A Novel Innovative Design Improvement Using Value Engineering Technique: A Case Study

Ali Mostafaeipour*

Assistant Professor, Yazd University, Yazd, Iran

Received 13 February, 2015; Revised 23 April, 2015; Accepted 27 June, 2015

Abstract

Manufacturers around the globe are competing for the identification of innovative value propositions to survive in the competitive and complex market. This paper addresses implementation of Value Engineering (VE) technique into the product design concept for necessary changes in the design of the humidifier system in order to lower unnecessary costs and to increase quality of the product. Humidifiers are used for ventilation and cooling the air in most of the houses in cities located in hot and dry areas. Value Engineering as a systematic attempt is used to increase efficiency of the products and to optimize the life cycle cost. This leads to a shift from traditional design towards new efficient designs. For this study, an 8-stage job plan is used for VE job plan. In this article, different components of a humidifier were analyzed thoroughly and then numerous suggestions were made at the brainstorming sessions. Function Analysis System Technique (FAST) was also utilized at the first stage. The main findings lead to a conclusion that there were more suggestions at the brain storming session. Further, it is concluded that the best suggestion for improved design of the humidifier is changing the material of fan cover from galvanized iron to hard plastic or fiber plastic.

Keywords: Product Design, Creativity, Innovation, Humidifier, Value Engineering.

1. Introduction

Countries have always been influenced by acts of design. Globally, designers have developed tools and techniques to help them in designing better products (Lutters et al., 2014). It is important to consider innovations for new product development more than quality and production speed of goods (Lin and Luh, 2009). For survival of the products in the market, variant product design plays a very important role responding to customer satisfaction (Chen et al., 2015). Lack of direct relationship between customers and manufacturing is very important for improving product design (Hartmann & Germain, 2015). The engineering techniques are important tools for process improvement which offers the ability to optimize manufacturing processes and design (Astner et al., 2015).

Companies try to deliver their products to consumers and markets as soon as possible with high efficiency and minimum possible cost. Designing new products is the main key which companies must consider in order to compete with others in order to participate in business. Strategic management can be applied as the main decisions making tool taken by management, in consulting with others to determine the long-term activities of the organization. Different tools and approaches can be applied to analyze strategic cases in the process (Dincer, 2004). Product innovations can be radical or incremental depending on many factors like new designs and ideas (Hauser et al, 2006). Radical innovation often requires new products with new performance and characteristics (Leifer & McDermott, 2000; Zhou et al., 2005; Lin et al., 2009).

Development of an existing product for overall improvement is called incremental product innovation. Incremental product innovation is very crucial and important for industries and organizations since the majority of so-called 'new' products are in fact reworked versions of old products (Grupp & Maital, 2001). The current paper focuses mainly on incremental innovation which is a part of value engineering job plan.

In the past, there have been wind catchers in the buildings for cooling the air. Today, air conditions and humidifiers are substitute to cool the air. It is not necessary to use air conditions in dry and semi dry arid lands like deserts, because humidifiers could perform well in these areas (Mostafaeipour, 2010; Dinpashoh et al., 2014). There have been many researches regarding renewable energies to find a sustainable solution using wind and solar energies in Iran for generating electricity which is required to operate the humidifiers[(Mohammadi & Mostafaeipour, 2013; Mohammadi et al., 2014; Khorasanizadeh et al., 2014; Mostafaeipour et al., 2014).

* Corresponding author Email address: mostafaei@yazd.ac.ir

There has been an increasing emphasis on factories' ability to produce high-quality consumer products with low price. Such products can be identified by measuring the associated customer satisfaction level regarding the price and quality. Market analysis is also an effective means to understand customer perception towards new products or new designs. Cooper(2001) believed that there are common attributes among established firms that develop better products. This could be achieved using cross-functional teams, up-front market planning and listening to the customer, early product concept definition, and product portfolio planning. It goes without saying that in value engineering methodology, the main concept is respect to ideas of everybody in brainstorming sessions regarding their positions (Marion & Simpson, 2009).
Researchers have shown that a wide variety of factors influence the outcome of NPD (New Product Design) activities. Such activities could be a combination of strategy, development process, organizational, environmental, and market factors (Marion & Simpson, 2009; Goldenburg et al., 2001). There are three traditional measures of project performance: time, cost, and quality. Project performance is measured by time and cost in this paper. For most incremental projects the target quality is often well defined. Hence, the objective for management is to achieve the required quality with less time and less cost. In value engineering, all these three measures would be considered at all stages. Gerwin and Barrwman investigated that Krishnan used lead time development as the important key for project performance (Gerwin & Barrwman, 2002).

