focused on that feature of the product that could maximize customer value.

The cost of the product under study was also compared with that of the current product, whose cost was defined as the target-price to the supplier. The mark-up was admitted to be an average factor used as a parameter in the company for the target-price calculation procedure (35% of mark-up = 7% of Adm./Com. Expenses, 10% of Profit and 18% of Taxes). Then, fixed costs were considered uncontrollable, just keeping the variable costs as

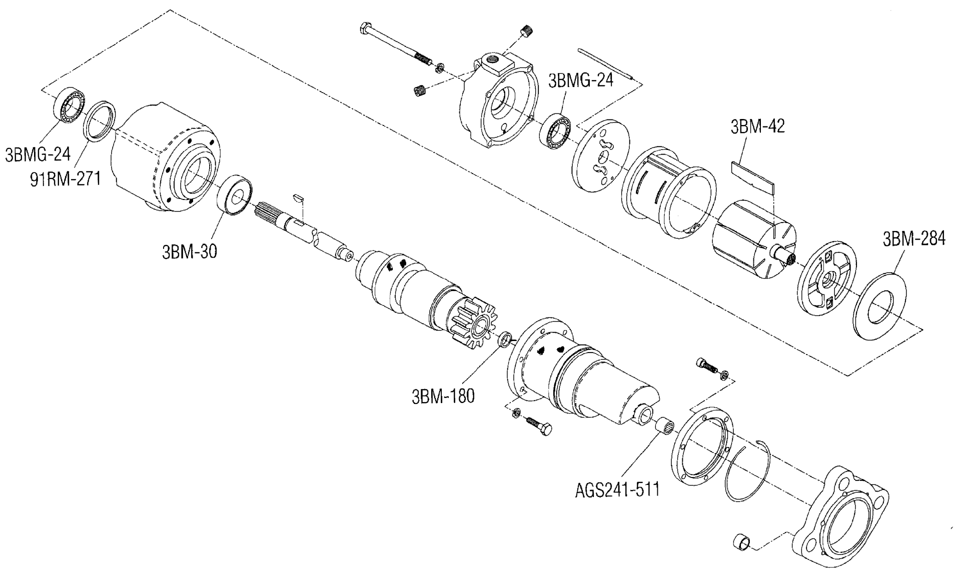

Fig. 4. Drawing of the pneumatic starter.

Table 1
Comparative between electric and pneumatic starter and system

Drive	Electric	Pneumatic
Engine-starter system	Battery, cables and electric-drive engine-starter	Compressed air tank, valves, tubes and pneumatic-drive engine-starter
Engine-starter parts	Relay, driving lever, pinon, shaft, electric-motor, cover and housing	Drive-shaft, pinon, shaft, blade, piston, cover and housing

9 - Strong relation
3 - Medium relation
1 - Weak relation

			Performance Specification											
		Importance	Potency (3~4 Kw)	Torque (~15 Nm)	Rotation (~1000 rpm)	Format (compact)	Compressed air tank Volume (2x40 L)	Noise level (80 dB)	Weight (~13 kg - engine starter)	Resistance to Impact (1000 N)	Durability (45000 hours)	Sealing (100%)	Drive system (pneumatic)	
Customer Desire	Immediate start	5	9	9	9		3					3	9	
	Capacity to sequence start	3					9					9	3	
	Resistance	4				3				9	9			
	Security	5								3	3	3	9	
	Low Maintenance	4								3	9	3	1	
	Low Noise level	1	3	3	3			9					3	
	Low Weight	2	3	3	3	9	3		9	3			3	
	No leakage	5								3	3	9	3	
	Easy to assembly/disassembly	3				9	1		3				1	
	Total	32												
	Weight		54	54	54	57	51	9	27	84	102	114	130	736
	Percentage (%)		7	7	7	8	7	1	4	11	14	15	18	100

Fig. 5. Matrix QFD of the pneumatic starter.

