International Journal of Sustainable Development & World Policy
2014 Vol. 3, No. 2, 31-44.
ISSN(e): 2305-705X
ISSN(p): 2306-9929

STRATEGIC EVALUATION OF DISTRIBUTED POWER GENERATION TECHNOLOGY: A SUSTAINABLE APPROACH

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ABSTRACT

As reliability of large, centralized electrical power grid is decreasing, it is an opportune moment to investigate other sources of energy for critical operations. Distributed Power Generation (DPG) technologies are cost-effective and reliable alternate source to help organizations keep the power coming. Distributed power generation means "Power generation at or near customer sites, grid connected or isolated, small in size, quick responsive". The present paper is an attempt to draw a Strategic Planning framework for the Distributed Power Generation. With the increase in energy requirements and the consequent diminishing conventional sources such as petroleum, coal etc, there is a need to look into new methods and sources of energy generation. The present study is based on judgmental data of the people involved in the business. This paper gives more emphasis on Strategic Analysis and Strategic Evaluation by Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) tools.

Keywords: Distributed power, Analytic hierarchy process, Analytic network process (ANP), Wind power, SWOT analysis, PEST analysis

1. INTRODUCTION

Distributed Power Generation starts with a Distributed Power Unit (DPU) which can be either a custom designed system or one of the marine or industrial product lines. A DPU consists of three main components like Electrical Energy Source (EES), Switch Gear that transfers the electrical power created by the energy source to the user, and Control system to coordinate and ensure the proper function of the various components.

Distributed energy resources capacity ranges from kilowatts to megawatts. They are small and modular and can be located on site or nearby the location. Hence greater local control, efficient utilization of waste heat, lower emissions can be achieved. The portfolio of distributed energy resource comprises of Advance, Micro and Wind Turbines; Photovoltaic Systems; Concentrated Solar Power Collectors; Fuel Cells and Geothermal Energy Systems (Rowley *et al.*, 1997). This system consists of technologies which can be installed at the customer's site or at a

nearby location like power parks, district energy systems or minigrids. There are Environmental and Social & Developmental benefits of these technologies which are shown in Table 1.

Table-1. Potential Environmental, Social and Developmental Benefits

	Parameters	Benefits
	Potential Environmental Benefits	
1	Air quality	Renewable technologies, such as wind and solar, can completely eliminate pollutants like SO_2, CO, particulates, smoke dust, and NO_2.
2	Water quality	Anaerobic digester technologies at industrial sites could simultaneously treat wastewater and provide natural gas. Hence, solar and wind energy provides clear-cut gains as compared to the conventional means. (Wadhwa, 2002)
3	Water availability	Water depletion and runoff problems can be solved through Sustainable forest management, especially if practiced over a wide area.
4	Soil conservation	Sustainable forest management will also have a positive impact on soil conservation. Silviculture plantations and tree webs may lead to reduced soil erosion and wind erosion respectively.
5	Solid waste	These technologies can reduce or remove solid waste.
6	Noise	Wind pumps can lead to substantial reductions in noise pollution as compared to diesel pumps.
7	Flood prevention/ protection	In comparison to the present logging practices, sustainable forest management can lead to considerable benefits.
8	Biodiversity protection	Mining pressures can be reduced through the use of cogeneration and renewable technologies.
	Social and Developmental Benefits	
1	Employment	The new technology shall help generate employment opportunities both in skilled, semi-skilled and general domains.
2	Rural development	Electrification of rural and remote areas can be achieved through renewable energy sources not otherwise possible given high transmission costs.
3	Poverty alleviation and equity	Increased demand for unskilled labour in the projects shall generate positive equity impacts and shall help in alleviating poverty.

1.1. Types of Distributed Power Generation Technology (DPG)

There are four types of DPG systems.

