VALUE ANALYSIS OF GEARED TYPE WATER PUMPING WIND MILL USED FOR IRRIGATION & DRINKING WATER APPLICATIONS

A MAJOR THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING

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CERTIFICATE

I, ASHISH KUMAR, hereby certify that the work which is being presented in the thesis entitled "VALUE ANALYSIS OF GEARED TYPE WATER PUMPING WIND MILL USED FOR IRRIGATION & DRINKING WATER APPLICATIONS" in the partial fulfillment of requirement for the award of Degree of MASTER OF ENGINEERING submitted in the Department of Mechanical Engineering at DELHI COLLEGE OF ENGINEERING under DELHI UNIVERSITY, DELHI, is an authentic record of my own work carried out during a period from July 2006 to July 2007, under the supervision of Sh. Vipin, Asstt. Professor (Mechanical Engg. Department). The matter presented in this thesis has not been submitted in any other University/ Institute for the award of any degree.

(ASHISH KUMAR)

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This is to certify that the above statement made by the candidate is correct to best of my knowledge.

(Sh. VIPIN)
Asst. Professor
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ACKNOWLEDGEMENT

It is a matter of great pleasure for me to present my dissertation report on "VALUE ANALYSIS OF GEARED TYPE WATER PUMPING WIND MILL USED FOR IRRIGATION & DRINKING WATER APPLICATIONS". First and foremost, I am profoundly grateful to my Guide **Sh. Vipin**, Asstt. Professor, Mechanical Engg. Department for his expert guidance, encouragement, and valuable advice at all the stages in this Project Work.

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Last, but not the least, I would like to thank **my family members** for their help, encouragement and prayers through all these months. I dedicate my work to them.

(ASHISH KUMAR)

ABSTRACT

In today's manufacturing environment, we are constantly being besieged with "New" Quality Initiatives. The general thrust of these systems appears to be the improvement of the quality at the least cost appropriate to satisfy the customers' needs. This states the need for application of Value Analysis in every organization that strives for Quality.

This project, "Value Analysis of Geared Type Water Pumping Wind mill used for irrigation & drinking water applications" was done at Scientific Instruments Co. Ltd., Ghaziabad. In this project the Job Plan suggested by Mudge is being used.

Initially all the required information about the product was secured and the Functions of various parts are defined in Noun and Verb form according to the rules in the Job Plan. Later all the Primary Functions are compared for their relative importance and their Percentage weight factor is found out. Then a Function Cost Matrix was developed which shows the percentage cost associated in providing each function. Then a VIP index is calculated for these Functions and the Poor Value Functions are identified which are carried to next phase to develop Creative ideas. In the creativity phase, Brainstorming section was done for generating ideas in order to improve the product quality or reduce cost. All the Creative ideas are then subjected to systematic appraisal and creative judgment with positive frame of mind to develop the workable solutions. After consulting with vendors and specialists in the concerned areas the ideas are finalized and cost savings are found to be Rs.7.3 lakhs per annum (approximately).

In the recommendation phase all the suggestions are presented before management and it was assured that these suggestions will be taken up for implementation.

CONTENTS

LIST OF ABBREVIATIONS

BOM	Bill of Material
SICO	Scientific Instrument Company Ltd.
LCC	Life Cycle Cost
FAST	Functional Analysis System Technique
HC	High Cost
INVEST	Indian Value Engineering Society
OR	Operation Research
PF	Primary Function
PV	Poor Value
QFD	Quality Function Deployment
SF	Secondary Function
SAVE	Society of American Value Engineers
SIVAM	Society of Indian Value Management
TQM	Total Quality Management
VA	Value Analysis
VE	Value Engineering
VIP	Value Improvement Potential

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CHAPTER 1 INTRODUCTION

Most of Indian industries are plagued by the high costs, low profitability, dependence on imported or scarce material, market problems like cut throat competition due to establishments of foreign manufacturers etc. Each firm produces only small percentage of total Market output; therefore it exercises no control over market price. For example it can't restrict output in the hope of forcing up the existing market price. In such scenarios profits can only be made effectively by reducing the cost of product. How this can be achieved? That is what Value Engineering is entirely about which is aimed to eliminate unnecessary costs right from pipe line stage to final stage without affecting the functionality of the project. Hence, to overcome such shortcomings, Value Engineering/Value Analysis has emerged as most effective and an appropriate management tool/technique in recent years.

Value Engineering is a powerful tool of cost reduction in industrial business, a tool different from the ordinary methods of cost reduction, is obviously of vital importance.

1.1 Value Engineering / Value Analysis

Value engineering is a branch of industrial engineering in which the value of a system's outputs is optimized by crafting the optimum mix of performance and costs. In most cases this practice identifies and removes unnecessary expenditures, thereby increasing the value for the manufacturer and/or their customers.

Many people have defined Value Engineering in their own way but the specific objective of Value Engineering / Value Analysis is stated in its definition by the **Society of American Value Engineers (SAVE):**

"Value engineering is the systematic application of recognized techniques which identify the function of a product or service, establish a monetary value for the function and provide the necessary function at the lowest overall cost."

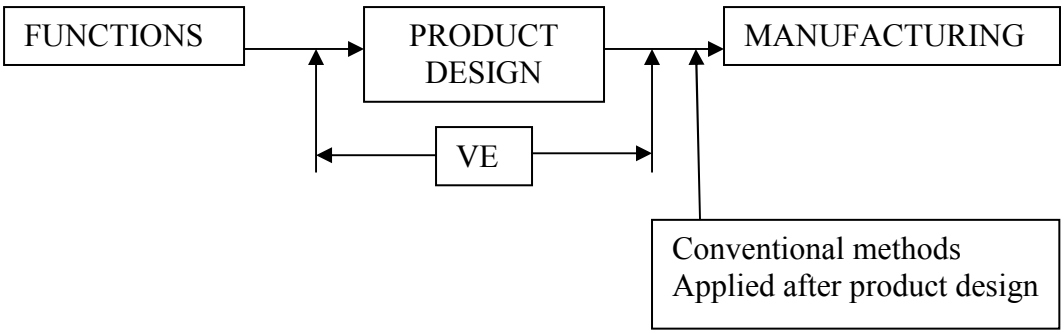
1.2 Difference between Value Engineering and Value Analysis

A.D. Raven differentiated between Value Engineering and Value Analysis as Value Engineering refers to the product yet to be produced i.e., in the design stage which means Cost prevention.

Value Analysis refers to the product which is already being produced which means cost correction. A.D. Raven also added a few more terminology like "Value Administration" and "Value Management."

1.3 Difference from Conventional Cost Reduction

In conventional methods (like OR, Method Study etc.,) product design is taken as it is. But most important cost reduction can occur before or at the product design stage. In Value Engineering the emphasis is on *Function.*



S.No.	Conventional Method	Value Engineering
1.	Item oriented	Function oriented
2.	Costs are calculated part wise or operation wise	Costs are calculated Function wise
3.	Individual approach	Team approach
4.	Analytical in approach	Creative in approach
5.	Limited scope of cost reduction	Much scope of cost reduction.
6.	It focus on high cost items	It focus on poor value functions

1.4 History and growth of Value Engineering

Value Engineering originated as a result of the efforts of Larry Miles. Mr.Miles is considered the "father of Value Engineering". An engineer by training, during World War II (1943), he was charged with procuring material for General Electric (GE) manufacturing products that had a comparatively low military priority. Lawrence quickly found that he would not be able to obtain the parts he needed through traditional methods. Through this functional mechanism, he was able to obtain the results and parts needed. The process was continuously improved by Mr. Miles and later, GE formed a group for the process which also improved it. By the 1950's lots of companies and some parts of governments were using it and ball really got to rolling.

Several organizations have been formed to help learn the process monitors it, and set standards, these include SAVE International, Miles Foundation, INVEST, SIVAM etc.

1.5 Motivation for the VA Project

1. VA/VE is the systematic approach/job plan and part of TQM continuous improvement technique, which has found wide application in all types of industries e.g. automobile industry, process industry, construction services, manufacturing plants etc.
2. It is totally different approach and uses function of a product for value improvement and cost reduction. It directly attacks on functional cost rather than component wise unlike in other methods of cost reduction.
3. By doing a project in Value Engineering one can get knowledge in all fields like R&D design, production, marketing etc.
4. The various part studies done by many organizations like TELCO, GE, FORD etc., have proved that VA/VE is the most effective technique while applied in the systematic manner.
5. Company facing tough competition in this product from competitors (China, Brazil, etc…) due to high cost of production, high material cost and pressure from customer to reduce price of the product.
6. The cost of all commodities and raw materials has reached to high in the past years. In addiction to it the government polices, availability of resources, stock market in the country, foreign currency depletion and globalization; all have made it impossible to contain the price hike and also restricted the profits due to increased competition in the global market. In these circumferences VA/VE is the most effective method of

cost reduction along with maintaining the same or improved quality with the same cost as it is a systematic approach.

1.6 OBJECTIVE OF THE PROJECT

Typically the objective of the object is

- Identifying the poor value high cost functions of the components in the assembly.
- Eliminating the unnecessary costs right from pipe line stage to final stage without affecting the functionality of the project.
- There by, reducing the total cost of the water pumping windmill, geared type by means of applying VE concepts.

In this chapter a brief description of various topics and words related to Value Engineering is mentioned. After development of Value Analysis/ Value Engineering technique way back in 1947 by L.D. Miles, many modifications and assisting techniques were developed to make this as a systematic approach. But Aurthur E. Mudge has defines those terms in VA/VE like value, function, unnecessary cost etc.

A) Concept of Value

The value of a product will be interpreted in different ways by different customers. Its common characteristic is a high level of performance, capability, emotional appeal, style, etc. relative to its cost. This can also be expressed as maximizing the function of a product relative to its cost:

$$Value = \frac{\text{Pr}\,oduct\ quality / Performance / function}{Cost\ of\ \ product\ \ function}$$

Value is not a matter of minimizing cost. In some cases the value of a product can be increased by increasing its function (performance or capability) and cost as long as the added function increases more than its added cost. The concept of functional worth can be important. Functional worth is the lowest cost to provide a given function. However, there are less tangible "selling" functions involved in a product to make it of value to a customer.

There are two types of Value:

Use Value: Derived from properties which make the product work & hence sell.

Esteem Value: Derived from properties which make the product only sell.

B) Function

Any performance characteristic that a product or service or its part accomplishes. The expression of all functions must be accomplished in two words, a verb and a noun. All functions can be divided into two levels of importance, primary (basic) and secondary.

i) Primary Function: The needed performance characteristic of a product or service that is required in order to make it work and/or sell.

ii) Secondary Function: These functions are necessary in order to allow the designer's choice for means of accomplishing the basic function to do so effectively.

The expressions of work and sell functions uses different categories of verbs and nouns.

a) Work functions are always expressed in action verbs and measurable nouns which establish quantitative statements.

b) Sell functions are always expressed in passive verbs and non measurable nouns which establish qualitative statements.

C) Cost of Function: All costs directly associated with the performance of a particular function involved in different parts of the product.

D) Unnecessary Cost: The total cost of items that do not contribute to the essential function, reliability, or maintainability. There are two major reasons for the existence of this cost-

1) Due to over estimation of the customer requirements.

2) Due to accomplishing the function in an inefficient or uneconomic way.

E) Value of Function: Maximum value is achieved when function is performed at minimum cost and still meets all the user's need or requirements.

F) Value Improvement: It refers to efforts applied to existing items/parts of a product to create one better value.

G) Functional Analysis System Technique (FAST): A method for analyzing, organizing and graphically displaying the interrelation of the primary and secondary functions of a system, product, design, procedure, facility etc. It was introduced by Charles Bytheway in 1960.

FAST differs from value analysis in the use of intuitive logic to determine and test function dependencies and the graphical display of the system in a function dependency diagram or model. Another major difference is in analyzing a system as complete unit, rather than analyzing the components of a system. When studying systems it becomes apparent that functions do not operate in a random or independent fashion. A system exists because functions form dependency links with other functions, just as components form a dependency link with other components to make the system work. The importance of the FAST approach is that it graphically displays function dependencies and creates a process to study function links while exploring options to develop improved systems.

There are normally two types of FAST diagrams, the technical FAST diagram and the customer FAST diagram. A Technical FAST diagram is used to understand the technical aspects of a specific portion of a total product. A customer FAST diagram focuses on the aspect of a product that the customer cares about and does not delve into

the technicalities, mechanics or physics of the product. A customer FAST diagram is usually applied to a total product.