Table 2
Target-cost × estimated cost of the engine-starter

	Electric (current)	Pneumatic, imported (proposed)	Difference
Target-price	283.15	1500.00	1216.85
Mark-up (35%)	99.10	525.00	425.90
Target-cost	184.05	975.00	790.95

All values in R$. Exchange rate as of December 2002: US$1 = R$3.5.

target-cost, according to Eq. (1) below:

$$\text{Target-cost} = \text{Target-price} - (\text{Target-price} \times \text{Mark-up}). \quad (1)$$

As a result of the cost comparative, a great difference between the cost of the current and the proposed systems was realized (Table 2 (Ibusuki and Kaminski, 2003)), which is due to the fact that the latter was 100% imported, with increase in logistic costs and non-measurable costs such as royalties, since the product is an exclusive development of the supplier. Consequently, the study focused on nationalization of its parts in order to reduce costs and make it economically feasible. At this point the VE study came into play and the product was deployed (through tear-down) in functional needs and, by means of an importance analysis (value), the highest potential of improvement was identified.

5.2.3. Analytic

At this stage, the following steps were accomplished.

1. *Identify and define the product's functions, in accordance with the functional analysis, which uses measurable substantives and active verbs*. At first the product under analysis was deployed in five systems: Drive, Rotation, Feeding, Fixture and Lubrication Systems. For each system, the main function was identified according to the components that compose it. The functional study was simplified to a list containing only functions with larger relevance.
2. *Classify functions as main or secondary*. The identified functions were classified as main, those that are essential to the product function (i.e., "start engine") and, secondary, those that only support the main function (Table 3 (Ibusuki and Kaminski, 2003)).
3. *Build the functional structure of the product*. The diagram of the Function Analysis System Technique (FAST) was drawn to determine the interaction of the functions, supplying a systemic vision of the product under analysis, besides facilitating the scope of the study (Fig. 6 (Ibusuki and Kaminski, 2003)).
4. *Estimate the cost of the functions*. To minimize the difference in cost between the current and the proposed system, cost calculations were done for all the engine-starter components, through one of the VE techniques of analyzing each component and estimating its system cost at the level of its parts (reverse engineering).

The cost calculation was done using the procedure for target-price calculation. This calculation supplies parameters for the advanced planning of project costs, besides being the basis of the target-cost and cost reduction target for suppliers. For the

Table 3
Functional identification and classification

Component	Function		Classification	
Designation	Verb	Substantive	Main	Secondary
Drive system	Position	Pinon	x	
Piston	Convert	Energy		x
Drive-shaft	Drive	Pinon		x
Rotation system	Rotate	Wheel	x	
Turbine	Convert	Energy		x
Rotating shaft	Rotate	Pinon		x
Pinon	Generate	Torque		x
Feeding system	Conduct	Pressure	x	
Compressed air tank	Provide	Compressed air		x
Sealing	Seal	System		x
Valves	Control	Volume flow		x
Silencer	Control	Air flow		x
Tubes	Direct	Volume flow		x
Fixture system	Fix	Engine-starter	x	
Flange + front housing	Provide	Fixture		x
Central housing	Connect	Tubes		x
	Protect	Engine-starter		x
Rear housing	Connect	Tubes		x
	Protect	Engine-starter		x
Screw	Provide	Fixture		x
Lubrication system	Facilitate	Movement	x	
Lubricant	Lubricate	System		x