As a designer, one must be an optimist. Facing difficulties, a designer has to solve the problems based on the opportunities. When we need to value the product, we need to value its design first. Valuing the product explains what decisions should be taken while designing (Manzini & Milano, 2009; Dong et al., 2009)

This study is intended to focus on the way designers solve the problems and the way value engineering optimizes the quality of the humidifier system at a low cost. To decrease the extra cost and increase the efficiency and the quality of the product, this study provides a special procedure for assistive product design. The humidifier system has not changed since it was introduced several years ago.

The organization of the rest of the paper is as follows: Section 2 presents the background of value engineering. In Section 3 the technique of value engineering is presented. Section 4 offers the product design. The humidifier structure is brought forward in Section 5. Value engineering job plan is illustrated in section 6. Section 7 introduces Industry application for this product. Finally, the conclusions are presented in Section 8.

2. Background of Value Engineering

After the World War II, there was a growing need for materials. To maintain production, value methodology was introduced by the US industry. Value analysis, which was later used to decrease cost during the design stage known as value engineering was developed by Larry Miles (Cheah and Ting, 2005). The concept of VE is used in a variety of projects from buildings to water treatment works. There are good prospects for the use of VE in systemic context.
However the US Department of Defense agreed to use VE to gain the best practical value and employ it in contract clauses under the Armed Forces Procurement Regulations (AFPR) in 1961(Male & Kelly, 2007). There has been a controversy over VM generated by the creation of standards all over the world, mainly in Europe, Australasia, and China (Male & Kelly, 2007)

3. Technique of Value Engineering

Value Engineering is defined as a systematic attempt to increase efficiency of a product, project or system and optimize the life cycle cost. Its purpose is to eliminate the unnecessary cost while improving the quality, reliability, and other important features which live up to the consumers' expectations (Design method fact sheet, 2001; Shong Liew, 2002). It is also used to maintain the best balance between the cost, reliability and the function of a product or service. In value-oriented design, "what is the mechanism?" is of importance, while in a classical design "what should the thing be like?" was critical (Seni, 2004).

4. Product Design

There are different opinions about selection of materials for designing of the products, but all the barriers must be considered. New ideas must yield to a better product for consumers. Clearly, the function of a product is not the only reason for new design, but there should be more requirements regarding of this issue. For example, a cooler or humidifier is built to cool the air, but designers should not focus only on cooling the air as the only purpose, but quality of the product, availability of materials, useful life and many other factors must be considered. Some designers have not directed their attention toward the physical and metaphysical features. Product design has received a lot of attention in an intensely competitive situation (Ljungberg & Edwards, 2003;). Therefore, designers should implement all the design aspects. The competitive edge of a company is achieved by three main standards: lower product cost, shorter product development time, and customer

satisfaction. An appropriate design concept evaluation can meet the customer needs (Zhai et al., 2009).

5. Humidifier Structure

This cooling system is used in arid and hot areas for cooling; it directs air through the rectangular galvanized iron sheet channels to the room. It looks like a box (Figure 1) in which there is a fan and the bottom of the box is like a tray where there is water (about 4 cm) inside it and the water pump would then send it to the vertical filters in order to change the incoming hot air into cold and humid. The box has four vertical sides, one on top and the other is in the bottom which holds water.

Fig. 1. Humidifier (cooler)

Of the four vertical sides, three of them are not fixed and we could remove or open them in order to clean filters, because the filters which are made of shredded wood are attached to three doors. The other vertical side is fixed and the out coming air goes through a rectangular channel which is in middle of this fixed side. So the incoming air comes from three removable doors or sides and outgoing air is sent by the fixed side through a channel.
Inside of this box, there is a motor which rotates the fan by a belt. The fan should be covered all around except from two sides, because the fan just directs the air (not air and water) to the channel. The water gets pumped to the top of filters and then returns to the down tray and it circulates all the time. If the high speed fan works without cover, the water would also get mixed with air and goes through the channel. To prevent mixing of the water with air, there is a galvanized sheet cover which is circular and fan would be placed inside that cover (Figure 2).