2.1 Methodology Adopted in VA Study

In this project, the following systematic job plan (Procedures or techniques) suggested by A.E. Mudge is followed:

2.1.1 General Phase: This is the foundation of Value Engineering Job plan. The strength of the project depends on the foundation. Project selection is the main activity in this phase. The different techniques adopted in this phase are

a) Use good human relations.

b) Inspire Team work.

c) Work on specifics.

d) Overcome roadblocks.

e) Apply good business judgment.

2.1.2 Information Phase: In this all the information regarding the product selected is gathered. The information collected must be reliable and accurate. In this phase job plain contains only three techniques which are as follows:

a) Secure the facts.

b) Determine the costs.

c) Fix costs on Specification and Requirements.

2.1.3 Function Phase: This is the heart of the Value Engineering job plan. The success of the plan depends on the proper definition of the functions of various parts. Functions

must define precisely in two words, a verb and a noun and must defined clearly without any ambiguity. The techniques adopted in this phase are:

a) Define the Function.

b) Evaluate Functional Relationships.

2.1.4 Creative Phase: Till now the product has been considered in its original form nothing has been done on the product to improve its quality or reduce cost. On the basis of Value index, functions identified as poor value functions in the functions in the function phase are taken up and creative ideas are generated in order to improve the product quality and reduce its cost. This phase uses the following two techniques:

a) Establish Positive Thinking

b) Develop Creative Ideas.

2.1.5 Evaluation Phase: The creative ideas that are developed in the creative phase are evaluated by careful appraisal and creative judgment coupled with positive thinking so as to see that each and every good idea can be implemented. In this process it must be seen that the product is not degraded or cheapened. This phase employs the following techniques:

a) Refine and Combine Ideas

b) Establish Cost on All Ideas

c) Develop Functional Alternatives

d) Evaluate By Comparison

2.1.6 Investigation Phase: The three techniques of this phase further refine the selected ideas into workable and salable solutions, providing lowest – cost methods of performing

the required and desired functions through the application of additional, vast resource of knowledge. The techniques employed in this phase are:

a) Use Company and Industrial Standards.

b) Consult Vendors and Specialists.

c) Use Specialty Products, Processes, and Procedures.

2.1.7 Recommendation/Implementation Phase: This phase corresponds to the finishing of the systematic job plan of VE. The main aim of this phase is present the facts and costs of the new design to the management with plan of implementation and cost. In this phase the following techniques re adopted.

a) Present Facts.

b) Present Costs.

c) Motivate Positive Action.

2.2 Foundation of VA Job Plan

The General Phase is the foundation for the VA job Plan. Other phases from different floors of Value structures. The various steps that are needed to have to a good foundation are give below.

a) Use Good Human Relations: Value analysis is more a team work than individual work. So, it is necessary to have good relationship among the team members so that all the data required to carry out the analysis is acquired with out any difficulty. The important that has to be kept in mind is we have to work on “give and take basis” and must discuss everything with open mind.

b) Inspired Team Work: As said before, VA is a team work and is the orientation of group of persons towards the goal of the organization irrespective of individual interests. The team consists of members from all the departments i.e. Design, Marketing, Production and R&D etc. By working in a team the subjectivity involved in taking various decisions will be reduced.

c) Overcome Roadblocks: Road blocks are the natural tendencies in any kind of change and VA insists on change. So, we have to anticipate the various road blocks and must overcome them either by providing extra information or by the pressure from the management.

d) Apply good business judgment: Business decisions and judgment must be based on facts. Poor business and poor judgment become prevalent when personal opinions and feelings take control. To apply good business judgment one must be resourceful, knowledgeable and creative.

All these steps are must be followed in order to have a proper foundation to the VA job plan. With the general phase as the base or foundation of the job plan, this overview can be continued into the Information Phase.

2.3 Literature Review from Research Papers

Many researchers and academicians of National and International repute have probed into the topic of Application of Value Analysis. Some of whose names and work abstract have given below:

- Lawrence D. Miles 1947, General Electric staff engineer, was assigned to the purchasing division to study a new design concept. He developed technique which

he named “Value Analysis” to generate saving based primarily on an analysis of product functions and costs.

- Ugo Ibusuki, Kaminski 2007, suggest a methodology for the product development process in Automotive company aiming at the correct systematic approach of Value Engineering (VE) and target costing in cost management. The proposed approach i.e. FAST, Matrix QFD, Mudge Diagram was validated in a case study focused on engine starter system of a vehicle aiming at improved product cost, functionality and quality accomplishment in accordance with customer’s needs and the company strategy.
- Silva Luis, 2004, shows that the aim of both Value Analysis (VA) and Quality Function Deployment (QFD) is to reduce waste by avoiding redesign and providing optimal location of cost in general. His work evaluates the integrated use of QFD and VA tools employing a survey that was carried out which intended to reveal the young male consumers requirements concerning a sports bicycle. He uses the techniques like FAST, Numerical evaluation and FCM.
- Ken L. Smith, 1984, Value Engg. Manager applied the Value Engineering studies on the Washington state department of transportation (WSDOT). By applying the simple seven point value analysis job plant (Investigation, speculation, evaluation, development, presentation, implementation and Audit), he proves that this exercise has helped yield the organization nearly 1.5 times more savings.
- D. Janz, W. Shin, 2005, identifies the product components which incur high costs compared to their functional value. In order to identify optimization potential, he used the methods of value analysis, qualify function deployment and life cycle

costing, which are matched to each other and integrated into a comprehensive concept.

- Chaudhary L. R., 1999, does the case study for improvement in tractor anchor plates by applying the techniques of Value Analysis right from information phase to recommendation phase.
- Ghose A, Rao R.D. ,1991, explain in his case study how the quality and reliability of a product can be increased with the implementation of Value Engineering.
- Vincent G. Reuter ,1986 ,shows that adopting common methodology of Value Engineering and Value Analysis programs help firms produce better quality products at lower costs. When VA programs are implemented during production, management finds them valuable in updating designs and plans that were made under the pressure of getting the product to market.
- Brun Alessandro, Ivan Ravelli, 2005 explains in his paper the decisional process of the introduction of a new information system for advanced planning and scheduling and supply chain management (APS/SCM), with particular care given to the value assessment.
- Dorina C., Petriu, C., Murray Woodside, 2004 present a novel methodology for flexible design of industrial systems based on their detailed differential value analysis (DVA) Evolving from graph theory, this methodology devises a mechanism for systematic structural decomposition of large-scale industrial systems into basic processing elements (paths and trees), combination of elements into subsystems and evaluation of individual elements/subsystem to correlate with the overall system margin.

CHAPTER 3 INFORMATION PHASE

It is the phase of collection of information and data pertaining to the project for the systematic approach to the VE job plan. Information phase is the backbone of complete VE job plan. The strength of the VA structure depends to a large extent on the accuracy and reliability of the data gathered about the design, manufacturing and selling aspects of the product. The costs of various components which are meant for achieving desired functions should be determined. This phase uses three techniques, which are as follows:

I. Secure the facts

II. Determine the costs

III. Fix costs on specifications and requirements

3.1 Secure the facts

The first step is to secure all the relevant data and information regarding the problem from all departments and sources viz. production, design, marketing etc. The information collected must be reliable and accurate i.e. authenticated. This information should be collected with the help of concerned team member.

All the information obtained is classified and presented on the information work sheet under the three main headings, which are:

a) Application and marketing: This includes information like

- Detailed specification and requirements established by user and producer.
- Expected market demands.

- Expected market life of the product.
- Environmental condition during use of the product.

b) Engineering: In this information on design and development aspects are given.

- Technical study of the product and the project.
- Physical description, which includes dimensions, tolerances, weight, color, density etc.

c) Manufacturing and Procurement: This includes information on

- Production process specifications- sequence of operations, specific methods applied, quantity produced, batch size, machines used etc.
- Make or Buy decisions.
- If purchased – past and present suppliers, lead time, delivery history, cost of transportation, cost of inventory and replenishment etc.

3.2 Determine the cost:

The objective of this technique is to determine the cost of various components and operations of the product so that VE team can identify poor value/high cost areas for analysis. The exact breakdown of the cost in terms of labor and material costs was difficult to estimate since almost all the parts are brought from the vendors. Directly the total costs of the components are used for the further analysis in this project.

The Table 3.1 shows bill of material along with the costs of various components. These costs are before the target price was decided with the supplier.

3.3 Fix Cost on the Specification and Requirement:

In this technique the specification and requirements of the functions that control the design of the product and contribute in the product cost. There are two types of specifications and requirements:

a) Imposed by the requirement of the customer: These are primary and secondary functions due to specification and requirements.

b) Imposed by the designer on himself: These can be secondary functions due to design approach.

The complications arise when the designer imposes some non-real or arbitrary specifications and requirements to over design of the product, which increases fix cost of specification & requirement. These secondary functions should be carefully identifies and eliminated without degrading quality of product from functional point of view, otherwise it would result into unnecessary cost.

Table 3.1 Bill of Material & Determining the Cost

Company : SICO Ltd., Ghaziabad

S. NO.	PART NAME	PART NUMBER	QTY	MATERIAL	TOTAL COST
1.	Blades	A 050-1003b	18	G.I. Steel 18 gauge	8000
2.	Tie Bars	A 010-1004a	6	M.S.	600
3.	Radial Arms	A 050-1011c	6	M.S.	900
4.	Sectors	A 010-1012a	6	M.S.	1700
5.	Hub	A 010-1013c	1	Medium C. Steel	1260
6.	Shaft-I	A 010-1014	1	Steel	900
7.	Vanes	A 010-1016c	2	Al. sheets	800
8.	Support tube & pin	A 010-1017c	1	Steel Tube & S.S.	1600
9.	Tie Rod	A 010-1018d	1	M.S.	400
10.	Spring	A 011-1019a	1	High C. Steel	400
11.	Housing box	A 010-1020b	1	Welded steel	5000
12.	Gears	A 010-1021b	1 set	S.G. Iron	2000
13.	Bearing-I	A 010-1112	2	Steel	1500
14.	Turn table plates	A 010-1023a	1	M.S.	1120
15.	Bearing balls	A 010-1024c		Steel	620
16.	Shafting-II	A 010-1014a	1	Steel	2400
17.	Universal Joint	A 050-1111d	1	Alloy steel	2800
18.	Bearing-II	A 010-1112a	4	Steel	1300
19.	Coupling	A 010-1113c	1	M.S.	500
20.	Flanges	A 010-1211b	1	M.S.	900
21.	Truing plate	A 010-1212	1	M.S.	900
22.	Pump	A 010-1025	1	Body C.I.	5000
23.	Pump support	A 010-1026	1	Steel	1380
24.	Piping	A 010-1027	1	Steel	2500
25.	Tower	A 050-1511a	1	Welded steel G.I. Coated	30000
26.	Working platform & ladder	A 050-1512b	1	Steel	5520
				Total	**80,000**

3.4 Geared type water pumping windmill

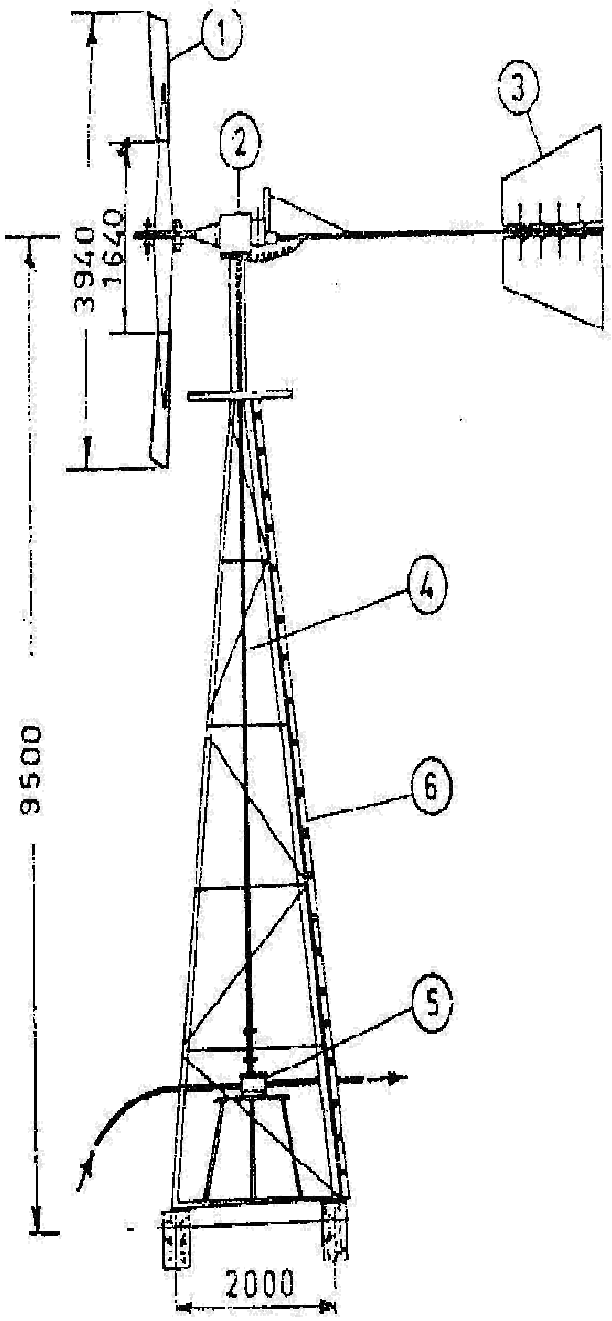
Windmill is a device which converts the kinetic energy of the wind in to the useful mechanical power. Water pumping windmills, as the name implies, are used for minor irrigation and drinking water applications.