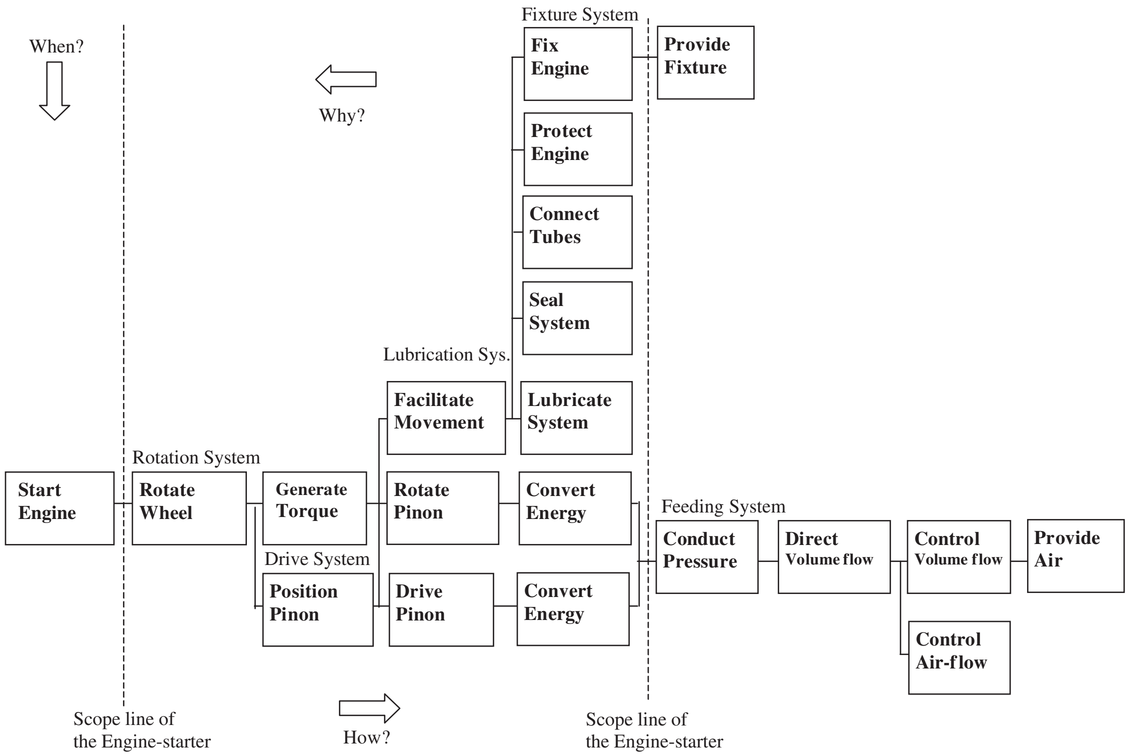

Fig. 6. FAST of the pneumatic starter and system.

Table 4
Estimated cost per component

Blade	14.00
Plunger	10.20
Drive-shaft	8.50
Piston	27.20
Rotating shaft	18.66
Pinon	7.00
Flange + front housing	23.82
Central housing	19.36
Rear housing	8.96
System assembly (with bearing, seal, spring and screw)	51.10
Total—nationalized	188.80
Non-measurable costs (logistic cost, royalties and others)	786.20
Total—imported	975.00

calculation of target-price, the supply of the engine-starter was considered to be nationalized.

As a result, the following final cost of industrialization was reached (Table 4 (Ibusuki and Kaminski, 2003)).

For the calculation of function costs, the functions that are related with the scope line of the engine-starter were selected (according to FAST). Based on the estimated cost per component, this cost was allocated to each function as a function of its effective influence to provide them. For components that provide only one function, the component cost was fully allocated to the function (Table 5 (Ibusuki and Kaminski, 2003)).

With the calculation of estimated cost per function, the target-cost per function should be determined, starting from the target-cost of the product. In order to do that, each function was compared with the others and the relative importance of each one was determined by means of a numeric evaluation supported by Mudge Diagram (Fig. 7 (Ibusuki and Kaminski, 2003)). This comparison has the purpose of determining how each function relates to the complete system, so as to determine which is of higher importance.

Considering the relative importance of each function, the target-cost per function was calculated, based on the estimated total cost of the product (Table 6 (Ibusuki and Kaminski, 2003)).

With the definition of the estimated cost and the target-cost per function, the cost reduction target per function was calculated (Table 7 (Ibusuki and Kaminski, 2003)).