Fig. 2. Galvanized sheet fan cover

6. Value Engineering Job Plan

Important elements should be taken into account, including the material selection, assembly method, and assembly sequence when developing the product (Ulrich & Eppinger, 2000). Roy et al.(2001) presented a 3-stage approach consisting of (1) Preparing functional element. (2) Mapping them to physical components, and (3) Defining interface specifications among components. Value engineering involves more stages, so it is more accurate. A computational method based on a similar idea is introduced, which changes the product's architecture using different mechanisms at each step.

6.1. Information Phase

This stage is intended to collect the relevant information, examine the function, the cost, and to find the chances for lifecycle savings. The task is broken down into its main functions by answering the following questions: What is it? What does it do? How much does it cost?
There is a pressing need for expertise to offer products as they become more complicated to meet the customers' needs (Bertoni et al., 2009; Saaksvuori & Immonen, 2005). The organizations are able to improve their operational efficiency.
The Humidifier (cooler) comprises the following 28 components with their market value prices in Iranian currency of Rials, and also description of the components (Table 1):

Table 1
Description of the cooler (Humidifier) components, part No, and Prices

INFORMATION PHASE		
The item for V.E. analysis is cooler that is being used in Iran which is hot and dry		
Part No	***Description***	***Price in Rials***
1	Down Tray	92500
2	Top Tray	85000
3	Back Tray	97000
4	Fan Cover	250000
5	Metal for holding fan cover	28000
6	Sheet metal for holding fan cover and its support	22500
7	Fan	120000
8	Metal sheet for directing air wind	11500
9	Three removable doors	195000
10	Small metal for holding doors	2000
11	Three shredded thin wood as air filter	17000
12	Air filter holder for three doors	14500
13	Three pieces of metals for spreading water to shredded filters	6000
14	Motor	420000
15	Water pump	45000
16	Electric box	2500
17	Metal shaft for holding fan	10000
18	Bearing	8000
19	Controller for water flow	6800
20	Key	10000
21	Plastic basket	5000
22	Pump hose	3000
23	Motor cable	3000
24	Top tray water hose	2500
25	Flexible plastic around fan cover	5000
26	Automatic device for water level	3000
27	Belt	10000
28	Top and bottom pullies	18000

6.2. Function Phase

The main focus of Value Engineering is functional analysis. Function Analysis System Technique(FAST) diagram (Figure 3) is the basic tool of functional analysis, revealing the hierarchical relationships of functions and concentrate on discovering better way to perform a specific function. FAST is a diagram illustrating the relations of all the functions. It shows the sequence of all the functions and their dependency and priorities. It also analyzes the functions and identifies the interrelationship of the functions of the product or system (Omidvar & Khodaei, 2008). This phase is of importance because it directs the attention toward the functions (away from the components), finding some other choices to do the same function at a lower cost (Chatterjee, 2002). Making a list of parts which complete a cooler is essential. Then the cost of each part should be estimated from the market and listed in a table.

The cost of the given part can be estimated from the market. Miles concluded that reducing the cost and maintaining performance would enhance the value, and the value might be enhanced by rising performance when the customer needed and asked for the enhanced performance (Miles, 1989). We should not make a hasty decision. For example, it is wrong to say that a part should be made of plastic, tight at the beginning. If the siding of the humidifier costs a small fortune, then we can take up a VE project on it. Therefore, it is essential to organize a cross functional team. Next, an in-depth functional analysis of the siding should be done. After calculating the worth, the value gap and value index are estimated for each function. The function with the greatest value gap is identified for VE. The team will brainstorm to recommend different choices which will operate this function. In accordance with specific given standards, the brainstormed opinions are evaluated, and the best opinion is implemented. The function with highest value gap / value index (Table 6) is identified for VE. The functional phase deals with the functional analysis of the assembly and subsequently with the basic and secondary functions of the components associated with the assembly. The function phase (Table 2) is useful as it helps to gradually shift the focus from components to functions and finding alternatives to perform the same function at lower cost.

Table 2
Function of the humidifier

FUNCTION of system	VERB	NOUNE
Humidifier	Cool	Air

A short write-up is necessary as to how the different parts are involved in overall functioning of the cooler. It is necessary to make a list of such parts which make the complete cooler. Once it is done, the cost for each of these parts are to be obtained from market and listed in tabular form. If in severe cases cost of some particular parts cannot be determined from the market, then some

proportions of the total cost of the cooler has to be apportioned for that part. Then the functional analysis (Table 3) has to be done where function of each part has to be described in terms of a verb and a noun. For example, blower's basic function is "suck air" and "throw air". A Secondary function of blower is "make noise" which is unwanted function, "suck moisture", you can think of any other functions also which the blower performs and categorize them as primary and secondary functions. Secondary functions can further be identified as required or undesired secondary functions. Similarly functions of side covers and other parts can be expressed in terms of verb and noun. Once these are completed, we will further proceed with the function -cost-worth analysis. Larry Miles recognized that value is increased by decreasing costs and maintaining performance and that value may be increased by increasing performance if the customer needs increased performance (Table 4).