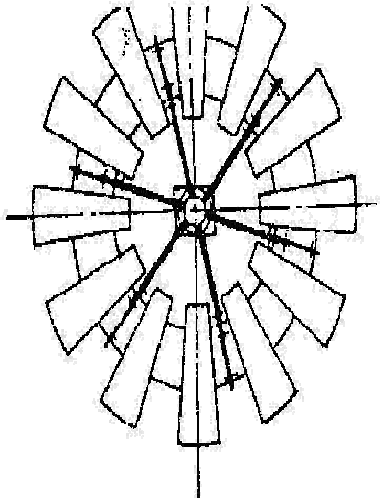
The main components of the water pumping windmill unit are **rotor, windmill head, tail vane, transmission system and supporting structure (tower).** An additional component that completes the unit in terms of use is the **pump.** The details of all these components are shown in figures 3.1 to 3.6.

Multiblade type horizontal axis rotor (as used in geared type water pumping windmill) are having high starting torque in light winds and are used for water pumping and other low frequency mechanical power.

The rotor and the tail vane are supported by the windmill head. To facilitate orientation of the rotor to face the wind, the windmill head is supported on ball bearings. The plate that houses the bearing balls is fixed to the top plate of the tower. The windmill head also houses part of the transmission system.

A feature of the design is, the power at the end use is delivered through rotary motion. This was necessitated by the choice of the pump- a rotary type. The restriction on the suction head made it necessary to locate the pump near ground level. Power delivery at this point through rotary motion is achieved by changing the axis of rotation of the rotor with the help of bevel gears housed in the windmill head. A vertical shaft connects the bevel gears in the windmill head and the pump suitably mounted at ground level





MAIN COMPONENTS

1	ROTOR
2	GEAR-BOX (W. M. HEAD)
3	TAIL VANE
4	TRANSMISSION SHAFT
5	PUMP
6	SUPPORTING STRUCTURE

FIG. 3.1 WATER PUMPING WIND MILL
(Source : SICO Ltd., Ghaziabad)

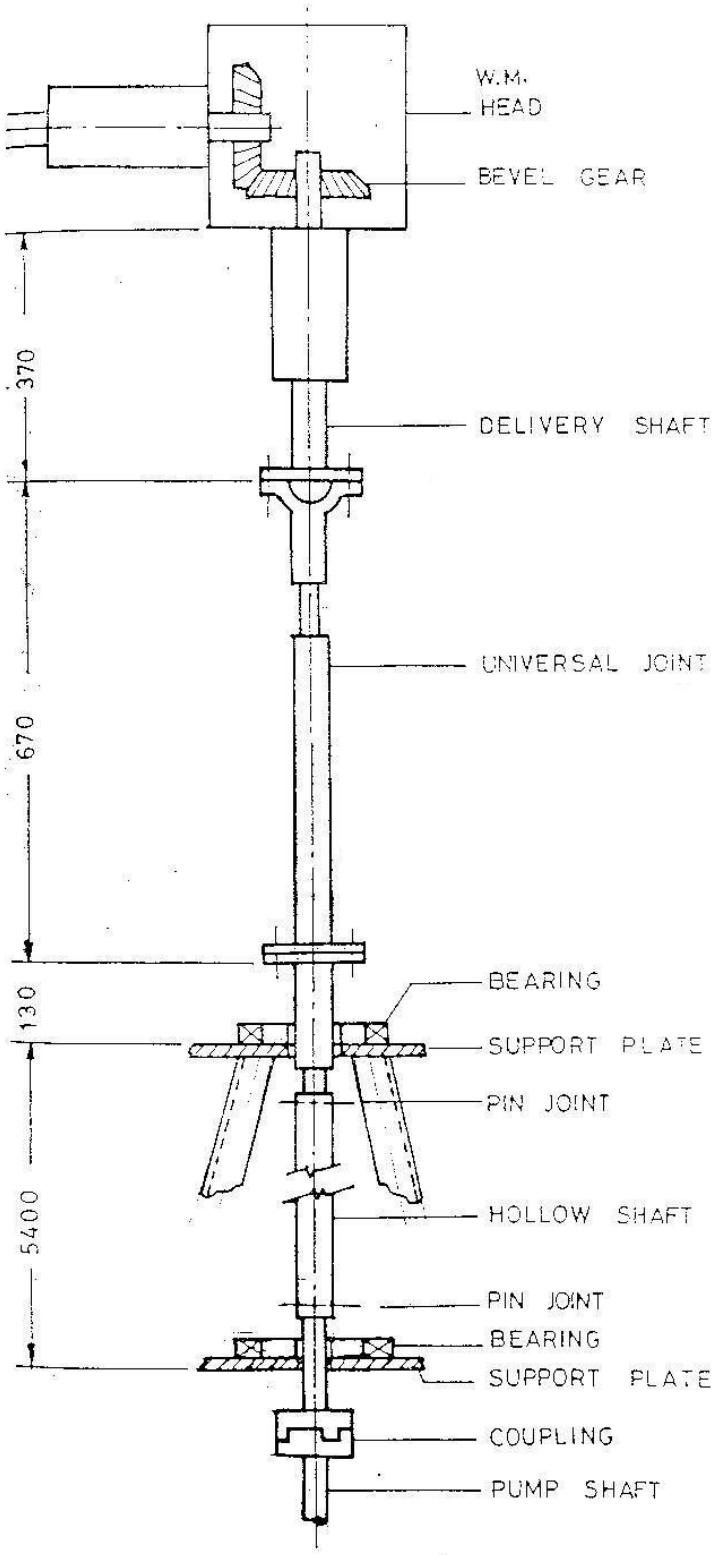


FIG. 3.2 **TRANSMISSION SYSTEM OF WATERPUMPING WINDMILL**

Source : SICO Ltd., Ghaziabad

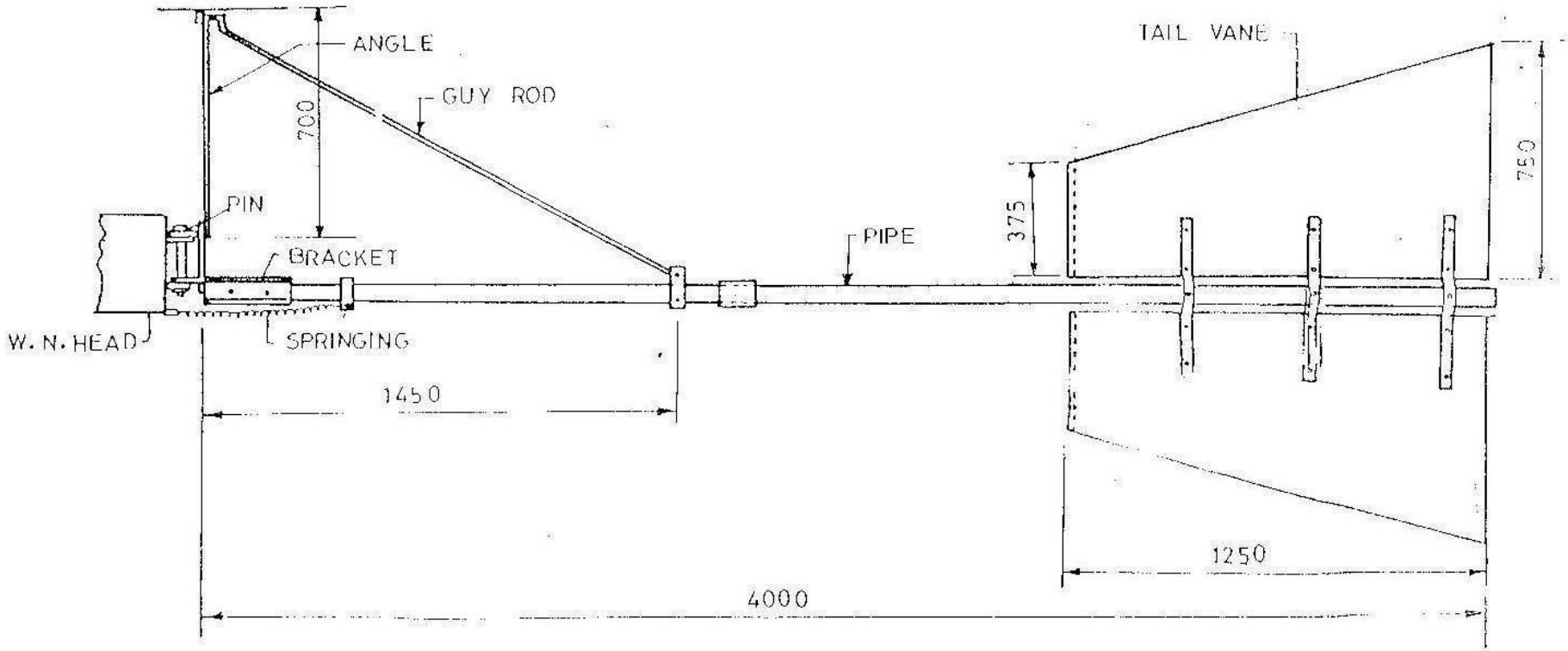


FIG. 3.3 TAIL VANE ASSEMBLY

(Source: SICO Ltd. Ghaziabad)