Table 5
Estimated component cost divided per function

	Rotate wheel A	Generate torque B	Rotate pinon C	Convert energy D	Position pinon E	Drive pinon F	Facilitate movement G	Lubricate system H	Seal system I	Connect tubes J	Protect engine L	Fix engine M	Cost per component
1 Blade	2.33	2.33	2.33	7.01									14.00
2 Plunger	1.70	1.70	1.70	5.10									10.20
3 Pinon	3.50	3.50											7.00
4 Rotating shaft	4.66	4.66	9.34										18.66
5 Drive shaft					4.25	4.25							8.50
6 Piston				13.60	6.80	6.80							27.20
7 Flange + front housing											11.91	11.91	23.82
8 Central housing										9.68	9.68		19.36
9 Rear housing										4.48	4.48		8.96
10 Screw												10.80	10.80
11 Seal									2.50				2.50
12 Spring							7.00						7.00
13 Bearing							7.20	3.60					10.80
14 Assembly							5.00	5.00	5.00			5.00	20.00
Cost per function	12.19	12.19	13.37	25.71	11.05	11.05	19.20	8.60	7.50	14.16	26.07	27.71	**188.80**
%	6.5	6.5	7.1	13.6	5.8	5.8	10.2	4.5	4.0	7.5	13.8	14.7	**100**

A	B	C	D	E	F	G	H	I	J	L	M
A	A1	A1	A3	A1	A3	A1	A3	A3	A5	A3	A3
	B	0	0	0	B1	0	B3	B3	B5	B3	B3
		C	0	0	C1	0	C3	C3	C5	C3	C3
			D	D1	D1	0	D3	D3	D5	D3	D3
				E	0	0	E1	E3	E3	E3	E3
					F	G1	F1	F1	F3	F1	F1
						G	G1	G3	G3	G3	G3
							H	0	H1	H1	0
								I	0	I1	0
									J	L1	0
										L	M3
											M

0 = Equal
1 = Minimum Importance
3 = Medium Importance
5 = Maximum Importance

Fig. 7. Mudge Diagram to determine the importance of each function.

After analysis of the estimated × target-cost, it was verified that the functions whose costs are above customer value are Drive Pinon, Lubricate System, Seal System, Connect Tubes, Protect Engine and Fix Engine. Cost reduction proposals must be developed to adapt the cost of these functions to the target-cost.

It was also verified that even though the cost reduction target in terms of engine-starter is small (2.5%), with this study the real potential of cost reduction (39.3%) could be identified.

5.2.4. *Creative*

This stage is considered essential for the study's success, because VE is based on the creation of new and different alternatives to provide the function. Thus, alternatives should be generated to provide the function at lesser cost, still maintaining the requested quality.

Table 6
Target-cost divided per function

	Function	Importance	%	Target-cost per function
A	Rotate wheel	27	21.9	40.40
B	Generate torque	18	14.6	26.93
C	Rotate pinon	18	14.6	26.93
D	Convert energy	19	15.5	28.44
E	Position pinon	13	10.6	19.45
F	Drive pinon	7	5.7	10.47
G	Facilitate movement	14	11.4	20.94
H	Lubricate system	2	1.6	3.00
I	Seal system	1	0.8	1.49
J	Connect tubes	0	0	0
L	Protect engine	1	0.8	1.49
M	Fix engine	3	2.5	4.51
	Total	123	100	184.05

For the alignment of the estimated cost with the target-cost, the work team formulated some proposals of cost reduction. Several of them were put forward in a brainstorming session, where proposals, regardless of their technical and economical feasibility, were listed for further analysis. The

Table 7
Determination of the cost reduction target per function

Function	Function estimated cost	Function target-cost	Difference	Cost reduction target	Reduction target (%)
Rotate wheel	12.19	40.40	−28.21	—	—
Generate torque	12.19	26.93	−14.74	—	—
Rotate pinon	13.37	26.93	−13.56	—	—
Convert energy	25.71	28.44	−2.73	—	—
Position pinon	11.05	19.45	−8.40	—	—
Drive pinon	11.05	10.47	0.58	0.58	5.2
Facilitate movement	19.20	20.94	−1.74	—	—
Lubricate system	8.60	3.00	5.60	5.60	65.1
Seal system	7.50	1.49	6.01	6.01	80.1
Connect tubes	14.16	0	14.16	14.16	100
Protect engine	26.07	1.49	24.58	24.58	94.3
Fix engine	27.71	4.51	23.20	23.20	83.7
Total	188.80	184.05	4.75	74.13	39.3

proposals focused on the functions Connect Tubes, Protect Engine and Fix Engine, which have a higher cost reduction potential.