(1) Wind Generator: The term "wind power" describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like (Narain *et al.*, 1997). Wind electric generator has become more reliable and efficient with time. Today, wind electric systems can power variety of loads, either directly or indirectly. The most common application is the production of electricity. Electricity generated from wind farms is sent out into the power line just like the electricity produced

(2) Micro Turbine: Micro Turbine is a term applied to a group of small gas turbines (20 kW-

100 kW) being used to provide on-site power. The technology is derived from automobile and aircraft turbochargers technology and it utilizes a single rotating shaft, which includes the air compressor, turbine and the generator. (Ronald, 1976)

(3) Fuel Cell: An electrochemical device that continuously changes the chemical energy of a fuel (hydrogen) and OXIDANT (oxygen) directly to electrical energy and heat, without combustion. Fuel cells can be used in stationary applications like generating electricity or heating buildings, and for powering vehicles, buses and trains. Fuel cells are at least twice as efficient as gasoline engines.

(4) Photovoltaic Energy: "Photovoltaic energy is the conversion of sunlight into electricity through a photovoltaic (PVs) cell, commonly called a solar cell. A photovoltaic cell is a non-mechanical device usually made from silicon alloys." (Rao, 1987) Photovoltaic systems are called as solar panels. These are made of discrete cells which are connected together to transform light energy into electricity. These cells always produce direct current (DC) electricity and must be converted into AC by invertor. The maximum efficiency of PV cell is 30% according to (Dhamse and Gandhare, 2012).

1.2. Comparison of Solar, Fossil Fuel, and Wind Systems

Table 2 gives basic advantage and disadvantage of different technologies of power generation.

Table 2. Comparison between Solar, Fossil Fuel and Wind Generator

Pump Type	Advantages	Disadvantages
Solar	• Low preservation • Zero fuel consumption • Easy to install • Long life • Low operating costs • System is flexible and can be matched closely to need	• High fixed cost (initial cost) • Low efficiency in cloudy weather
Fossil Fuel	• Low capital costs • Can be convenient • Extensive experience available • Easy to use	• Needs time to time maintenance and replacement • High Maintenance may reduce life • Fuel often expensive • Noise, dirt and fume problem
Windmill	• Potentially long-lasting • Works well in windy site	• High repairing cost • Difficult to find replacement parts • Periodic disadvantages • Labor intensive • Depends on velocity of wind

Source:(http://www.wcubed.com/solar/Solar%20Water%20Pumping.htm)

Table 3 shows the comparison between DPG technologies.

Table-3. Comparisons between different types of DPG's Technologies

Factors	Micro Turbine Generator	Photovoltaic	Wind Turbine	Fuel Cells
Capacity Range	20 kW - 750 MW	1kW - 1MW	10 kW - 1MW	200 kW - 2MW
Efficiency (%)	20-25%	6 - 19%	35%	40 - 57%
Energy Density (kW/m2)	---	0.02	0.01	1.0 - 3.0
Capital Cost ($/kW)	350-450	6,600	1,000	3,750
O&M Cost ($/kW)	.02	0.001- 0.004	0.01	0.0017
Natural Gas	0.10	n/a	n/a	0.003 - 0.02
-Oil	0.17	n/a	n/a	-
Technology Status	Commercial	Commercial	Commercial	Commercial

2. ECONOMICS ANALYSIS

Economic Analysis has been done only for Wind Generator. This analysis utilizes the information collected from the survey of the major stakeholders in the wind energy industry, viz., and the manufacturers of wind energy generators. The perceptions on the current package and alternative incentives which could be offered and some data on costs have been utilized to develop a typical cash flow for a wind farm. On this basis a financial analysis for a typical wind farm was conducted, and the impact of the fiscal incentives offered, namely the accelerated 100% depreciation benefit, on the returns from the project was identified. Financial sensitivity is determined by computing Rate of Return (ROR) for different scenarios.