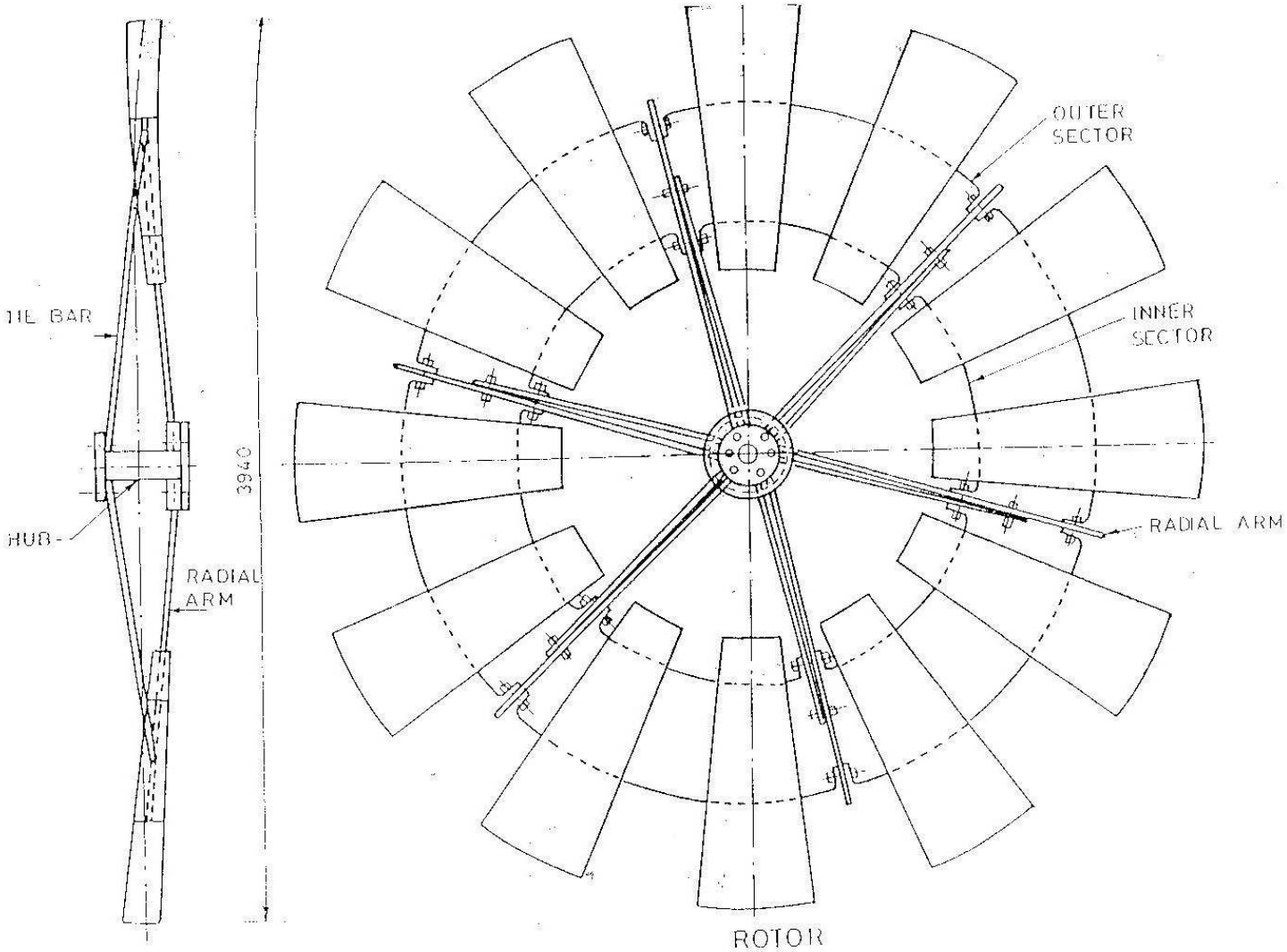
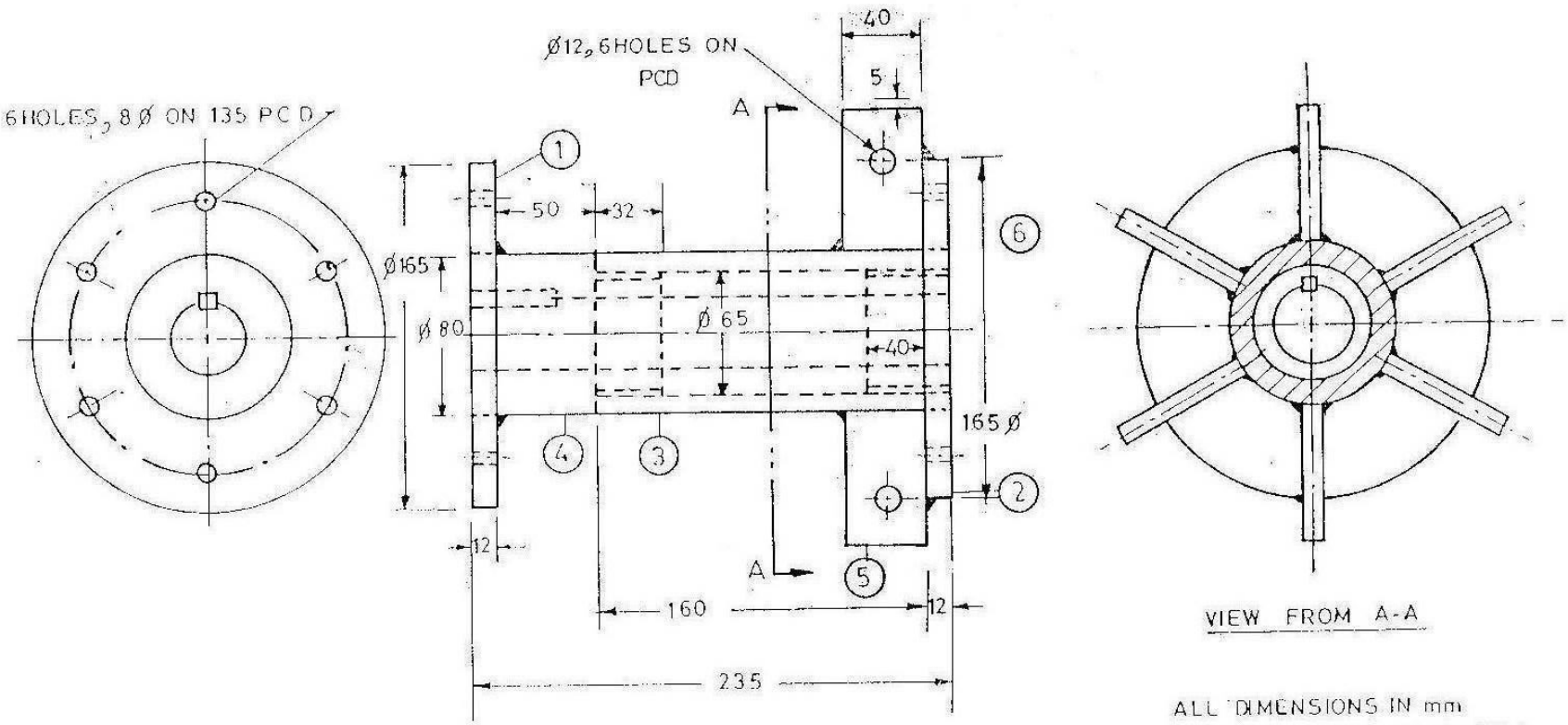


Fig. 3.4 Rotor of Water Pumping Windmill

(Source: SICO Ltd. Ghaziabad)

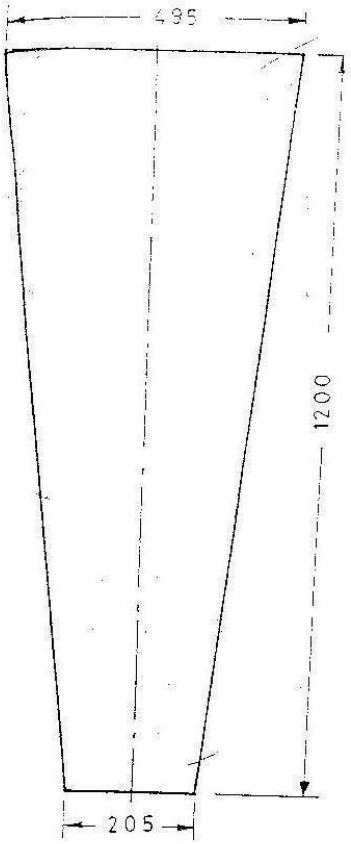


ALL DIMENSIONS IN mm

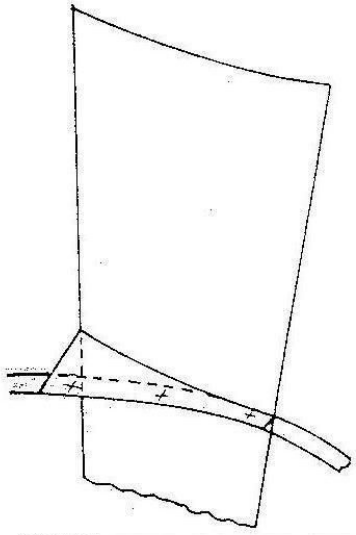
1	FRONT END PLATE	1
2	BACK END PLATE	1
3	PIPE	1
4	HUB	1
5	GUSSET	1
6	SLEEVE	1

Fig. 3.5 HUB DETAILS

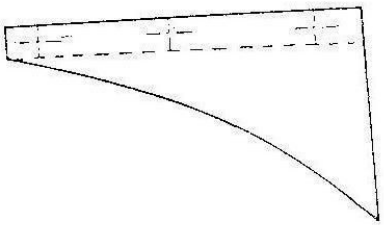
(Source: SICO Ltd. Ghaziabad)



BLADE SHAPE



BLADE



BLADE PROFILE SUPPORT

Fig. 3.6 BLADE WITH PROFILE SUPPORT
(Source: SICO Ltd. Ghaziabad)

Function phase is considered as the heart of Value Engineering. The entire Job plan revolves around it. Infact this is the phase that makes Value Engineering differ from other cost reduction techniques. The product functions are objectives to be achieved at minimum cost.

The term "Function" is defined as, in this systematic approach," that which makes a product work and sell, or sell only".

Value Engineering/Analysis is the function oriented, which examines the cost of the function –of which machining or assembling are a part. It is by no means simply a search for new materials and processes i.e. a search upon which magnifies concerns and engineering laboratories are constantly engaged. It brings new information into its discussion from areas within the company and from specialist supplier outside. The coordination of this new information allows function to be accomplished at lower cost by channeling the right decision. So value analysis is that the functions, and the cost of the function, are examined, Instead of the component or process with its appropriate cost with the help of a VE team's systematic job plan approach.

This functional approach comprises two distinct yet interdependent techniques. These are follows.

1. DEFINE THE FUNCTIONS.
2. EVALUATE FUNCTIONAL RELATIONSHIP.

After defining the functions should be evaluated to decide their relative importance and to identify primary function. For this a Numerical Evaluation method is

used. To understand relationship among various functions, a FAST diagram is also constructed. Then a Function Cost Matrix is prepared to find the % cost for accomplishing each function. The matrix provided the valuable aid for identifying the poor values which will be taken up for further study in the next phase.

4.1 DEFINE THE FUNCTIONS

The functions of all the parts are defined in two words and the primary and Secondary functions at part level are identified. To define functions clearly in this technique, certain basic established rules are used from which deviation is not possible to avoid any ambiguity or confusion. These rules apply to both the work and the sell functions.

Rule 1: All the functions must be defined in two words a verb and a noun without any ambiguity.

Rule 2: Expression of work and sell functions uses different category of Verbs and Nouns

a) Work functions are usually expressed in action verbs and measurable nouns which establish quantitative statements.

b) Sell functions are expressed in passive voice and non measurable nouns which establish qualitative statements.

Rule 3: All functions can be divided into two levels of importance, *Primary* and *Secondary.*

a) Primary Function: The primary purpose for a product or service.
b) Secondary Function: Other purposed not directly accomplishing the primary purpose but supporting it or resulting from a specific design approach.

Table 4.1

Company: Scientific Instruments Co. Ltd. Ghaziabad
Project: VA of Water Pumping Windmill

FUNCTIONAL DEFINITION WORKSHEET

S.No.	Part Name	Qty	Function Definition		Function Level	
					Part level	
			Verb	Noun	PF	SF
(A)	**ROTOR**					
1	Rotor Blades	18	Transmit	Energy		✓
			Provide	Torque	✓	
			Change	Motion		✓
			Withstand	Impact		✓
			Provide	Shape		✓
			Facilitate	Motion		✓
			Provide	Solidity		✓
2	Tie Bars	6	Provide	Support	✓	
			Withstand	Impact		✓
3.	Radial Arms	6	Provide	Support	✓	
			Withstand	Impact		✓
4.	Sectors	6	Provide	Support		✓
			Withstand	Impact	✓	
			Prevent	Bending		✓
5.	Hub	1	Provide	Support	✓	
			Transmit	Motion		✓
6.	Shaft	1	Transmit	Motion	✓	
			Change	Motion		✓
(B)	**TAILVANE**					
7.	Vanes	2	Help	Steering	✓	
			Guide	Movement		✓
8.	Support Tube & Pin	1	Join	Parts	✓	
			Help	Steering		✓
9.	Tie Rod	1	Provide	Support	✓	
			Withstand	Impact		✓
10.	Spring	1	Provide	Force	✓	
			Provide	Stiffness		✓
			Facilitate	Furling		✓
(C)	**WINDMILL HEAD**					
11.	Housing Box	1	Provide	Support		✓
			Provide	Housing	✓	
			Locate	Parts		✓
			Provide	Location		✓
			Provide	Protection		✓
			Provide	Appearance		✓

12.	Gears	1 set	Transmit	Motion	✓	
			Change	Motion		✓
13.	Bearing-I	2	Provide	Support		✓
			Facilitate	Motion	✓	
			Permit	Retention		✓
			Withstand	Impact		✓
			Transmit	Load		✓
14.	Turn Table Plates	1	Provide	Support		✓
			Provide	Retention	✓	
15.	Bearing Balls		Withstand	Impact		✓
			Take	Load	✓	
(D)	**TRANSMISSION SYSTEM**					
16.	Shafting	1	Transmit	Motion	✓	
			Change	Motion		✓
17.	Universal Joint	1	Prevent	Misalignment	✓	
18.	Coupling	1	Joint	Parts	✓	
			Transmit	Torque		✓
19.	Bearing-II	4	Facilitate	Motion	✓	
			Provide	Support		✓
			Permit	Retention		✓
			Withstand	Impact		✓
20.	Flange	1	Joint	Parts	✓	
			Facilitate	Mounting		✓
(E)	**PUMP**					
21.	Pump	1	Provide	Pumping		✓
			Convert	Energy	✓	
			Direct	Flow		✓
			Regulate	Flow		✓
22.	Pump Support	1	Provide	Support	✓	
23.	Piping	1	Direct	Flow	✓	
			Allow	Pumping		✓
			Join	Parts		✓
			Establish	Connection		✓
(F)	**SUPPORTING STRUCTURE**					
24.	Tower	1	Provide	Support	✓	
			Allow	Maintenance		✓
			Withstand	Impact		✓
			Transmit	Load		✓
25.	Working Platform & Ladder	1	Provide	Maintenance	✓	

4.2 FAST DIAGRAM

This is known as **Functional Analysis System Technique**. Its main purpose is to analyze the functions – Primary and Secondary of a system for the purpose of application of value analysis technique. In this various functions performed by various parts or components are listed down by using verb and noun technique. We select a basic function which would be performing as the main function of the assembly. After that logic questions are asked to determine functions in terms of WHY? and HOW? logic to analyze these functions. Once all listed functions are covered then this process is put into blocks and process continued till interface function is reached Now whatever are the remaining unused functions from amongst the list of functions are the supporting functions. These are now placed on FAST diagram by applying the logic question WHEN? If, even then few functions are left these are the functions known as All Time Functions. At this stage when all the functions are filled up and used up the FAST diagram is finalized.

