

Value engineering applications to enhance building energy performance of auditorium

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Abstract— *Reduction of energy consumption in building is a major challenge frequently faced by the designer. This paper uses Value Engineering methodology to analyze the energy consumption of the existing building. VE includes information collection of electricity data of the building under study, function analysis of the components, development of creative ideas, evaluation of ideas on some fixed parameters, development of ideas and recommendation of ideas by carrying out economic analysis. Study results indicate that VE is useful to find the solutions to high-energy consumption of the building and reveal the unnecessary cost occurring in the operation of the building. VE was used to minimize the electricity consumption and still satisfy the required basic function served by the system.*

Keywords— *Value Engineering, unnecessary cost, energy consumption, HVAC system, operation cost*

I. INTRODUCTION

Almost 50% of the energy demand is used to support indoor thermal comfort conditions in commercial building (3). Total energy demand has risen steadily with increase in population and improvements in the life-style of people. It is estimated that approximately 30 percent of the total energy consumption in building could be eliminated by energy conservation and the redesign of the existing building and structure. Factors affecting the energy consumption in building are:

- Orientation of building
- Building configuration
- Building envelope
- Fenestration
- Lighting
- Heat, Ventilation and Air Conditioning (HVAC)
- Temperature control

Many researchers addressed the ways to improve energy efficiency in building. Luis Perez-Lombard et al. analyzed the development of building energy codes concerning Heating, Ventilation and Air Conditioning (HVAC) energy efficiency. Rutvil Lathia et al. provided a mathematical framework for designing, emission free HVAC system with its components for auditorium and concluded that the building should be designed according to HVAC system. Vahid Vakiloroya et al. investigated different technologies and approaches to improve the performance of HVAC system in order to reduce energy consumption.

II. PROBLEM IDENTIFICATION AND OBJECTIVES

From the previous literature, this research had taken the case study of Dhirajlal J. Shah Town Hall at Anand, Gujarat. The main objective of this study is utilizing Value Engineering to find unnecessary cost occurring in the operation of the building. The objective of VE methodology is to find alternatives of high cost areas while still satisfying the required function. The methodology adopted to achieve the objectives is same as the VE job plan, which follows the steps used by inventors when they develop new ideas and procedures. Fig. 1 shows the methodology of the research

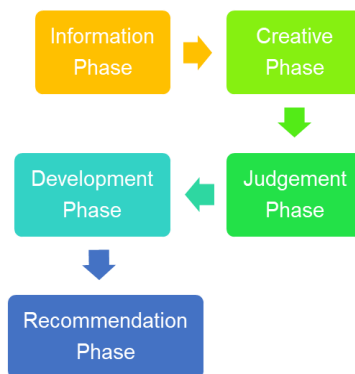


Fig. 1 Methodology

III. VALUE ENGINEERING

Value Engineering was a result of a material shortage problem during World War-II. Value engineering is a proven management technique using a systematized approach to seek out the best functional balance between the cost, reliability and performance of the project. Value engineering can be applied during any stage of project's development phase, as it is a life cycle oriented. The following are the phases of VE applied to the building under study

A. Information Phase

The following data was collected related to problem under study by various means like -

- 1) Visit at Anand Nagarpalika
- 2) Visit and observation, measurements at Dhirajlal J. Shah Town Hall
- 3) Visit at MGVCCL Sardar sub division, Anand

TABLE 1
PRIMARY SURVEY DETAILS.

Area of town hall	484.84 sq. m
Seating capacity of hall	760 seats
Size of stage	14.2 m X 10 m
Numbers of doors	8 nos.
Balcony area	139.37 sq. m
HVAC details	
Air Conditioning	10 TR 8 nos.
Temperature for level of comfort	25° C in Winter
	20° C in Summer
	25° C in Monsoon
Ventilation fans	8 nos. of 46W
Celling Fan	13 nos. 70W
Side fans	6 nos. 75W
Lighting details	
Stage lighting	10 nos. of 500W Scoop light
Stage lighting other than scoop light	20 nos. of 18W CFL
Lights near entry/exit door	6 nos. of 40W fluorescent tube lights
Lighting in the corridor and other places	42 nos. of 18W CFL

For electrical consumption, MGVCCL, Sardar Sub division provided the data of town hall. Following figures shows the electricity consumption of town hall