The basic functions identified based on value index as well as value gap are as shown below (Table 5).

The function with the greatest value gap is identified for VE. The team will brainstorm to recommend different choices which will operate this function. In accordance with specific given standards, the brainstormed opinions are evaluated, and the best opinion is implemented. The function with highest value gap / value index (Table 6) is identified for VE. Based on the above analysis the first three basic functions have been identified with a potential for value engineering. The basic functions are:

1-Fan cover
2-Fan
3-Base tray

The creative phase could be generated based upon these three ideas. But for this work, the analysis was done only on fan cover which is in top of the list with highest value gap.

Table 3
Function analysis of the humidifier

Item No	Description	Basic Function	Secondary Function	Secondary Unwanted
1	Base Tray	hold water	drain water	
2	Top Tray	hold air	provide support	
3	Back Tray	transfer air		
4	Fan Cover	hold fan	restrict water	add weight
5	Metal for holding fan cover	hold fan cover		
6	Sheet metal for holding fan cover	provide support		add weight
7	Fan	throw air		consume energy
8	Metal sheet for directing air wind	direct wind		
9	Three removable doors	hold air filter	allow air	
10	Small metal for holding doors	hold doors		
11	Three shredded thin wood as air filter	filter air	absorb water	
12	Air filter holder for three doors	hold air filter		
13	3 metals for spreading water to filters	drain water		
14	Motor	rotate belt		generate heat
				consume energy
				make noise
15	Water Pump	pump water		make noise
				consume energy
16	Electric box	provide electricity		
17	Metal shaft for holding fan	hold fan		
18	Bearing	provide support	help rotation	
19	Controller for water flow	control water flow		
20	Key	control power	control fan	
			control water pump	
21	Plastic basket	filter water		demand maintenance
22	Pump hose	transmit water		
23	Motor cable	transfer electricity		
24	Top tray water hose	distribute water		
25	Flexible plastic around fan cover	prevent water		
26	Automatic device for water level	drain water		
27	Belt	transmit force		make noise
28	Top and buttom pullies	hold belt	hold shaft	

Table 4
Function of each component

Sl. No.	Component / Process	Function		BASIC/SECONDARY
		VERB	NOUN	
1	Base Tray	Hold	Water	B
		Drain	Water	S
2	Top Tray	hold	air	B
		provide	support	S
3	Back Tray	Transfer	Air	B
4	Fan Cover	Hold	Fan	B
		Restrict	Water	S
		Add	Weight	S(U)
5	Metal for holding fan cover	hold	Fan Cover	B
6	Sheet metal holds fan cover & support	provide	Support	B
		Add	Weight	S(U)
7	Fan	Throw	Air	B
		Consume	Energy	S(U)
8	Metal sheet for directing air wind	Direct	Wind	B
9	Three removable doors	Hold	Air Filter	B
		Allow	Air	S
10	Small metal for holding doors	Hold	Doors	B
11	Three shredded thin wood as air filter	Filter	Air	B
		Absorb	Water	S
12	Air filter holder for three doore	Hold	Air filter	B
13	3 metals for spreading water	Drain	Water	B
14	Motor	Rotate	Belt	B
		Generate	Heat	S(U)
		Consume	Energy	S(U)
		Make	Noise	S(U)
15	Water Pump	Pump	Water	B
		Make	Noise	S(U)
		Consume	Energy	S(U)
16	Electric Box	Provide	Electricity	B
17	Metal shaft for holding fan	Hold	Fan	B
18	Bearing	Provide	Support	B
		Help	Rotation	S
19	Controller for water flow	Control	Water flow	B
20	Key	Control	Power	B
		Control	Fan	S
21	Plastic Basket	Filter	Water	B
		Demand	Maintenance	S(U)
22	Pump Hose	Transmit	Water	B
23	Motor Cable	Transfer	Electricity	B
24	Top Tray Water Hose	Distribute	Water	B
25	Flexible plastic around fan cover	Prevent	Water	B
26	Automatic device for water level	Drain	Water	B
27	Belt	Transmit	Force	B
		Make	Noise	S(U)
28	Top and buttom pullies	Hold	Belt	B
		Hold	Shaft	S