2.1. The Base Case: Key Assumptions

1. All calculations are done for a 55 kW machine, assuming the average annual capacity utilization factor to be 20% based on survey results.
2. The machine cost is assumed at the highest level observed in the survey, i.e., Rs. 17 lakhs.
3. No capital subsidies are assumed since these are just one time grants and would not be available if the promoter wishes to add to the capacity already installed by him. This consideration would give an overestimate of the return from the project.
4. The Operations and Maintenance (O&M) costs are assumed 4% of the total cost of the project. An additional 5% allowance is made every 5th year to handle capital maintenance.
5. The rate of interest is assumed to be 12%, with a 10 year repayment period, payable yearly, starting after drawing of the loan. These are the usual conditions for medium term loans advanced by the financial institutions.
6. Income from the project after 10 years is taxed at the rate of 40%.
7. It is assumed that the depreciation allowed on the wind project is absorbed in the profits of the parent company. The resultant tax saving for the parent company is

included as a cash inflow from the project.

8. The installation period for the windmill is assumed to be 6 months.
9. The life of the project is assumed to be 20 years, including the installation period.

Table-4. Base Key Assumptions

Machine Cost	**Rs. 17 Lakh**
Civil work, erection, Grid connection etc.	15% of Machine Cost
Transportation Cost	5% of Machine Cost
CF	20%
Depreciation	100%
Rate of Interest	12%
Loan Tenure	10 years
Tax Rate	40%
Life of Generator	20 years

2.2. Sensitivity Analysis

Effect on Pay Back and Net Present Value by varying the cost is shown in Table 5.

Table-5. Sensitivity Analysis

Rs. Cost/Kwh	**Pay Back period (in year)**	**Net Present Value (Rs in Lakhs)**	**ROI (%)**
4.78	10	5.11	13.5
4.65	11	4.14	12.2
4.56	12	3.55	11.6
4.35	13	2.21	10
4.27	14	1.68	9.6
4.16	15	1.17	8.78
4.1	16	0.90	8.5
4.04	17	0.63	8.2
4.0	18	0.48	8

2.3. Comparison with Conventional Coal-Based Power Generation

The initial fixed investment on land, machine and installation for wind mill accounts for almost **81%** of the present value of the total life time costs, against 33% for conventional power, at a 12% rate of discount.

Table-6. Cost Composition of Life Time Expenses

Costs	**Share in present value of Life time expenses (%)**		
	Solar	**Wind**	**Coal**
Machine	60	70	-
Transformers, line etc.	24	8	-
Ground & Building	5	3	-
Total Project Costs	89	81	33
Interest on debt	10	12	16
O&M	1	5	10
Fuel cost	-	-	40
Change in Working Capital	-	0.4	1
Total Running Expenses	11	17	67

The capital cost per unit of generation is much higher in wind than coal; solar sources are the costliest, while the opposite is true for the running expenses (in table 6). The differences between wind and conventional power become apparent from table 7. These figures are arrived at after building an inflation of 5% pa. in the O&M costs for both technologies.

Table-7. Levelized Cost: Wind vs. Coal based Power (Rs/kWh)

	Wind Power	Coal Power
Project Costs	3.23	1.11
Running Expenses	1.00	2.25
Total cost/kWh	4.23	3.33

Source: (Bakthavatsalam, 2000)

2.4. PEST Analysis for Distributed Power Generation

The PEST analysis analyses the external factors, impacting business. They can provide threats and opportunities for ABC COMPANY in DPG areas. These are following:

Political factors

- With progressive Liberalization of the economy the multinationals are coming into India giving the local companies a run for their money.
- For the last 10 years, the satiability of the govt. has been a major reason of worry to the business at large. The pace of liberalization has been fast or slow depending on who has been in power.
- The Indian govt. has taken up a major initiatives toward environmental issues and is encouraging renewable technologies for energy production and other works.

Economic Factors

- Renewable energy industry after going through a recessionary period of nearly five years has started growing now.
- Central bank has been reducing the interest rates for almost three years in these technologies. The rate of interest of has come down from 15% to 12%. This makes more liquid money available to the investors to put into business.
- Most of the state governments are wooing the investors to invest in their state providing discounts and infrastructure to these companies.
- Power sector is considered vital for country's economic strength. It has multiplier effect on the country's economy through increased production and gives a boost to the transport sector.
- The Indian economy is expected to grow at about 7% per annum. The increase in the demand of energy is likely to be significant in the industry and transport sectors.