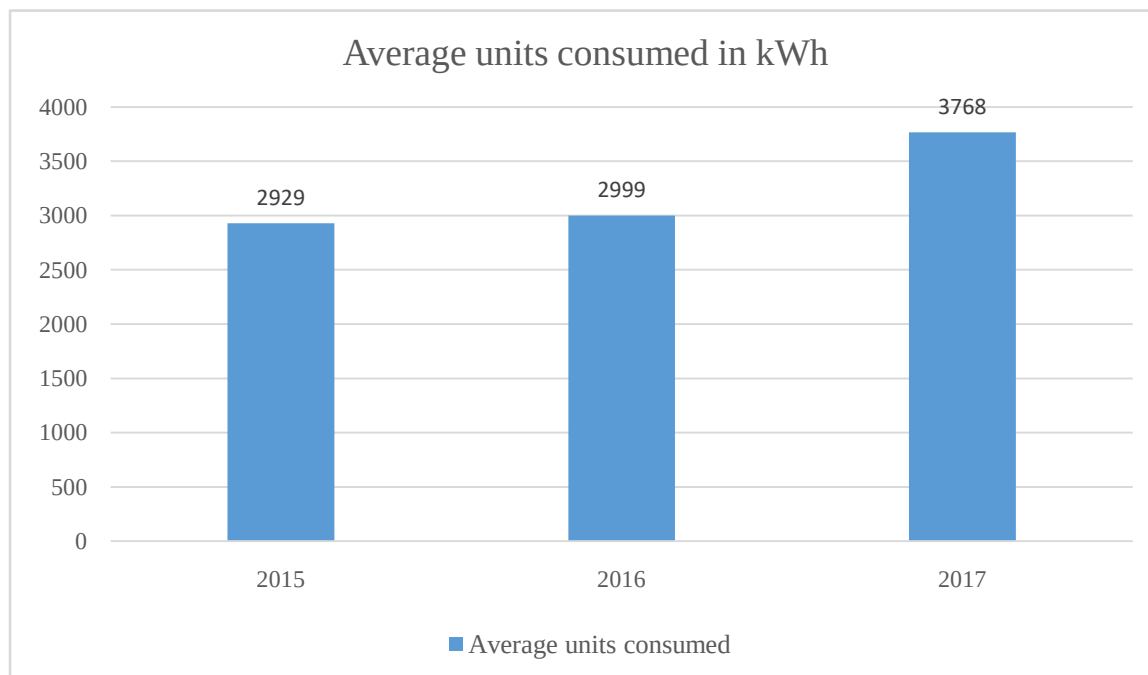


Fig. 2 Average units of electricity consumed

1) Function Analysis

The function analysis for a project is used to identify what it is and what does it does. The functions are defined using a two-word active verb/measurable noun context. Table 4 shows the function analysis of the components of the town hall.

TABLE 2
FUNCTION ANALYSIS

Item	Basic Function	Secondary Function
HVAC System	Control temperature	Control humidity Circulate air Heat air Cool air Distribute air
Air conditioning system	Reduce temperature Reduce humidity	Control temperature Supply air
Insulation – Building	Create barrier	Impede flow Conserve energy
Lamp – fluorescent	Illuminate space	Emit energy Receive voltage Ionize gas Produce heat
Roof surface Coating	Seal surface Improve appearance	Reduce refinishing Waterproof surface
Truss	Support roofing Span opening	Distribute load Resist deflection Accommodate penetrations
Roof structure	Support load	Transfer load Cover spans Accommodate loads Resist deflection
Solar panel	Generate electricity Convert energy	

When the heat gain by the building was calculated it was found that the roof was the main source of the heat entering in the building. The roof is uninsulated and is composed of asbestos sheet only. Therefore the required capacity of air conditioner is 72.5 TR.

B. Creative Phase

The main purpose of this phase is to generate more and more ideas irrespective of any judgement but idea are not to be out of the study area. The following table shows the ideas generated.