Table 5
Function cost analysis of the humidifier

SI. No.	Basic Function	Allocated cost (Rials)	Function Worth (Rials)	Basis of worth	Value Gap		Value Index
		C	W		(C-W)	No	(C/W)
1	Hold Water	92500	70000	cost of a hard plastic tray	22500	3	1.32
2	hold air	85000	65000	Hard plastic tray for top	20000	4	1.31
3	transfer air	97000	80000	hard plastic back tray	17000	5	1.21
4	hold fan	250000	170000	hard plastic fan cover	80000	1	1.47
5	hold fan cover	28000	25000	smaller size metal	3000	10	1.12
6	provide support	22500	20000	smaller size metal	2500	11	1.125
7	throw air	120000	80000	hard plastic fan	40000	2	1.5
8	direct wind	11500	5000	Plastic to direct wind	6500	7	2.3
9	hold air filter	195000	180000	3 pastic doors	15000	6	1.08
10	hold door	2000	1500	hard plastic	500	15	1.33
11	filter air	17000	16500	shredded wood	500	18	1.03
12	hold air filter r filter	14500	14000	holder	500	17	1.04
13	drain water	6000	5000	plastic spreader of water	1000	12	1.2
14	rotate belt	420000	415000	motor	5000	9	1.01
15	pump water	45000	44000	water pump	1000	14	1.02
16	provide electricity	2500	2400	electric box	100	19	1.04
17	hold fan	10000	9000	smaller metal shaft	1000	13	1.11
18	provide support	8000	7500	bearing	500	16	1.07
19	control water flow	6800	6790	Water leveler of constant depth	10	27	1.001
20	control power	10000	9900	key	100	20	1.01
21	filter water	900	850	plastic basket	50	21	1.06
22	transmit water	3000	2950	pumping hose for water	50	22	1.02
23	transfer electricity	3000	2950	motor cable	50	23	1.02
24	distribute water	2500	2490	top tray water hose	10	28	1.004
25	prevent water	5000	4950	Plastic arounf fan cover	50	25	1.01
26	drain water	3000	2950	automatic pich for water level	50	24	1.02
27	transmit force	10000	9950	belt	50	26	1.005
28	hold belt	18000	12000	Top & down plastic pullies	6000	8	1.5

6.3. Creativity Phase

It's aim is to ascertain the largest number of choice that can be used to implement the desired function. This is often called "the brainstorming phase." The creativity phase raises the following questions: What else can perform the task?, and how much does it cost?. Since VE relies on offering new choices, it is regarded as the necessary element (Ibusuki & Carlos Kaminski, 2007).
The choices should be offered to perform the function at a lower cost, and maintain the desired quality.
Creativity and innovation are interchangeably used by some researchers (Wang et al., 2008; Wuyts et al., 2004), but some others (Im and Workman, 2004; Wang et al., 2008) differentiate between them. Creativity means generating novel and useful ideas adopted and implemented.
In the brainstorming session 14 ideas were generated. It is should be noted that in value engineering, all proposed ideas must be respected and then would be evaluated based upon group discussion. There were many proposed ideas, but 14 of them were selected for final discussion and evaluation (Table 7).

6.4. Evaluation Phase

Some standards were chosen and ranked in accordance with their importance with paired comparison matrix.
The standards were recommended at brainstorming session. Each standard was scored and ranked in accordance with the idea of the group. In evaluation criteria, there are 10 different criteria (Table 8) which were proposed at brainstorming sessions. Each criterion was scored and ranked based upon the opinion of group.
Some criteria were selected and ranked based on their importance with paired comparison matrix (Table 9). Scores for all identifications of A to J were calculated and then placed in last column.
The five ideas generated in the creative phase were evaluated based on the criteria decided with the help of decision matrix as shown in Table 10. The best idea with the highest total score was recommended for approval and also implementation in the future works. There are five proposed creative ideas with scores of ranging from 206 to 316. The best idea would be chosen based upon higher generated scored, means choosing proposal No 3. Therefore, changing the outer cover of the fan holder to plastic of fiber is the best to be implemented and recommended for further decision.