Social Factors

- The Demographic composition of the global market available to MNCs has changed- for example, potential markets include an aging population in Europe and Japan, a young population in China, Mexico, and India, and an aging and young population in US. Furthermore, customers spend their time and money differently. Lifestyles and fashions are evolving. The spread of television in emerging markets and the Internet worldwide gives consumers access to vast amounts of information. In many industries, such as software, consumers are actively involved in product design and development.
- Business is moving swiftly from a position of compliance to active involvement with environmental issues, a development that has a significant impact on packing, product design, and technology choices. Social issues- child labor, family orientation, worker's rights, and consumers' rights- are becoming major topics of social and political debate.
- Customers are very few. These are Central govt., state govt., some private companies etc.
- Consumers have become more aware of the function of various components.

Technological factors

- Government is putting lot of pressure on the renewable technologies, which will affect the efficiency and cost of components.
- With the product life cycle becoming shorter in the hard core engineering applications, vendors need to continuously come out with newer technologies to keep themselves in the business.
- Many Institutes are researched on cost reduction technologies

PEST analysis reveals that political factors have the most significant influence on the market sentiments. Government budget and subsidies influence the demand. Social factors (Demographic profile, consumer behaviors) have a mild impact; whereas economic factors don't have any significant impact.

2.5. SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis of DPG Technology:

SWOT analysis is essential for a company to formulate its long term strategy.

2.5.1. Strategic Formulation

To develop strategies that take into account the SWOT profile, a matrix of these factors can be constructed. The SWOT matrix (also known as a TOWS Matrix) is developed, which is helpful in creating a strategic matrix.

SWOT Analysis for ABC Company in area of DPG

Strengths	Weaknesses
1) Good Market Image	1) Weak Spending on R&D
2) Relations With other Institutes	2) Poor IT Services
3) Proprietary Knowledge	3) High cost Product
4) Less no of Competitors	4) Not Availability of Resources
5) Available Expertise in Different technology	
6) Committed Employees (Enthusiastic and knowledgeable managers and staff.	
7) Collaboration with foreign Companies	
Opportunities	**Threats**
1) Government Support	1) Entry of Foreign Competitors
2) New Technology Developments	2) Introduction of New Substitutes
3) New Application Developments	3) Rival Firms Adopt New Strategies
4) Reduction in Traditional Energy Resources	4) Threats of New Entrants
5) To emerge global market	5) Trade Liberalization
6) IT Development	

TOWS Matrix for Strategic Formulation

Internal Capability →	**Strengths**	**Weaknesses**
External Issues for ABC Company ↓	1. Good Market Image 2. Relations with other Institutes 3. Proprietary Knowledge 4. Less no of Competitors 5. Expertise in handling technology 6. Collaboration with Foreign Companies 7. Committed Employees	1. Weak Spending on R&D 2. Poor IT Services 3. Less Man Power 4. Non Availability of Resources
Opportunities 1. Government Support 2. New Technology Developments 3. New Application Developments 4. Reduction in Traditional Energy Resources 5. IT Development	1) To Develop the Hybrid system by Exploiting Opportunities (like: Wind-Solar System) 2) To Develop New Applications by Using Committed Employees and Govt. support 3) Vertical Integration Strategy	1) Take advantage of new technology to reduce cost
Threats 1. Entry of Foreign Competitors 2. Introduction of New Substitutes 3. Adoption of New Strategies by rival firms 4. Threats of New Entrants 5. Trade Liberalization	1) Product Market Development Strategy	1) To have Strategic Alliance for Technology Acquisition for Cost Competitiveness 2) Applying Cost Leadership Strategy

2.5.2. Strategic Options Evaluation Model

The first step is to construct the model to be evaluated. The relevant criteria and alternatives are shown in the form of a hierarchy as in fig. 1. Strategic decisions are shown according to the

scores obtained in descending order. The model development requires the selection of attributes and a definition of relationships amongst themselves. The strategy obtaining high scores shall be selected for decision making. The decision in this case is the selection of a strategy for the ABC Company. The next level of the model consists of criteria for selection and evaluation of strategy – the Technical, Marketing and Management branch of the ABC Company. The Technical, Marketing and Management functions are affected by a change in the strategy. The input of all three would result in better utilization of the model and the firm could choose an effective strategy. The next level in the hierarchy consists of the metrics for the comparison of the four strategies.