In order to limit the FAST diagram to a specific problem area, the scope of the problem is identified in the FAST diagram by means of two vertical dotted lines called scope lines. The left scope line is placed between the basic function under consideration and higher order basic function and the right scope line is drawn to the left of the function that is an acceptable interface to the product or service under consideration which is suitable input to the system.

In the project, the Fast Diagram is started by choosing the function “Convert Energy”. Now asking “How” Logic question –

How do we convert energy? The answer is by “Transmit motion”.

How do we Transmit motion? The answer is by “Facilitate motion”.

How do we facilitate motion? The answer is by “Locate parts”.

How do we locate parts? The answer is by “facilitate Housing”.

How do we facilitate housing? The answer is by “Permit retention”.

How do we permit retention? The answer is by “Provide support”.

How do we provide support? This logic series end here with answer as Procuring/Providing bearings, Tie bars, Radial arms, sectors, bracket, Hub, Tower, which are input of the system.

Now “WHEN?”logic is to be questioned on all the above functions in the blocks. Then continue by applying “How” and “why” logic to reach up to system inputs.

When do we ”Transmit” motion? with answer as “provide torque”. How do we provide Torque? The answer is by “change motion”.

How do we change motion? The answer is by providing Rotor Blades , shafts, gears, which are another input to system.

Similarly “When” logic question asked on “Provide Torque”which answers to “Provide pumping “.From here again “How” series starts. How do we “provide pumping” with answer as “Directing Flow”. How do we “direct flow”- This logic series ends here with answer as “Provide pump, pipings” is another input to system.

Similarly “when” logic question asked on the “Facilitate Motion” which answers to “Guide movement / Help Steering”.

How do we Help Steering? by “providing Force”.

How do we provide Force? by procuring tail vane, spring which are input to system.

Similarly “when” logic question asked on the “Locate parts” which answers to “Prevent misalignment”.

How do we prevent misalignment? By providing universal joint which is input to system.

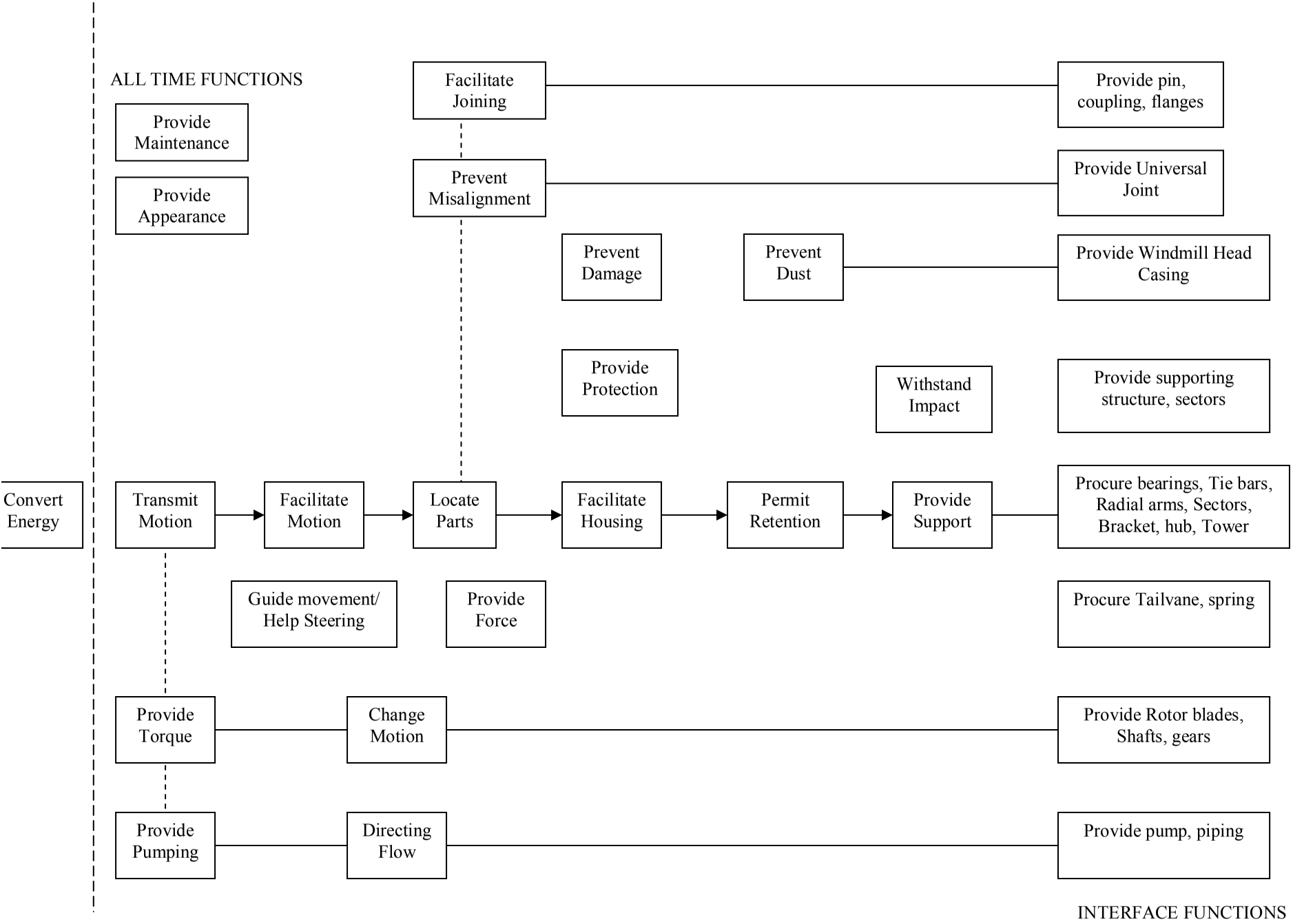
When do we prevent misalignment? Which answers to “Facilitate Joining.”

How do we facilitate joining? This logic series ends here with answer as by providing pins, couplings, flanges which are another input to system.

The “facilitate Housing” series leads to another input by “providing windmill Head casing” and “provide support” series ends with providing supporting structure, sectors which are inputs to the system.

The scope of study is shown between two vertical dotted lines with the left scope line between the function “convert energy” and “transmit motion” with “transmit motion” as the basic function of the windmill assembly. The right scope line is placed between different functions and the parts that are needed to procure in order to provide that function.

FIG. 4.1 FUNCTIONAL ANALYSIS SYSTEM TECHNIQUE (FAST) DIAGRAM OF GEARED TYPE WATER PUMPING WIND MILL



4.3 EVALUATE FUNCTIONAL RELATIONSHIP

A precise functional balance is that makes a product work and / or sells most effectively at the lowest cost. This balance determined only through a comparative process pair wise, which in turn leads to perpetual evaluation. To attain this balance, first to have an understanding of the relationship between all functions is must in terms of their importance. The purpose of this technique is to determine that relationship.

Once all the functions are defined in terms of Verb and Noun, these functions are listed in Functional Definition Worksheet as in Table 4.1 Their level as primary and secondary at their own particular part level is established. By this technique, compare and evaluates these defined functions and determine interrelationship and order of their relative importance to the whole. The establishment of this order of importance and these interrelationships coupled with the derived numerical value for the importance of each function makes it possible to study the results and draw specific conclusions on the problem's complexity.

This method for the numerical evaluation of functional relationship is capable of determining the primary function of the product under study as well as determining the descending order of importance of secondary functions. Equally important, it provides with a means of separating those function, which are in the product because of specifications and requirements and those that are there because of the present or earlier approach design. There are two methods for evaluating functions

1. Numerical Evaluation.
2. Function Rating Grid.

4.3.1 Selection of functions for the Creativity Phase: For selecting functions there are two approaches.

Approach I:

This approach is based on concept of Function Cost Matrix (FCM). All the functions are arranged in the descending order. Then compare % weight, % cost. We have to find out mismatch between % Cost and % weight. Find out the functions which exists poor value of function. Value Improvement Potential Index (VIP) defined as

$$VIP = \% \text{ Cost} / \% \text{ Weight}$$

If VIP >1, these functions are selected for creativity phase. This approach is refined by considering functional cost. For the selected functions we will do VA in other phases. Local improvement in design with respect to poor value and high cost functions and minor changes will take place and basic design approach is not changed Therefore savings obtained may not be significant. But this approach is easier to apply (We will be taking one function at a time),hence preferred in case of large and complex projects.

Approach II:

In this approach the functions which are taken up for subsequent phases are the one due to specifications and requirements of the customer i.e. primary function and Secondary function (Level 1).

We make a design which satisfies all the customer required functions at minimum cost by taking all the functions at the same time. It is very difficult to apply, because it requires lot of intelligence, patience, skill and understanding. So it is applied in small and simple projects. Here the customer designed functions not changed. This approach major change in design. This approach is sub sequential savings in cost.

Reasons for following Approach I for this Project

The product selected for value analysis is complex and available time and resources are less. The company doesn't want to have the major changes in the design because their customers/Ministry are satisfying with the present design. So we are following Approach I.

4.4 Numerical Evaluation of Functional Relationship

In this technique the basic function of each part of the item being identified and assigned a key letter. This key letter is used throughout the succeeding comparisons and evaluations of the functions. Each function is compared width all other functions only once and the difference in importance of the functions and signified by weight factors, 1,2 or3 where 1 denotes a minor difference in importance, 2 a medium, and 3 shows a major difference of importance.

When function A has been compared and evaluated with function B and the key letter of the more important function has been noted, with its weight factor in the corresponding cell. This procedure is repeated with the remaining functions listed in the

evaluation summary. After filling up the cells, the weightage points of each function are obtained by adding up all the numerical figures following the corresponding letter both horizontally and vertically. Then adjusted weights are calculated by adding 1 in the total weight factor. Now % importance is calculated for each function by dividing its adjusted weight with the total of adjusted weight. The total weightage scores indicating functional importance are shown in Evaluation Summary.

The functions having maximum weightage is the basic function of the assembly. List all the functions in their descending order of importance, retaining with them their weight factor totals. With the data from Evaluation Summary, a graph is drawn between functions and % weight factors.

To find out whether the Numerical Evaluation is correct or to reduce the biased ness in comparing the functions, some checks of consistency are to be carried out and found them satisfactory-

1. The Pattern of graph should confirm the basic shape of the graph.
2. The Primary Function and SF-I should be compared with customer requirements.
3. The weight factor of one of the function must be zero.
4. There should be no loop formation.
5. No two functions should have identical weight.