Table 6
Function arrangement for value gap

Sl. No.	Value gap	Basic Function	Item / Process
4	80000	hold fan	Fan Cover
7	40000	throw air	Fan
1	22500	Hold Water	Base tray
2	20000	hold air	Top tray
3	17000	transfer air	Back tray
9	15000	hold air filter	Three removable doors
8	6500	direct wind	Metal sheet for directing wind
28	6000	hold belt	Top and bottom pulley
14	5000	rotate belt	Motor
5	3000	hold fan cover	Metal for holding fan cover
6	2500	provide support	Sheet metal for holding fan cover and its support
13	1000	drain water	Three pieces of metals for spraying water to shredded filters
17	1000	hold fan	Metal shaft for holding fan
15	1000	pump water	Water Pump
10	500	hold door	Small metal for holding doors
18	500	provide support	Bearing
12	500	hold air filter	Air filter holder for three door
11	500	filter air	Three shredded thin wood as air filter
16	100	provide electricity	Electric Box
20	100	control power	Key
21	50	filter water	Plastic Basket
22	50	transmit water	Plastic Basket
23	50	transfer electricity	Plastic Basket
26	50	drain water	Automatic device for water level
25	50	prevent water	Flexible plastic around fan cover
27	50	transmit force	Belt
19	10	control water flow	Controller for water flow
24	10	distribute water	Top Tray Water Hose

Table 7
Creative ideas at brainstorming

IDEAS
1. Support fan with a stand instead of the cover.
2. Hang fan from the top
3 Change the outer cover of the fan holder to plastic/fibre
4 Instead of the pulley holding the fan, mount the motor shaft directly onto the fan shaft
5. Use aluminium for fan cover which is light in weight and reduce some of the structural supports
6.Use plastic for fan cover which is light weight and reduces the structural support
7.Use hard pastic pulleys instead of metal
8.Use hard plastic for three removable doors instead of metal
9.Use hard plastic for buttom tray
10.Use hard plastic for top tray
11.Use plastic sheet for directing wind
12.Use a plastic fan
13.Use a plastic air filter holder
14.Use a hard plastic shaft for fan

Table 8
Evaluation Criteria identification

Identity	**Criteria**	**Score**	**Rank**
A	Easy to implement	**8**	**5**
B	Easy to design	**9**	**4**
C	Easy availability	**6**	**7**
D	Maintainability	**7**	**6**
E	Power consumption	**3**	**9**
F	Higher useful lifetime	**12**	**1**
G	Customer Satisfaction	**10**	**3**
H	Good appearance	**3**	**9**
I	less weight	**5**	**8**
J	Easy to sell	**11**	**2**

Table 9
Paired comparison matrix

	B	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**SCORE**
A	B2	A1	D2	A1	A2	G1	A3	I1	A1	**8**
	B	B2	B2	B1	F1	B1	H1	I3	B1	**9**
		C	C2	C1	F3	G3	C1	C2	J1	**6**
			D	D2	F2	G2	D1	D2	J2	**7**
				E	E2	G1	E1	I1	J1	**3**
					F	F1	F1	F3	F1	**12**
						G	G1	G3	J2	**10**
							H	H2	J3	**3**
								I	J2	**5**
									J	**11**

Comparision	**Pts**
Major Difference	**3**
Medium Difference	**2**
Minor Difference	**1**
No Difference	**0**

Table 10
Decision matrix

Easy to design	**Easy avilability**	**Maintainability**	**Power consumption**	**Higher useful lifetime**	**Customer Satisfaction**	**Good appearance**	**less weight**	**Easy to sell**	
B	C	D	E	F	G	H	I	J	Total Score
9	6	7	3	12	10	3	5	11	
4	4	4	3	3	2	2	1	3	221
36	24	28	9	36	20	6	5	33	
2	1	2	3	4	4	3	1	3	206
18	6	14	9	48	40	9	5	33	
4	2	4	3	5	5	4	5	4	316
36	12	28	9	60	50	12	25	44	
3	4	3	5	4	4	3	3	3	248
27	24	21	15	48	40	9	15	33	
4	2	3	3	5	5	4	5	4	301
36	12	21	9	60	50	12	25	44	

6.5. Recommendation Phase

The alternative agreed on is offered to the sponsor for the final approval.

6.6. Implementation Phase

The design team or the project management team is held responsible for implementing the change. Measures must be taken to ensure that the change is completely applied. Since the price of hard plastic or fiber in Iran is much less than galvanized steel, it is economically feasible to substitute the new outer cover which its weight is also much less than steel. It is feasible from a manufacturing perspective.