The proposals were elaborated targeting at functional alternatives, as well as material and production process improvement. At the following stage, the proposals should be selected in terms of their technical and economical potential, and a more detailed study should be developed.

5.2.5. *Judgment*

The creative stage is followed by the analysis and judgment stage, where ideas are evaluated and the feasible ones are combined and selected. Table 8 (Ibusuki and Kaminski, 2003) shows the judgments of the presented proposals.

The proposals selected by the specialists with the highest technical and economical potential were proposals 3, 5 and 9. A combination of these three proposals was elaborated, suggesting a change in the housing material to formed steel instead of cast aluminum, with connection of the tube by clamp through an intermediary rubber tube, as shown in Fig. 8 (Ibusuki and Kaminski, 2003). As a result, a reduction in weight of the engine-starter was estimated, making it possible to reduce the number of screws. However, a more detailed study should be developed, mainly at resistance level to impact, which could require a thicker steel, making its forming in conventional manufacturing processes unfeasible.

The proposals were calculated in terms of their costs, resulting in the following differences, according to Table 9 (Ibusuki and Kaminski, 2003). And calculating in price (targeted at cost), the estimated cost of the engine-starter with VE-proposals is shown in Table 10 (Ibusuki and Kaminski, 2003).

Therefore, the project was thoroughly analyzed at technical level, whether the proposed characteristic of the product was feasible to be designed/manufactured, and at economical level, whether the cost of the proposed product was within the customer paying value, and also in terms of the return on investment (payback) (Table 11 (Ibusuki and Kaminski, 2003)).

5.2.6. *Planning*

The main objective of this stage consists in developing a plan with all the technical and economical details approached in the case study, attempting to show how the initial project was conceived and which are the team's proposals, highlighting the cost reduction proposals, besides the necessary resources to obtain them. The best way "to sell the idea" should be explored.

In terms of technical feasibility: According to the product supplier used as reference, greater technical modifications are not required to adapt the pneumatic system in substitution to the conventional electric system. Even so, it is necessary to implement some valves and tubes for additional control of the pneumatic system. On the other hand, the electric cables of the engine-starter could be eliminated.

In terms of economical feasibility: An economical comparison between the current (electric) and the proposed systems (pneumatic) was carried out with the cost reduction proposals. It was verified that the

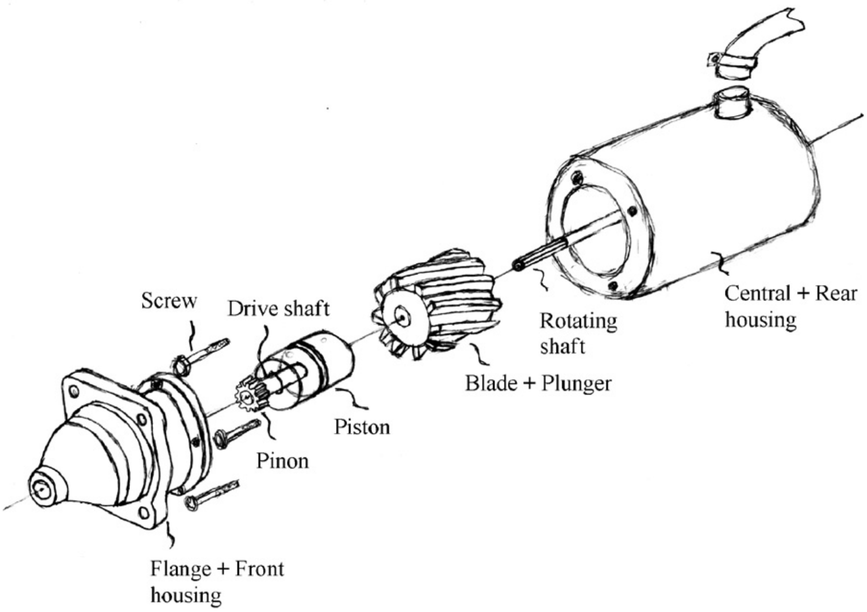

Fig. 8. Sketch of the pneumatic engine-starter (with VE proposals).