Table 4.2 NUMERICAL EVALUATION OF FUNCTION

A	B	C	D	E	F	G	H	I	J	K	L	M	TOTAL WT.
A	A-2	A-3	D-1	A-2	A-3	A-3	A-3	A-2	A-3	A-3	A-1	A-3	28
	B	B-2	D-3	B-2	B-2	B-2	B-2	I-2	B-3	B-2	L-3	B-3	18
		C	D-3	E-2	C-2	C-2	C-3	I-3	C-1	C-1	L-3	C-3	12
			D	D-3	D-3	D-3	D-3	D-1	D-3	D-3	D-1	D-3	30
				E	E-1	E-1	E-3	I-2	E-2	E-2	L-1	E-3	14
					F	G-2	F-3	I-3	F-1	F-2	L-3	F-2	8
						G	G-3	I-3	G-2	G-2	L-3	G-2	11
							H	I-3	H-2	K-1	L-3	H-2	4
								I	I-3	I-3	L-1	I-3	25
									J	K-2	L-3	J-2	2
										K	L-3	K-2	5
											L	L-3	26
												M	0

LETTER	FUNCTION	LETTER	FUNCTION
A	Change Motion	H	Provide Housing
B	Provide Support	I	Facilitate Motion
C	Withstand Impact	J	Permit Retention
D	Transmit Motion	K	Prevent Misalignment
E	Help Steering	L	Convert Energy
F	Join Parts	M	Provide Maintenance
G	Provide Force		

Functional Importance (Weights)

1→ Minor difference

2→ Medium difference

3→ Major difference in the importance

Table 4.3 EVALUATION SUMMARY

KEY LETTER	FUNCTION	WEIGHT	ADJ. WEIGHT	% WEIGHT
D	Transmit Motion	30	31	15.81
A	Chain Motion	28	29	14.79
L	Convert Energy	26	27	13.77
I	Facilitate Motion	25	26	13.26
B	Provide Support	18	19	9.69
E	Help Steering	14	15	7.65
C	Withstand Impact	12	13	6.63
G	Provide Force	11	12	6.12
F	Join Parts	8	9	4.59
K	Prevent Misalignment	5	6	3.06
H	Provide Housing	4	5	2.55
J	Permit Retention	2	3	1.53
M	Provide Maintenance	0	1	0.003

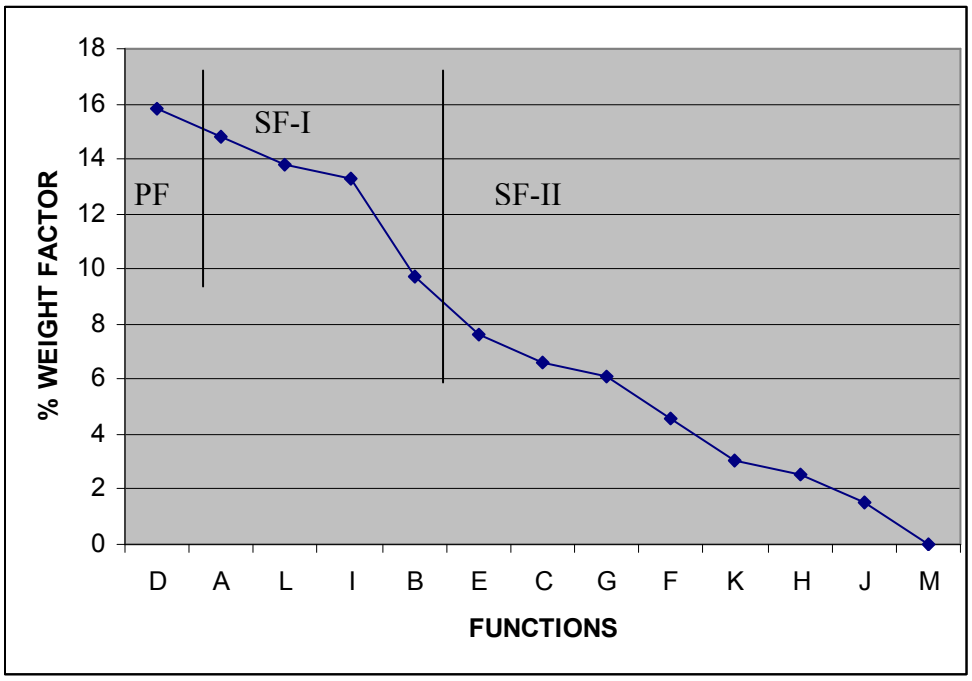


Figure 4.2 GRAPH OF NUMERICAL EVALUATIONS OF FUNCTIONS

In this project 13 key letters A to M are used to denote various functions and the numerical evaluation is carried out which is shown in Table 4.2. The weights are listed in evaluation summary from numerical evaluation. The adjusted weights and the % weights are shown in the Evaluation summary in the Table 4.3, in descending order of importance. Using the data a graph is drawn between Percentages of weight factors v/s key letters of function which is shown in figure 4.2. In this case the primary function is at highest level and after that is the first drop. After functions “change motion”, “convert Energy ”, “Facilitate Motion” and “Provide Support” these are secondary functions in the project to meet the customer’s specifications and requirements. Functions after second drop are secondary functions, which are in the project because of the present design approach.

4.5 Function-Cost Matrix

The FCM is another important quantitative tool to give the information about the percentage cost for accomplishing each function. In this all the functions are listed in the FCM along with their total cost and quantity. The cost of each part is allocated to functions to which it contributes –where one component interacts with several functions.

The total cost of each function is at the bottom of each column. The cost is allocated for the part name “Rotor Blades”, it contributes to the functions “change motion ”, “Facilitate Motion” and “Convert Energy . Cost is assigned to these functions in proportions to their importance. So let it be Rs.3500, 1000 and Rs.3500 respectively.

Table 4.4 FUNCTION COST MATRIX

part name	qty	cost	A	B	C	D	E	F	G	H	I	J	K	L	M
(A) Rotor															
BLADES	18	8000	3500								1000			3500	
TIE BARS	6	600		384	216										
RADIAL ARMS	6	900		517	383										
SECTORS	6	1700		1000	700										
HUB	1	1260		260		1000									
SHAFT	1	900				900									
(B) Tailvane Assembly															
VANES	2	800					800								
SUPPORT TUBE & PIN	1	1600					1100	500							
TIE ROD	1	400		300	100										
SPRING	1	400					267		133						
(C) Windmill Head															
HOUSING BOX	1	5000		2000						3000					
GEARS	1 set	2000				2000									
BEARINGS-I	2	1500		250	250						900	100			
TURN TABLE PLATES	1	1120		800								320			
BEARING BALLS		620		400	220										
(D) transmission system															
SHAFTING	1	2400				2400									
UNIVERSAL J.	1	2800						200					2600		
BEARINGS-II	4	1300		350	175						775				
COUPLINGS	1	500						500							
FLANGES	1	900						900							
TRUING PLATE	1	900		750	150										
(E) pump															
PUMP	1	5000												5000	
SUPPORT	1	1380		975	405										
PIPING	1	2500						2500							
(F) Structure															
TOWER	1	30000		21000	9000										
WORKING	1	5520													5520
PLATFORM & LADDER															
TOTAL COST		**80000**	**3500**	**28986**	**11599**	**6300**	**2167**	**4600**	**133**	**3000**	**1675**	**420**	**2600**	**8500**	**5520**

A. Change Motion
B. Provide Support
C. Withstand Impact
D. Transmit Motion
E. Help Steering
F. Join Parts
G. Provide Force
H. Provide Housing
I. Facilitate Motion
J. Permit Retention
K. Prevent Misalignment
L. Convert Energy
M. Provide Maintenance

4.6 Value Improvement Potential Index

After calculating cost of each function, % cost of each function is calculated. When this % cost of each function is divided by its corresponding % importance (Weight Factor), it will give us the Value Improvement Potential Index (VIP) for each function.

If VIP Index is more than "1' then that function will indicate it as a "poor value/High Cost (PV/HC) " .It means for providing that function we are spending more cost. These PV/HC functions are taken up in the Creative Phase to generate new ideas and for development of alternatives for the cost reduction with out compromising the quality of function.

The Function Cost Matrix is shown in the Table 4.4. The functions along with their key letters, % cost, % weight factor and their VIP index are shown in the Table 4.5.

Table 4.5 FUNCTION COST WEIGHT MATRIX

FUNCTION	COST	% COST	% WEIGHT	VIP INDEX	REMARKS
B	28,986	36.23	9.69	3.738	PV/HC
C	11,599	14.49	6.63	2.185	PV/HC
L	8,500	10.625	13.77	0.771	
D	6,300	7.87	15.81	0.497	
M	5,520	6.9	0.003	-	PV
F	4,600	5.75	4.59	1.252	PV/HC
A	3,500	4.37	14.79	0.295	
H	3,000	3.75	2.55	1.470	PV/HC
K	2,600	3.25	3.06	1.062	PV/HC
E	2,167	2.7	7.65	0.352	
I	1,675	2.09	13.26	0.157	
J	420	0.525	1.53	0.343	
G	133	0.166	6.12	0.027	

THE FUNCTIONS SELECTED FOR CREATIVITY PHASE ARE

(1)	Provide Support	B	(4)	Provide Housing	H
(2)	Withstand impact	C	(5)	prevent misalignment	K
(3)	Join Parts	F	(6)	Provide Maintenance	M

Creativity phase is the one that produces as many as possible alternatives through imagination and creativity. Once the value study determines the poor value functions, creativity process begins. In this segment of study, the emphasis is on creating a large numbers of ideas. The most common technique most Value specialist use for creativity is "focused brainstorming". But we don't stop there. To generate the maximum quantity of ideas for the Evaluation Phase, we usually add a modified affinity techniques. Three techniques are used within it: innovation, improvement and avoidance.

Till now the product has been considered in its original form. Nothing has been done on the product to improve quality or reduce cost as per the customer's specifications and requirements. But in this phase we will think about all the possible changes that can be made in the product without any kind of judgments so as to improve the Value of the product.

This phase encompasses the following techniques:

1. Establish Positive Thinking.
2. Develop Creative Ideas.

5.1 ESTABLISH POSITIVE THINKING

"*The mind is like a parachute------- it works only when it's open!"*

Establishing the positive thinking is must to develop creativity. It helps to develop a state of mind in which one can think positively through open mind and develop number of

ideas to achieve required function. These are direct opposite of the judicial thinking arising from poor habits and negative attitudes.

To develop creativity, it deals with the following essential requirements:

1. Constant use of creativity.
2. Principle of deferred judgment – set aside the judicial thinking.
3. Overcome mental blocks to creativity. These are –
    a. perceptual blocks:- it is failure or inefficiency of sensing of body.
    b. Emotional blocks:- it is as fear of consequences.
    c. Cultural blocks:- it is the result of confirming to what normally accepted in the society.
    d. Habitual blocks:- it is normally by the development of a way of working, thinking etc and doesn't want to change
4. Detach from the existing solutions:- one should concentrate to the functions not on the existing design or solutions.
5. Understanding of problem relevance:- usefulness of idea depends upon level of understanding the problem by them. Problem should be presented clearly with all facts and figures.
6. Scope of creative work depends on ones mental reservoir of knowledge.
7. Complete conviction or confidence:- one should have firm belief that something new and better can be developed as existing design is of poor value and lead to discontent.

8. Human mind contains knowledge and to be creative, one must have capability to recall the habits of knowledge from ones memory and join these to get new ideas.

9. Stimulation:- To motivate /stimulate thinking of people to generate ideas, idea activators are to be used. These can take the form of checklists, which may consists of direct or indirect questions to be asked about the problem under study. These are classified as:-

a. Idea Needlers:- Why does it have this shape?
What if this were larger? Wider? Thicker?
What other materials would do this job?
How do competitors solve problem similar to this?
Could vendor supply this for less?

b. Idea Simulators:- Can the dimensions be changed?
Can the form or material be changed?
How the weight can be reduced without reducing strength?
What else can be done?

And we can use rules of creativity: Rule 24, Rule 25 and rule26 must be followed to generate new ideas i.e. think over problem for all 24hours, try to develop at least 25 ideas for each function and use 26 letters of alphabet when you encounter mental blockade.

5.2 DEVELOP CREATIVE IDEAS

The scope of VE team's creative work depends on member's knowledge, constantly engaged in its development by study, observation, and experiment. Therefore be capable of self-instruction and maintain enthusiasm, devotion and passion. To develop creative ideas, team members can use any of the creative thinking techniques viz. Brainstorming, Gordon technique under free association techniques, checklist technique etc.,but mostly used technique is Brainstorming and it is used in this project.