7. Industry Application

The new design for humidifier fan cover is practical enough to be implemented in many industries which make this product. It is easily applicable and managements could substitute the old system with the newly proposed one which has been analyzed in this article. In analyzing these patterns, it became clear that the best solution is to change the material of fan cover from galvanized iron to hard plastic. By implementing this proposed change, maximum cost saving would be attained (Table 10) and quality of the part would be more acceptable.

8. Conclusion

In this article, Value Engineering (VE) technique was used to improve the efficiency and functionality of humidifier. VE is a creative management approach for promoting efficiency in products, systems and all different cases. Since it is usually implemented for a variety of cases, it has not been used in humidifiers so far. In value engineering often high value components /processes are targeted for the choice of a project. But even if the cost is comparatively low, setting targets to reduce cost of such assemblies can lead to high savings. The proposal will be further extended to other suggestions where there is scope of further savings. The main aim of this study was to identify an appropriate management problem solving technique tool to increase the quality for humidifier and also decrease manufacturing cost of new designed parts. In this study, it was demonstrated that it is possible to perform a value engineering analysis wherein the possible dependencies among factors are included. The VE technique, which enables measuring inter-factor dependencies, is utilized in this work. The method is also used to compare the effects of other decisions on prioritizing the alternative strategies for lowering unnecessary costs, and increase quality of the new design. The main findings lead to the conclusion that there were 14 creative ideas (Table 7); then 10 different criteria were identified to evaluate all creative ideas at the brain storming session. Paired comparison matrix (Table 9) was utilized for final decision making. Table 10 illustrates 6 of the best ideas which were ranked to find the best solution or suggestion for humidifier. In analyzing these patterns, it became clear that the best solution is to change the material of fan cover from galvanized iron to hard plastic or fiber plastic.

References

Astner, A.F., Young, T.M., and Bozell, J.J. (2015). Lignin yield maximization of mixed biorefinery feedstocks by organosolv fractionation using Taguchi Robust Product Design. Biomass and bio energy, 73, 209-216.

Bertoni , M., Bordegoni , M. , Cugini M. , Regazzoni, D. and Rizzi, C. (2009). PLM paradigm: How to lead BPR within the Product Development field. Computers in Industry, 60, 476–484.

Chatterjee, P. (2002).Value Engineering on Speedo-Assembly of Tata Vehicles, HV Transmissions Limited, Jamshedpur, India.

Cheah, C.Y.J., Ting, S. K. (2005). Appraisal of value engineering in construction in Southeast Asia. International Journal of Project Management, 2, 151–158.

Chen, C.Y., Liao, G. Y. and Lin K. S. (2015). An attribute-based and object-oriented approach with system implementation for change impact analysis in variant product design, Computer-Aided Design, 62, 203–217.

Cooper, R. G. (2001). Winning at new products, Perseus Publishing, Cambridge, MA.

Dincer, O. (2004). Strategy Management and Organization Policy, Beta Publication, Istanbul.

Dinpashoh Y. Mirabbasi R., Jhajharia D., HAbianeh .Z., Mostafaeipour A. (2014). Effect of short-term and long-term persistence on identification of temporal trends. Journal of Hydrologic Engineering, 19(3), 617- 625.

Dong, A., Kleinsmann, M. and Valkenburg, R. (2009). Affect-in-cognition through the language of appraisals. Design Studies, 30, 138-153.

Gerwin, D. and Barrowman, N. J. (2002). An evaluation of research on integrated product development. Management Science, 48 (7), 938–953.

Goldenburg, J., Lehmann, D. R. and Mazursky, D. (2001). The idea itself and the circumstances of its emergence as predictors of new product success. Management Science, 47(1) 69-84.

Grupp, H. & Maital, S. (2001). Managing New Product Development and Innovation: A Microeconomic Toolbox, Edward Elgar, Cheltenham, UK.

Hartmann, J. and Germain, R. (2015). Understanding the relationships of integration capabilities, ecological product design, and manufacturing performance. Journal of Cleaner Production, 1-10. Article in press: http://dx.doi.org/10.1016/j.jclepro.2014.12.079

Hauser, J., Tellis, G. J. and Griffin, A. (2006). Research on innovation: A review and agenda for marketing science.Marketing Science, 25(6), 687–717.