TABLE 3 CREATIVE IDEAS

Component	Idea	Code
Insulation	Reflective Insulations Material Pure Aluminum Foil + FR Air Bubble Film + FR Air Bubble Film + Pure Aluminum Foil	I1
	XLPE 9-MM with Both Side Aluminum Foil Laminated with Both Side Aluminum Foil	I2
	XLPE 9-MM with ONE Side Aluminum Foil Laminated with One Side Aluminum Foil	I3
Lightings		
Hall lightings	LED lights	HL1
Dias lightings	LED lights	DL 1
Passage lightings	LED lights	PL1
Roofing structure	Solar roof top system	R1

C. Evaluation Phase

Based on the following criteria the creative ideas are evaluated.

TABLE 4
CRITERIA AND WEIGHTAGE FOR EVALUATION OF INSULATION MATERIAL

Identity	Criteria	Weightage
A	Availability	8
B	Initial Cost	9
C	Maintenance	7
D	Aesthetic	5
E	Durability	9
F	Ease of installation	6
G	Performance	9

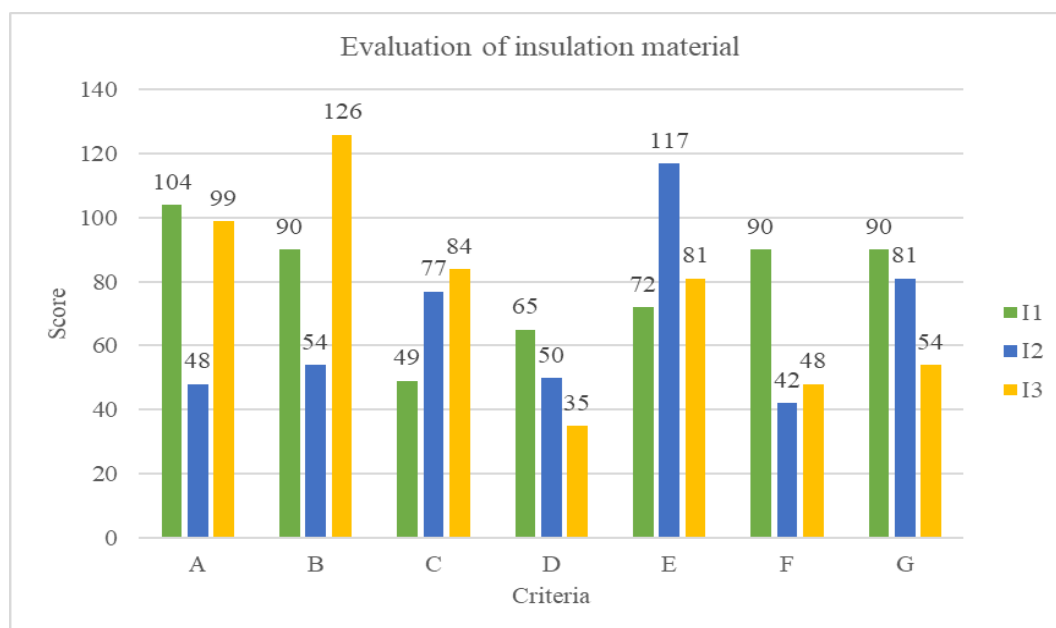


Fig. 3 Evaluation of insulation material

TABLE 5
EVALUATION PHASE – IDEA RANKING

Component	Creative Idea	Code	Benefits	Limitations	Rank
Insulation	Reflective Insulations Material Pure Aluminum Foil + FR Air Bubble Film + FR Air Bubble Film + Pure Aluminum Foil	I1	Provides maximum insulation	Low strength	1
	XLPE 9-MM with Both Side Aluminum Foil Laminated with Both Side Aluminum Foil	I2	Better appearance	High initial cost	3
	XLPE 9-MM with ONE Side Aluminum Foil Laminated with One Side Aluminum Foil	I3	Relatively low cost	Less attractive	2

D. Development Phase

The ideas evaluated in the previous phase are further developed into workable solution.

TABLE 6
DEVELOPMENT PHASE – INSULATION MATERIAL

Existing	Proposed
The current roof has no insulation material and is composed of ACC sheets. This causes more heat entering in the building through roof.	The roof can be insulated with the identified material and this will result in negligible heat gain through roof
The current lighting fixtures is halogens for stage. This consumes more electricity and adds in the internal heat gain of the building.	Installing LED fixtures of 70W serves the same purpose and is more energy efficient.
The current lighting fixtures for seating area and lobby consists of two pair of 18W CFL.	Installing 20W of LED floodlights. This will reduce the numbers of lights required for the purpose
The current roof space is un-used.	The existing roof can be used for installation of Solar Roof Top System

1) Economic analysis of Solar Roof top System

Total area of roof available for installation of solar roof top system is 508 sq. m. therefore feasible plant size is 50.8 kW.