5.2.1 Brainstorming is the most common technique for the generation of alternative ideas. There are three basic types of brainstorming techniques: random or freewheeling, round robin and associative or function focused. Many facilitators will combine these techniques during the VE analysis. The basic rules of brainstorming section:

1. All ideas are recorded, no matter how silly the idea may seem.
2. No criticism is permitted during the brainstorming session. Any criticism will quickly " kill" the creativity process.
3. Combining several ideas into one concept is encouraged. This banking of ideas usually gives a significant concept.
4. Team members are encouraged to jot the ideas down on a note pad as they review the design information in preparation for the VE report.
5. Quantity of ideas is most important at this stage of analysis. Quality will be addressed as part of the idea evaluation process.
6. Using another idea to generate a second concept is encouraged.
7. The brainstorming lists are never closed to the addition of new alternative ideas.

The brainstorming ideas can be collected for the entire design or specific elements of the design.

5.2.2 Free wheeling: This is the quickest way to collect ideas. Team members are encouraged to "free-wheel" and shout out their ideas as they are found. All the ideas are recorded by the facilitator in order as best as possible. There are two drawbacks to this approach. Some team members may not participate, letting the more vocal members of the VE team put forth their ideas. Several ideas may be fired simultaneously, which may cause garbling of the stated concept.

5.2.3 Round Robin: The approach is somewhat slower than random brainstorming. Each team, in turn, is asked to put forward their individual ideas. The facilitator will call on each team member, working around the assembled team in sequential order to ensure that no member is missed. The facilitator will cycle through the VE team at least twice during the brainstorming. The disadvantage with this approach is idea collection is slower. However, this approach will call on the more introverted team members to ensure their participation in alternative ideas generation. The round-robin approach is frequently used in facilitators to ensure that as many alternative ideas as possible have been harvested when the random idea generation efforts have stalled.

5.2.4 Associate or Function Focused: Associate brainstorming is more focused than random brainstorming. Ideas are sought for specific elements, functions selected by the VE team, that have the highest potential for cost savings opportunities ideas are then collected either randomly through free-wheeling or systematically through round-robin generation.

Alternative ideas for the poor value functions are developed in discussion with the team members are shown in the Creative Worksheets.

CREATIVE WORKSHEET NO.1

Function : Provide support

Parts considered : Tie bars, Radial arms, Sectors, Hub, Bearings, Bracket, Tower.

Creative Ideas :

1. Change the material of the supporting structure.
2. Change the material of the Hub
3. Change the design of the Channel
4. Reduce the height of the Channel.
5. Make the Tie Bars and Radial arms hollow
6. Use of carbon fibre blades.
7. Use of gun metal bracket.
8. Use of centrifugal casting for Hub

CREATIVE WORKSHEET NO. 2

Function : withstand impact

Parts considered : Tie bars, sectors, bearing, tower

Creative ideas:

1. Reduce the no. of sectors.
2. Use of ball bearings instead of Roller bearings.

3. Change the supplier from SKF to NBC Bearings.

4. Use of standard bearings available in market.

5. Change the material of the bearing parts.

6. Plastic bearings can be used.

CREATIVE WORKSHEET NO. 3

Function : Join parts

Parts considered : Pins, couplings, flanges, Universal J., spring

Creative ideas:

1. Use of case hardened low carbon steel for pin material

2. Use of standard couplings.

3. Use of spring steel instead of high C. Steel for spring material

4. Provide splined shaft for coupling

CREATIVE WORKSHEET NO.4

Function : Provide Housing

Parts considered : Housing box

Creative Ideas :

1. Use of casted housing box.

2. Use of Triangular shaped housing box, trapezoidal or aerodynamic shape.

3. Change the material of housing box.

4. Change the design of housing box.

5. Use of AI housing.

CREATIVE WORKSHEET NO.5

Function : Prevent misalignment

Parts considered : Universal Joint

Creative ideas :

1. Reduce the length of Universal Joint.

2. Change the material of Universal Joint.

CREATIVE WORKSHEET NO.6

Function : Provide Maintenance

Parts considered : Working platform, steel ladder

Creative ideas :

1. Use of bamboo base in platform

2. Use of bamboo ladder

3. Selected periodic maintenance.

CHAPTER 6 EVALUATION PHASE

The key to growth is in increasing value, and the key to increasing value is essentially one of good evaluation.

Function and functional approach in this phase, as well as in previous phases, is the guiding force which leads us to low-cost alternatives. The objective of this phase is to analyze the ideas developed in creativity phase with careful appraisal and creative judgments.

We should try to make each idea workable and progressively eliminate those ideas which work against specified requirements of the component. All the ideas developed on each required functions are subject to systematic appraisal and creative judgment to delete the infeasible and uneconomical alternatives. Some ideas are to be refined and combined to generate more workable solutions. In this process of making the idea workable, we must make sure that the product is not cheapened or degraded.

In order to guard against these possibilities, this phase employs following techniques to develop, or combine and develop alternatives that work.

1. Refine and Combine Ideas.
2. Establish Cost on all Ideas.
3. Develop Function Alternatives.
4. Evaluated by Comparison

This phase all these four techniques are employed almost simultaneously in the development process. However, before going into study of these combined application each technique discussed individually.

6.1 Develop Functional Alternatives

Ideas generated in the Creativity phase are subjected to refinement and combination of ideas. When a single idea appears to be unusable in its present form, a combination with other ideas should be sought to make usable. For this purpose ideas/functions can be rated in the following manner:-

'A' means Acceptable idea. ; 'AD' means acceptable with Development.

'U' means Unacceptable idea ; 'NF' not feasible now.

'FD' Require future development ; 'R' means Rejected Idea

After rating the ideas, appraisal of ideas is carried out on the basis of estimating the cost of idea. High cost ideas, more than the present cost are deleted and low cost ideas are accepted and taken up for the next technique. The low cost selected for various functions are combined together judiciously and intelligently into a number of workable solutions. This starts the elimination of unnecessary cost and development of valuable alternatives at low cost.

In Evaluation by Comparison technique developed workable solutions or alternatives are compared on the basis of cost functional performance, reliability, maintainability, advantages-disadvantages etc. like attributes. For comparison purpose, Decision Matrix method is used to find performance score of each workable solution. Then this performance score of each workable solution is compared to select the cost and performance effective workable solutions. At the end selected some best alternatives are taken up for final development in the Investigation phase.

Now after finalizing the ideas and the costs of the accepted ideas, the entire summary is shown under various Functional Development Worksheets.

In case of water pumping windmill, following specifications must be met:-

1. Bearings should be withstood for static and dynamic loads such a thrust and radial loads.
2. The economic life of bearings should be minimum 40 million operating cycles.
3. The bearing housing should be accurately bored to ensure perfect shaft alignment.
4. Casting should be defect less and good material properties in grain formation.
5. There should be very less friction in the bearings during the rotation of the Rotor and the shaft.
6. The material of the Tower and Blades should be corrosion resistant.
7. Should have easy operation
8. Should have minimum maintenance i.e. should not require frequent repair/replacements.
9. Low initial or total cost
10. Ease of installation at site
11. Rotor assembly should be able to withstand wind impact loads.
12. Pump should provide adequate discharge rate at known heads.

Functional Development Worksheet No.1

Function : Provide support

Parts considered : Tie Bars, Radial arms, sectors, Hub, Housing Box, Bearing, Bracket, Tower

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Material change of supporting structure/channel	FD	-
2.	Reduce the height of the channel from existing	A	Rs.26,500
3.	Change the material of Hub	R	-
4.	Change the design of the channel	FD	-
5.	Use of Hollow Tie Bars and Radial arms	A	Rs.1200
6.	Use of carbon fibre blades	R	-
7.	Centrifugal casting for Hub part	A	Rs.1690

For this function 'provide support', the idea of changing material of supporting Tower looks to be feasible but no other alternative found suitable regarding cost and anti corrosion properties, so it requires further development. The idea of reducing the height of channel is accepted, as the standard height for water pumping applications is around 8 to 10 m and we are reducing height from 9.5m to 8.5m thereby saving the material. The idea of using another material for Hub is unacceptable because presently company using Medium C. Steel, that is having good fatigue life. The idea of design change of channel requires future development if possible, because with present design having taken all stress factors into account no failure of windmill takes place in past. The idea of using Hollow tie bars and radial arms is accepted as it saves the material but we have to increase strength accordingly. The idea of using carbon fibre blades is unacceptable, as they are highly economic and less weight and will not provide enough torque for water pumping applications. The idea of using centrifugal casting instead of sand casting for

Hub is accepted because centrifugal casting process is defect free tight grain structure and vendor is having this facility also.

Functional Development Worksheet No.2

Function : Withstand impact

Parts considered : Tie Bars, sectors, Bearing, Tower

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Reduce the No. of sectors	AD	-
2.	Use Ball bearings instead of Roller bearings	R	-
3.	Change the vendor of Bearing	A	Rs.3120
4.	Use of Standard bearings	NF	-
5.	Use of plastic bearing	R	-

For this function 'withstand impact', the idea of reducing the no. of sectors is looked to be acceptable but it should be verified against the stability of Rotor and design consideration of Rotor. The idea of using ball bearings instead of roller bearings is unacceptable because the ball bearings thrust capacity is less than roller bearings. The next idea changing vendor is acceptable because the cost of bearings the latter one is providing in less than for the same standard bearings. Using plastic bearings is dropped because plastic bearings are not designed for heavy loads, moreover plastic bearings are not that much widely used and also processing plastic bearings is also not that easy.

Functional Development Worksheet No.3

Function : Join parts

Parts considered : Support Tube & Pin, couplings, flanges, U.J., springs

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Use of case hardened Low C. steel for pin	A	Rs.310
2.	Use of medium C. steel spring	A	Rs.345
3.	Use of standard coupling	NF	-
4.	Provide splined shaft for coupling	R	-

For the function 'join parts', idea using case hardened low C. steel instead of stainless steel for pin material is acceptable as they are good wear resistant, toughness and shear strength values comparable to stainless steel. The next idea, changing spring material from High C. steel to spring steel is acceptable as they are low allow medium C. steel with very high yield strength. This allows objects made of spring steels to return to their original shape despite significant bending or twisting. The idea of using splined shaft for coupling is rejected because slight axial misalignment between transmission shaft and pump shaft causes heavy friction between mating parts causing wear and tear of coupling.

Functional Development Worksheet No.4

Function : Provide housing

Parts considered : Housing box

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Casted housing box	A	Rs.4350
2.	Change the design of housing box	A	Rs.3600
3.	Use of AI Housing	R	-

For the function 'provide housing', the idea of casted housing box is acceptable, as the casting process is cheaper, there is no need of special casting process as the function of housing box is to provide housing to gears and to support Rotor and the Tailvane. The next idea, changing the design of housing box is also acceptable and possible due to the casting process involved. We can shift from cubical to triangulated, trapezoidal or aerodynamic shape. The idea of AI housing is rejected as the Aluminium is costly and its weight is also less so it unable to withstand the load of the Rotor.

Functional Development Worksheet No.5

Function : Prevent misalignment

Parts considered : Universal Joint

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Reduce length of Universal J.	R	-
2.	Change the material of Universal J.	A	Rs.2515

For the function ‘prevent misalignment’, the idea of using stainless steel Universal J. inspite of alloy steel Universal J. is accepted as it is serving our purpose at cheaper cost. Although alloy steel Universal J. forks have induction hardened bearing areas; Body (Hubs) in annealed state, centre blocks and pins are carburized and case hardened to generate super wear characteristics, stainless steel Universal J. have comparable properties in addition to corrosion resistant, avoid premature oxidation and deterioration and exposed to environmental extremes for longer periods. Next reducing length of Universal J. is not possible as they come in standard lengths.

Functional Development Worksheet No.6

Function : Provide maintenance

Parts considered : Working platform, steel ladder

S.NO.	CREATIVE IDEA	STATUS OF IDEA	COST OF THE IDEA
1.	Use of Bamboo base in platform	A	Rs.3000
2.	Use of bamboo ladders	A	
3.	Selective periodic maintenance	R	-

For this function ‘provide maintenance’, both the ideas Bamboo platform and Bamboo ladders are acceptable as they helps in saving the material hence reducing cost.

6.2 EVALUATION OF IDEAS BY COMPARISON:

After developing various ideas and findings which are the workable ideas then we have to select best alternative among the various accepted ideas. If we have two workable

ideas for comparison then we will directly select the ideas with less cost and easy to implement. But if we have more than two workable ideas then we have to apply for judgment correctly and have to select the best idea. For this purpose "Decision matrix" will be used.

For the function 'Join Parts', the ideas are change material for pin and spring is accepted. From these two ideas, change spring material is accepted as spring steels are commonly available in market with any supplier and as some suppliers are not having heat treatment process for pin material.