Table 8
Analysis of the cost reduction proposals per function

Function	Proposal	Judgement
Connect tubes	1. Paste tube	Difficult to dismount and maintenance
	2. Weld tube	Difficult to dismount and maintenance
	3. Fix tube with clamp	Risk of faulty fixture. Intermediary rubber tube could minimize that risk
Protect engine	4. Use material with polymer	Risk of not resisting on high temperatures
	5. Use material with formed steel	Thickness according to the needed impact resistance
	6. Use material with cast-iron	Cheaper but higher weight.
	7. Reduce thickness of the housing	Thickness according to the needed impact resistance
Fix engine	8. Fix on the engine block	Change engine block. High investment
	9. Reduce number of screw	Feasible with weight loss

Table 9
Determination of the cost reduction target per function with the proposals

Function	Function estimated cost	Function target-cost	Difference	Cost reduction target	Reduction target (%)
Rotate wheel	12.19	40.40	−28.21	—	—
Generate torque	12.19	26.93	−14.74	—	—
Rotate pinon	13.37	26.93	−13.56	—	—
Convert energy	25.71	28.44	−2.73	—	—
Position pinon	11.05	19.45	−8.40	—	—
Drive pinon	11.05	10.47	0.58	0.58	5.2
Facilitate movement	19.20	20.94	−1.74	—	—
Lubricate system	8.60	3.00	5.60	5.60	65.1
Seal system	7.50	1.49	6.01	6.01	80.1
Connect tubes	5.00	0	5.00	5.00	100
Protect engine	15.00	1.49	13.51	13.51	90
Fix engine	23.71	4.51	19.20	19.20	81
Total	164.57	184.05	−19.48	49.90	30

Table 10
Determination of the potential reduction in terms of price

	Electric (current)	Pneumatic—nationalized (proposed)	Difference
Target-cost	184.05	164.57	−19.48
Mark-up (35%)	99.10	88.61	−10.49
Target-price	283.15	253.18	−29.97

Table 11
Economic feasibility study of the engine-starter system

	Electric (current)	Pneumatic–nationalized (proposed)
Engine-starter	283.15	253.18
Battery	150.00	150.00
Cables	50.00	25.00
Compressed air tank	80.00	80.00
Valves	60.00	90.00
Tubes	35.00	50.00
Total	658.15	648.18
Saving per vehicle	—	9.97
Saving per year (6000 vehicles)	—	59,820.00
Investment	—	268,000.00 on forming-tool
Payback (16% interest rate)	—	8.5 years

Table 12
Determination of the residual cost to achieve cost reduction target

	Project-VE (achieved)	Validation-VE (target)	Residual cost reduction
Saving per vehicle	9.97 (in price)	15.95 (in price)	3.89 (in cost)
Saving per year (6000 vehicles)	59,820.00	95,700.00	35,880.00
Investment	268,000.00 on forming-tool	268.000.00 on forming-tool	—
Payback (16% interest rate)	8.5 years	4 years	—

proposed system was economically feasible if nationalized.

5.3. Validation-VE

At this stage of the study, the product must be available for physical tests. A specific plan was drawn up to reach the potential cost reduction not accomplished at the stage of Project-VE. More objectively, as stated by the company's rule, the return on investment should have a payback of less than 4 years. Therefore, the following residual cost to achieve the cost reduction target was calculated (Table 12 (Ibusuki and Kaminski, 2003)).

In order to do that, the plan of Validation-VE was divided in four stages.