3. STRATEGY DESCRIPTION

Strategy1: Applying Cost Leadership Strategy

Strategy 2: Product Market Development Strategy

Strategy 3: Strategic Alliance for Technology Acquisition for Cost Competitiveness

Strategy 4: Take Advantage of New Technology to Reduce Cost

Strategy 5: To Develop New Applications by Using Committed Employees and Government Support

Strategy 6: Vertical Integration Strategy

3.1. AHP Approach for Strategic Selection

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process to help people set priorities and make the best Strategy selection when both qualitative and quantitative aspects of a decision need to be considered. An AHP approach to the problem presented below includes the following step:

3.2. Construction of Hierarchy Structure

The problem must be structured into a hierarchy (see figure 2). The first level denotes the overall goal of the decision-maker. The second level consists of several different factors that contribute to this goal. The numbers of factors involved are three factors, which are Technical, Marketing, Organizational. The third level denotes the sub-criteria of each alternative. The last level of the hierarchy then describes the strategic alternatives, which are to be evaluated in terms of the technical, marketing & management criteria.

Fig- 1. Model for Strategy selection

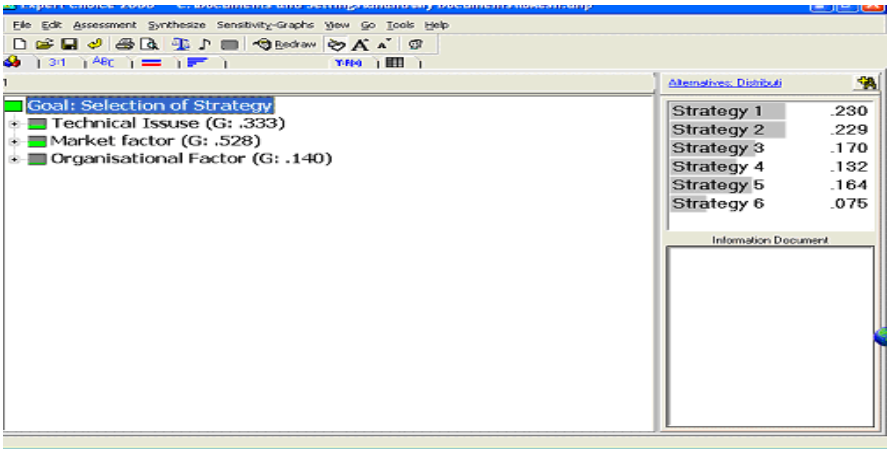
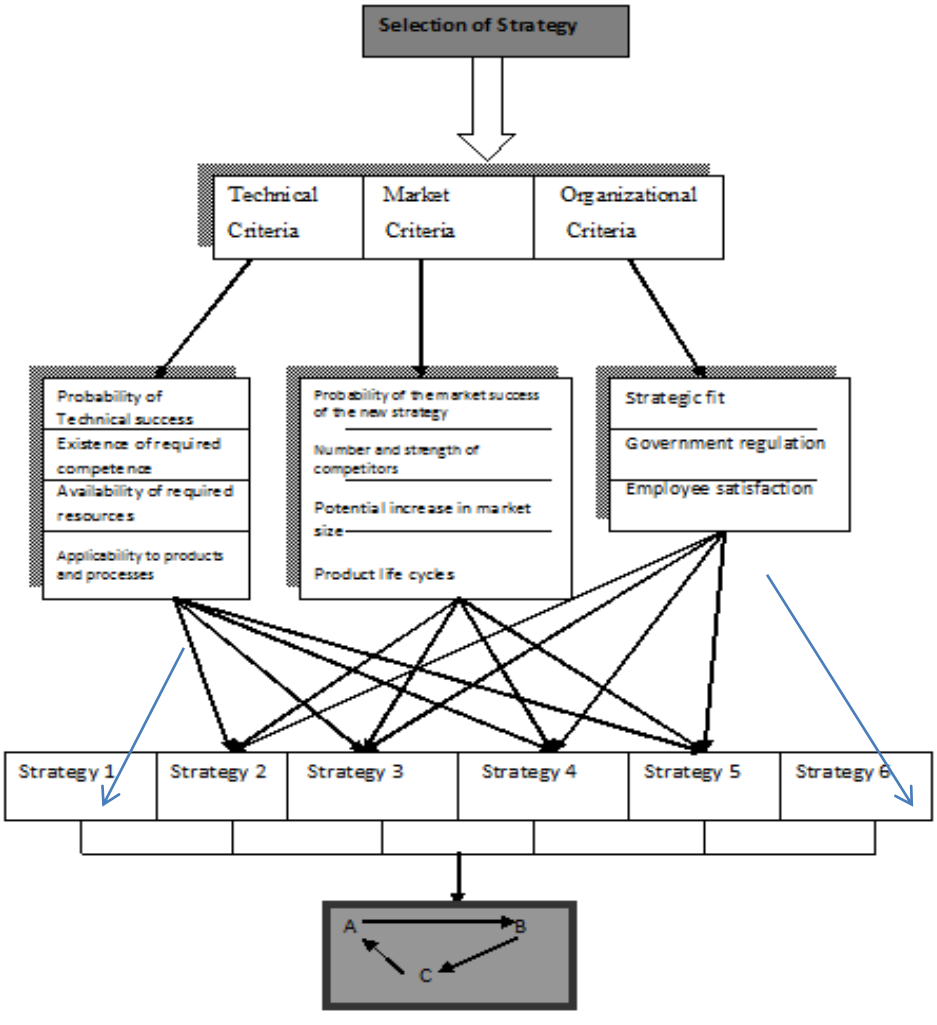