TABLE 7
ECONOMIC ANALYSIS OF SOLAR ROOF TOP SYSTEM

Sr. No	Items	Amount
1	Roof top area	508 sq. m.
2	Feasible power plant size	50.8 kW
3	Permissible size of Solar roof top system is half of the contract demand	45 kW
3	Current benchmark cost as per Ministry of New and Renewable Energy	Rs. 65000 / kW
4	Total cost of solar roof top system	Rs. 29,25,000
5	Electricity generated from solar roof top system per month	5625 kWh
6	Total electricity generation from solar roof top system per year	67500 kWh
7	Electricity generated during life-time (25 years)	1687500 kWh
8	Average current electricity consumption	3201 kWh
9	Average excess power returned to electricity company	2424 kWh
10	Worth of electricity generated monthly	Rs. 27,563
11	Worth of electricity generated yearly	Rs 3,30,750
12	Worth of electricity generated during life-time of solar roof top system (25 Years)	Rs. 82, 68, 750
13	Return on investment time period	8.8 Years

E. Recommendation Phase

The following are the list of recommendations, which are made after Value Analysis

TABLE 8
RECOMMENDATION OF IDEAS AFTER VALUE ANALYSIS

Sr. No		Material cost	Remarks
1	Reflective Insulations Material Pure Aluminum Foil + FR Air Bubble Film + FR Air Bubble Film + Pure Aluminum Foil	Rs. 150 per Sq Mtr	Installation cost Rs. 45 per Sq Mtr Rs 6000 transportation Total cost = $(508 * 150) + (45 * 508) + 6000 = 1,05,060$
2	LED 70W for Dias lightings	Rs. 5270 per piece	5270×10 Nos. = 52,700 Rs
3	LED 20W for Hall lightings	Rs. 285 per piece	285×20 Nos. = 5700 Rs
4	LED 20W in Passage lightings	Rs. 285 per piece	285×30 Nos. = 8550 Rs
5	Use of solar roof top Area = 508.476 Sq Mts Permissible Capacity = 45 kW	Rs. 29,25,000	Electricity generated = 67,500 kWh per year
6	Capacity of Air Conditioner with insulation material	55 TR	Existing is of 80 TR use the existing but operated only at required capacity
		Total Cost	Rs. 30,97,010

Electricity consumption of existing Air Conditioner and lightings are as follows

Air Conditioner of 80 TR = $80 * 3516$
 = 281.28 kWh
 Stage lightings = $(500 * 10) + (20 * 18)$
 = 5.36 kWh
 Hall lightings = $(46 * 18) + (6 * 40)$
 = 1.068 kWh
 Total electricity consumption = 287.708 kWh

Electricity consumption of proposed Air Conditioner and lightings are as follows

Air Conditioner of 55 TR = $55 * 3516$
 = 193.38 kWh
 Stage lightings = $(70 * 10) + (10 * 20)$
 = 0.9 kWh
 Hall lightings = $(25 * 20)$
 = 0.5 kWh
 Total electricity consumption = 194.78 kWh
 Total saving in electricity consumption = $287.708 - 194.78$
 = 92.92 kWh

IV. CONCLUSIONS

In this study, we have applied VE to a town hall for reducing the operating cost without affecting the intended functions and thereby making the building more energy efficient. On careful analysis, we observed the following

- 1) Roof was not insulated and major source of heat entering the building and this was causing unnecessary load on the cooling system.
- 2) If the roof is insulated with the recommended insulating material the capacity of cooling system can be reduced up to 68 %.
- 3) The current lighting of the stage consisted of halogens of 500 W, which resulted in excess electric consumption, and by using proposed lighting fixture electricity can be reduced up to 83.2 %
- 4) The lighting of the seating hall and lobby used conventional CFL lights, which were required more in number compared to proposed LED lighting fixtures and electricity consumption can be reduced up to 53.2 %
- 5) Total reduction in electricity consumption can be 32.3 % after proposed changes are made.
- 6) The unused roof space can be utilized to install solar roof top system, which generates electricity of worth Rs. 27,563 / month.

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