Ibusuki, U. and Carlos Kaminski, P. (2007). Product development process with focus on value engineering and target-costing: A case study in an automotive company. Int. J. Production Economics, 2, 459–474.

Im, S. and Workman, J. P. (2004). Market orientation, creativity, and new product performance in high-technology firms. Journal of Marketing, 68 (2), 114−132.

Khorasanizadeh, H., Mohammadi, K., Mostafaeipour A. (2014). Establishing a diffuse solar radiation model for determining the optimum tilt angle of solar surfaces in Tabass, Iran. Energy Conversion and Management, 78, 805-814.

Leifer, R., McDermott, C. M., O'Connor, G. C., Peters, L. S., Rice, M. & Veryzer, R. W. (2000). Radical Innovation: How Mature Companies Can Outsmart Upstarts, Harvard Business School Press, Cambridge, MA.

Lin, C. C. and Luh, D. B. (2009). A vision-oriented approach for innovative product design, Advanced Engineering Informatics 23, 191–200

Lin, J., Chai, K. H., Brombacher , A. C. and Wongd, Y. S. (2009). Optimal overlapping and functional interaction in product development. European Journal of Operational Research, 196, 1158–1169.

Ljungberg, L. Y. and Edwards, K. L. (2003). Design, materials selection and marketing of successful products. Materials and Design, 24, 519–529.

Lutters, E. , van Houten, F. J.A.M. , Bernard, A., Mermoz, E. and Schutte, C.S.L. (2014). Tools and techniques for product design, CIRP Annals - Manufacturing Technology, 63, 607–630.

Male, S. and Kelly J. (2007). A Re-appraisal of Value Methodologies in Construction, SAVE International.

Manzini, E. and Milano, P. (2009). New design knowledge. Design Studies, 30, 4-12.

Marion, T. J. and Simpson, T. W. (2009). New product development practice application to an early-stage firm: the case of the Paper Pro Stack Master. Journal of Design studies, 30(5) 561- 587.

Miles, Lawrence D. (1989). Techniques of Value Analysis and Engineering, Third Edition, Eleanor Miles Walker publishing, Miles Value Foundation.

Mohammadi K., Mostafaeipour A., Sabzpooshani M.(2014). Assessment of solar and wind energy potentials for three free economic and industrial zones of Iran, Energy 67, 117-128.

Mohammadi K., Mostafaeipour A. (2013). Economic feasibility of developing wind turbines in Aligoodarz, Iran. Energy Conversion and Management, 76, 645-653.

Mostafaeipour, A. (2010). Historical background, productivity and technical issues of qanats. Water history,
(2), 61–80.

Mostafaeipour, A., Jadidi, M., Mohammadi, K., Sedaghat, A.(2014). An analysis of wind energy potential and economic evaluation in Zahedan, Iran. Renewable and Sustainable Energy Reviews, 30, 641–650.

Omidvar, B., Khodaei, H. (2008). Using value engineering to optimize flood forecasting and flood warning systems: Golestan and Golabdare
watersheds in Iran as case studies. Nat Hazards, 47:281–296.

Roy, U., Pramanik, N. , Sudarsan, R. , Sriram, R. D. and Lyons, W. (2001). Function-to-form mapping: model, representation and applications in design synthesis. Computer- Aided Design, 33(10), 699–719.

Saaksvuori, A. and Immonen, A. (2005). Product Lifecycle Management, Springer, New York.

Seni, D. A. (2004). Function Analysis as a General Design Discipline, SAVE International.

Ulrich, K. T. and Eppinger, S. D. (2000). Product Design and Development, McGraw Hill.

Wang, Q., Bradford, K., Xu J. and Weitz, B. (2008). Creativity in buyer–seller relationships: The role of governance. Intern. J. of Research in Marketing, 38, 109–118.

Wuyts, S., Stremersch, S. and Dutta, S. (2004). Portfolios of inter firm agreements in technology- intensive markets: Consequences for innovation and profitability. Journal of marketing, 68(2), 88−100.

Zhai, L. Y., Khoo, L. P. & Zhong, Z. W. (2009). Design concept evaluation in product development using rough sets and grey relation analysis. Expert Systems with Applications, 36, 7072–7079.

Zhou, K. Z., Yim, C. K. and Tse, D. K. (2005). The effects of strategic orientations on technology- and market-based breakthrough innovations. Journal of Marketing, 69(2), 42–60.