For the function 'provide housing', the ideas are casted Housing box and change design of Housing Box is accepted. From these two ideas, casted housing box having cubical shape is accepted as it is easy to implement and requires no special casting process.

For the function 'withstand impact', the only idea change vendor is accepted and for the function 'Prevent misalignment' only one idea stainless steel Universal Joint is accepted. For the function 'provide maintenance' only one idea changes material is accepted.

DECISION MATRIX TECHNIQUE FOR FUNCTION 'PROVIDE SUPPORT'

Function : Provide support

Attributes

A	=	Cost	B	=	Ease of implementation
C	=	Ease of maintenance	D	=	Safety / Reliability/Strength

Decision Matrix

	B	C	D	Wt.	Aw	% Wt
A	A-2	A-1	A-2	5	6	46.15
	B	B-1	B-2	3	4	30.76
		C	D-1	0	1	7.69
			D	1	2	15.38
				9	13	

Ranking of alternatives for different attributes

Alternatives

1. Reduce height of channel a
2. Hollow tie bar & radial arm b
3. Centrifugal casting for Hub c

Attribute "A" Cost

	b	c	wt
a	a	a	2
	b	b	1
		c	0

Attribute "B" Ease of implementation

	b	c	wt
a	a	a	2
	b	c	0
		c	1

Attribute "C"Ease of maintenance

	b	c	wt
a	a	a	2
	b	b	1
		c	0

Attribute "D"Safety/Reliability

	b	c	wt
a	a	c	1
	b	c	0
		c	2

Ranking of Alternative Proposals

Attributes Alternatives	**A**	**B**	**C**	**D**	**Performance Score**
% wt	46.15	30.76	7.69	15.38	
a	46.15×2 =92.3	30.76×2 =61.52	7.69×2 =15.38	15.38×1 =15.38	184.58
b	46.15×1 =46.15	30.76×0 =0	7.69×1 =7.69	15.38×0 =0	53.84
c	46.15×0 =0	30.76×1 =30.76	7.69×0 =0	15.38×2 =30.76	61.52

From the above ranking of alternatives of various creative ideas, creative idea "a" is having the highest performance score; hence it is selected as best design option.

CHAPTER 7 INVESTIGATION PHASE

The alternative ideas selected in the Evaluation Phase are needed further investigation for better work and sell. The wisdom of the Investigation phase is in asking the right questions to determine the advantage and disadvantage of an idea and from this knowledge, ways of overcoming the disadvantages and of the strengthening the advantages are developed so that an idea that is both workable and salable is generated. This phase comprises of three techniques. These are:-

1. Use company and Industrial Standards
2. Consult Vendors and Specialists
3. Use Specialty products, Processors and Materials.

The usage of standard items provides many advantages and yield as better value because of the following attributes.

a) No development cost is required.

b) No tooling costs are entailed.

c) Good quality and reliability are ensured.

d) Standard items are easily available so less inventory carrying cost and less lead time is required.

e) Their performance characteristics are readily ascertainable and competition among their suppliers is universal.

Hence it is necessary to select most usable and economical standards should be selected form number of standards. But falling in Standard Hypnosis

type of traps should be avoided when selecting standards by being over biased or over prejudiced.

It is necessary to consult vendors and specialists to find how they can help/guide us in achieving the desired result because they have special and concern knowledge and experience. We should be readily employed for the purpose. These may be in better position to evaluate solutions better or suggest ways and means to reduce cost. Vendors might have developed similar solutions for other clients, which we are seeking for. But in many situations, vendors can equally suggest cheaper and effective design or material etc.

First the tear down analysis is done on the water pumping windmill assembly for finding the standard parts. On seeing the entire assembly various standard parts found are ball bearings, roller bearings and couplings. These are available in India and other countries (London, Singapore, Thailand and Romania) with low costs.

Replacing the present supplier of bearings from SKF to NBC was accepted after consulting the specialist in bearing manufacturing and replacing the welded steel construction Housing box with the casted Housing box is accepted after consulting the vendors related to casting. At many times, investigation phase overlapped with evaluation phase. All the costs of workable ideas are fixed by taking vendors into consideration.

After applying all the above technique the advantages and disadvantages of the completely finalized ideas are listed in various Idea Evaluation Worksheets.

IDEA EVALUATION WORKSHEET NO. 1

Function : PROVIDE SUPPORT

Finally developed idea : Reduce height of the channel

Advantages	Disadvantages
1. Good reduction in cost.	1. At some places, lower Capturing of wind velocity
2. Helps in material saving	
3. Easy to implement.	
4. Simple in design	
5. Ease of maintenance	
6. More strength & rugged.	

IDEA EVALUATION WORKSHEET NO. 2

Function : WITHSTAND IMPACT

Finally developed idea : Change supplier of bearing.

Advantages	Disadvantages
1. Good reduction in cost.	1. New vendor
2. Same standard bearings with less cost.	2. Parts used in other industries.
	3. They are not a local supplier.
	4. Payment should be 25% of order value in advance with order.

IDEA EVALUATION WORKSHEET NO. 3

Function : PROVIDE HOUSING

Finally developed idea : Use of casted Housing Box

Advantages	Disadvantages
1. Cheaper than existing design.	1. Dependant on outside vendor
2. Simple in design	2. Delay in delivery time causes problem.
3. Easy to implement	
4. Lots of time saving	

IDEA EVALUATION WORKSHEET NO. 4

Function : JOIN PARTS

Finally developed idea : Use of spring steel for spring material

Advantages	Disadvantages
1. Reduction in cost	1. Less harder and less strength as compared to High C. steel.
2. Commonly available in market	
3. Can be hardened & tempered also	
4. Standard spring material	

CHAPTER 8 RECOMMENDATION PHASE

This phase corresponds to the finishing phase of the value engineering job plan. The fruits of all previous efforts is depends upon successful accomplishment of this phase. The objective of this phase is to motivation of positive action in favor of implementation of the suggestions. In this phase the team will present their ideas to the management for approval. The proposal must be carefully planned, correctly stated and firmly carried through to successful completion/implementation.

Generally many proposals are selected but for actual implementation, they have to compare with available manpower and resources, delays have to be reduced for implementation. The savings will ensue only after implementation. This phase consists the following techniques:-

1. PRESENT FACTS
2. PRESENT COSTS
3. MOTIVATE POSITIVE ACTION

All the facts relate to VA proposal are to be presented one by one in proper sequence so that it is accepted by management. Facts should be presented for the both parts of the problem i.e. present and proposed methods and costs. The presentation should be like that the Decision maker has the time and willingness to read it completely. Costs should be realistic and not the optimistic. Following costs are to be considered in presenting the costs:-

1. Existing Design Cost.

2. Recommended Design Cost.

3. Cost Savings.

To motivate positive actions, it is necessary as we discussed above that the complete picture should be clear by organization of the presentation of the ideas and their supporting facts. The development steps to be taken to implement these ideas in the most rapid and economical manner when these are accepted.

8.1 RECOMMENDATIONS

After completion of all the phases of value analysis job plan, the following recommendations are made to the company.

1. Change the existing design by reducing the height of the channel. The advantages associated with this suggestion are given in the idea evaluation worksheet no.1.
2. Use of casted Housing box instead of welded steel construction Housing box. The same vendor who is supplying Hub to company will serve this purpose.
3. Use of Medium carbon spring steel for spring material. The advantages associated with this are given in idea evaluation worksheet no.4.
4. Change the supplier of the Bearings, as the new supplier is supplying the same standard bearings with less cost.

8.2 NETWORK DIAGRAM

The comparison of the costs of the present and suggested components are given in the Table 8.1. An Approximate Schedule for the implementation of the proposed changes in shown by the construction of a Network diagram. From the Network diagram

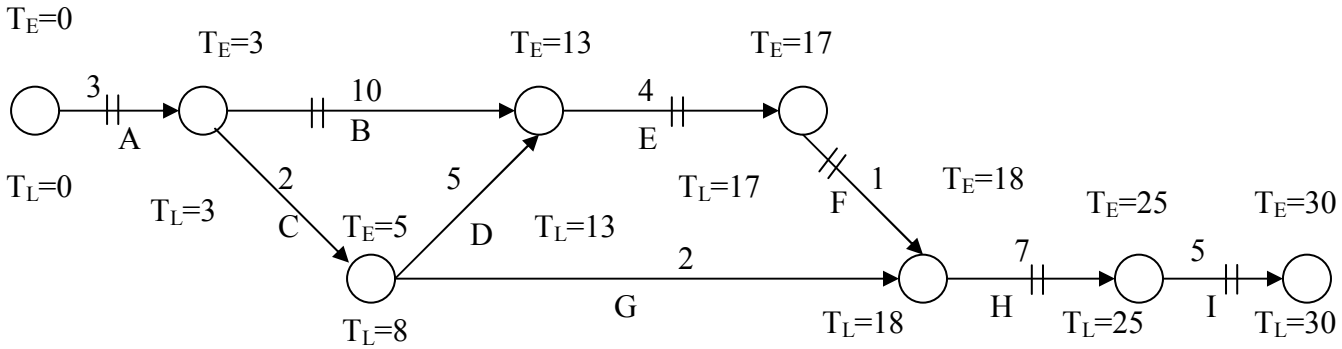
the critical path is found out and the time needed to implement the suggested changes is also found out.

The various activities in the network diagram, their key letter and precedence relationship along with the number of days required for that activity to be completed are given below:

Table 8.1 Activities for Implementation

S.No.	Activity	Letter	Predecessor	No. of days
1.	Meetings & Discussions on VA proposal	A	---	3
2.	Approval of changes from Technical Dept.	B	A	10
3.	Discussion with Vendor regarding material procurement	C	A	2
4.	Supply of samples by vendor for testing	D	C	5
5.	Testing of samples in Laboratory	E	B,D	4
6.	Approval from Test lab (R&D)	F	E	1
7.	Approval from Ministry/marketing	G	C	2
8.	Phase out old design	H	F,G	7
9.	Phase in implementation of proposed design	I	H	5

Fig. 8.1 Implementation of Network Diagram



The Critical Path found by Forward and Reverse Path method is **A-B-E-F-H-I**

Total No. of days to complete Implementation = 30 days

Table 8.2 : Comparison of Present and proposed costs

S.No.	Present Component	Present Cost	Suggested Component	Estimated Cost
1.	Existing Tower	Rs.30,000	Proposed tower	Rs.26,500
2.	High carbon Steel spring	Rs.400	Medium carbon spring steel	Rs.345
3.	Welded steel housing box	Rs.5000	Casted housing box	Rs.4350
4.	Alloy steel Universal Joint	Rs.2800	Stainless steel Universal Joint	Rs.2515
5.	Steel platform & ladder	Rs.5520	Bamboo platform & ladder	Rs.3000
6.	Bearings	Rs.3420	Supplier change	Rs.3120
	Total	Rs.47140		Rs.39830

Total saving = Rs.7310

Percentage saving = (7310 / 47140) × 100 = 15.5%

Total value improvement = (7310 / 39830) × 100 = 18.35%

Demand/Production = 100 (approximately) per annum

Total savings = 100 × 7310 = Rs.7,31,000 per annum

CHAPTER 9 CONCLUSION & FUTURE WORK

Value Analysis of Water Pumping Windmill has been carried out for SICO, following the systematic approach suggested by A.E. Mudge. After completion of all the steps in job plan, certain recommendations are made at the end, which if implemented will result in the considerable savings to the company.

After completion for all stages in Value Analysis, we have been able to save Rs.7.3 lakhs per annum (approximately) depending upon the demand and rate of production. There is no implementation cost as no design changes are made and there is no need to procure any additional equipment to implement the changes. The product will work with same endurance and safety as it is being used.

LIMITATIONS OF WORK:

In this work the major changes is on the selecting the alternative supplier using a proposed methods for manufacturing the part and selecting alternative material. The management is not interested in making design changes as the product performance in the market is good. There are many restrictions on the company to use particular type of design aspects.

SCOPE OF FUTURE WORK:

After completion of all the techniques, there is still some considerable scope for improvement of design and cost reduction, but it will be possible only when they allowed changes in the design of the product. In this project main consideration was on the

changes in the manufacturing methods and reduces the unnecessary cost for manufacturing by changing new supplier for manufacturing the parts with our proposed methods, as the company is not interested in making changes in design. Also those functions which are termed as High cost function can be taken up for development of Alternatives even though their VIP index is not greater than one. Finally if we can integrate value Analysis with QFD we may get very good results that improves the value of the product.

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