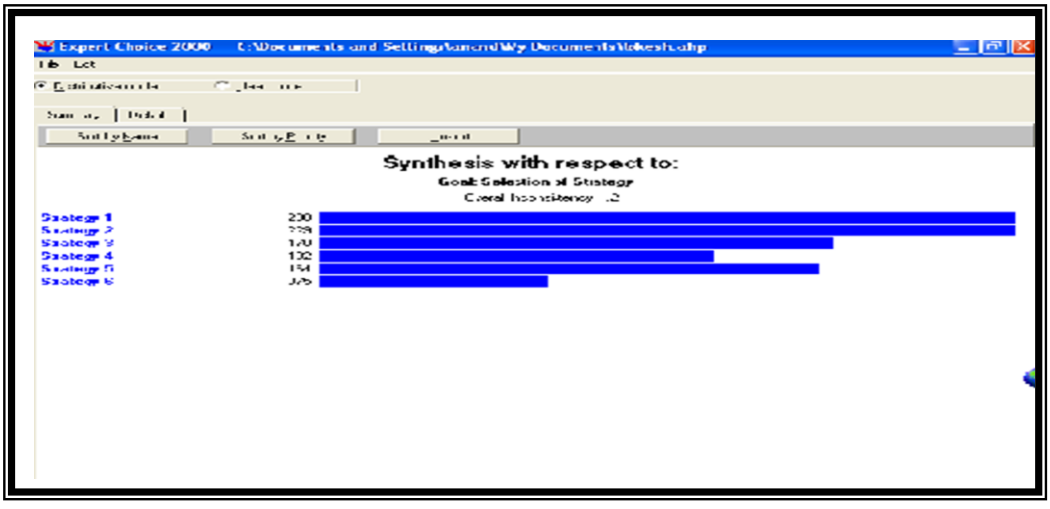
Fig- 2. Hierarchy Structure of problem



3.3. Obtaining the Overall Ranking

AHP gives the overall ranking of the alternative strategies. (Show in fig.3). It gives weightage to 0.231 to strategy1, 0.228(strategy 2), 0.170 (strategy 3), 0.132 (strategy 4), 0.164 (strategy 5) and 0.075 (Strategy 6). The implication is that strategy1 and 2 are quite important, and strategy3 and 5are least important. AHP has not given specific results. Hence further process for evaluation is required. For further evaluation AHP is applied to only 4 strategies: strategy1, strategy 2, strategy 3, and strategy 5.