1. *Set up the prototype to verify the proposed technology and the proposals of cost reduction.* The workflow should follow a cycle of five stages according to Fig. 2 (Ibusuki and Kaminski, 2003).
2. *Carry out studies on manufacturing in-house or outsourcing (make or buy).* Try to reduce material cost for the whole value chain or seek new suppliers. Here comes into play the development of suppliers for specific components that need a specialized production process. The correct choice of suppliers can usually allow great improvements, not only at the level of production process but also improvements in the product itself. Therefore, the prototype should be assembled/built with components of potential suppliers.

3. *Accompany the process of nationalization of parts*. Another focus at this VE-stage consists in the nationalization plan, for gradual increase of the nationalization index after product market launch. The implementation curve of nationalization follows the production increase, from the start of production to the volume scale, which is sales volume with the targeted market-share for the product. This planning should include the study of Factory Investments, besides Technical and Labor Capacity, both in the company and in its suppliers.
4. *Implement process improvements at the stage of try-out and production*. During the validation stage of the production process and assembly, a certain number of products go through the process, in three stages as follows.

   Try-out 1: for employee training in the process and assembly plan, and identification of critical processes both in operation time (takt-time) and in ergonomics;

   Try-out 2: for the observation of the process quality and the gathering of specific indicators of quality, already with the implemented improvements;

   Try-out 3: for final adjustments of the process within the desired quality and operation time.

6. Conclusion

Cost management does not mean establishing limits of value, but guaranteeing, prior to the beginning of production, that they will be reached. Any attempt to forecast profit or market participation will be hindered without the definition of target-cost for the whole productive chain, without the involvement and the commitment of suppliers and employees to the objective of reaching the target-cost and without taking into consideration the product life cycle.

Therefore, the incorporation of VE and target-costing in a work methodology could be interesting in that it advances for the PDP problems and decisions that would have direct impact on the economic result of a company. VE and target-costing are complementary processes, because while one allows the identification of where cost reduction could be achieved, the other shows the target to be achieved to guarantee the long-term profitability plan of a company.

This study allowed the identification of some positive points that are the keys to the success of an integrated system of VE and target-costing. They are as follows.

1. *Strong performance of cost planning in the PDP*. Although the company possesses an image of developing expensive products, with strong focus on quality, cost planning is increasingly present as an active parameter of the project. The PDP has three clear objectives: time, quality and cost.
2. *Development through multifunctional teams*. The basis of the multifunctional teams involves people from the Engineering, Purchase and VE departments. This allows an exchange of knowledge to make cost reduction proposals in order to achieve the goals of target-cost. Strong coordination and cooperation among people from all departments of the company allow the maintenance of a good activity flow.
3. *Important function of Finance*. The financial function is essential to manage target-costing. It acts to supply information that guides the activities of cost planning for the entire company, measuring and monitoring the activities to achieve the company's strategic objectives.
4. *Integration of cost planning with the company's global strategy*. The head office in Germany develops a great part of product design, and its unit in Brazil essentially implements the project, except the systems under its responsibility (technical competence). This limits the activities of VE that could be implemented locally, as the basic concept and its parameters have already been set. However, it was verified that there are still many improvement opportunities in product design, which are developed after consent by the head office. It is possible to improve the original design by developing studies with local suppliers, changing materials or production processes and simplifying the design for local needs.
5. *Use of tools and techniques that support VE*. As described previously, VE is not applied in a systematic way to the cost reduction process to achieve the target-cost. However, it was observed that many of the cost reduction techniques used by the company, e.g., Reverse Engineering, DFMA, QFD, modularity and part standardization, support the methodology of VE and target-costing.

In conclusion, through this case study, it was possible to identify the real cost reduction opportunity (~10% in the price of electric drive engine-starter), even improving the main function of the product (efficiency of the pneumatic drive for the function "start engine"). But the real gain of this approach lies in the critical analysis of the implemented solutions, making it possible to realize the real benefits of a product to its customers, and trade off new innovative ways with multifunctional teams and also suppliers to overcome market challenges and establish a win–win relationship.

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