Fig-3. Final Weightage of Strategies



3.4. ANP Process for Strategy Selection

A model based upon the Analytic Network Process proves useful in this case to model scenario and come up with priorities for different strategies.

Strategy1: Applying Cost Leadership Strategy

Strategy2: Product Market Development Strategy

Strategy3: To Have Strategic Alliance for Technology Acquisition for Cost Competitiveness

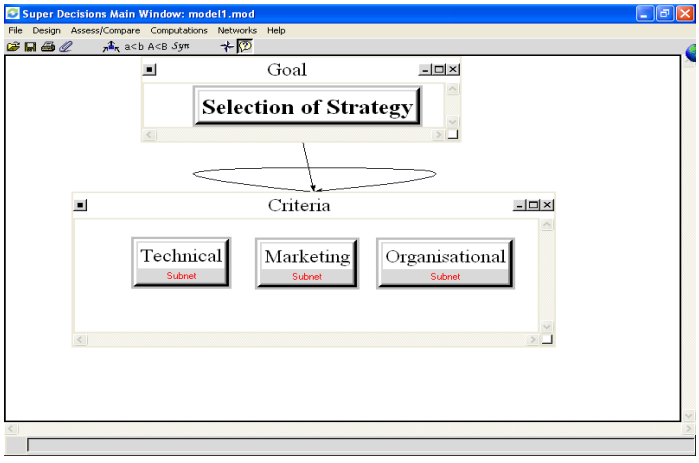
Strategy4: To Develop New Applications by Using Committed Employees and govt. support

An ANP approach to the problem presented below includes the following steps:

4. MODEL CONSTRUCTION

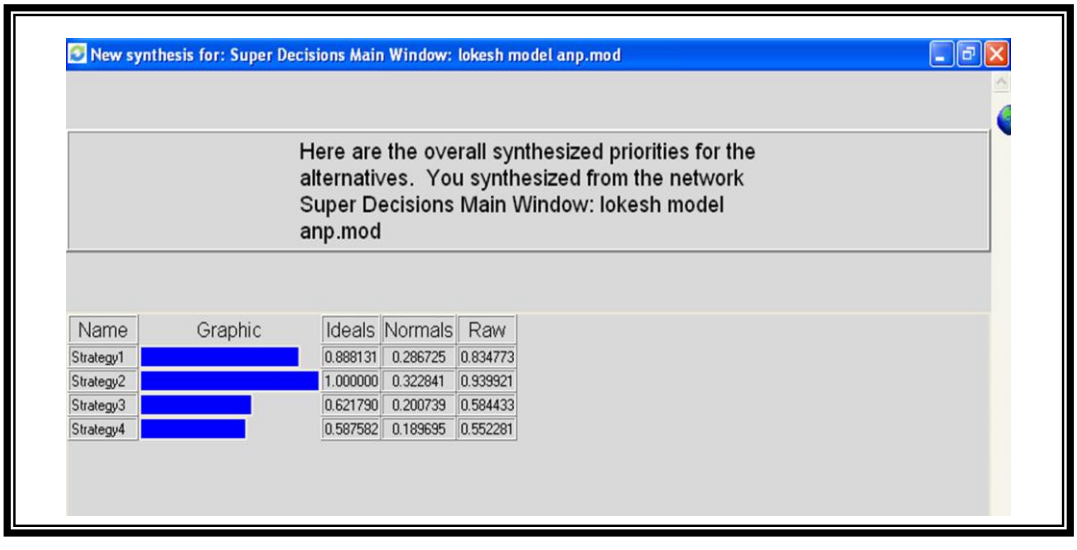
For Modeling Cluster and Sub networks are built in fig 4. The goal and criteria cluster and their interdependence are also shown in the figure.

Fig- 4. Sub Network of Criteria Clusters



The limiting priorities are synthesized by weighing each limiting supermatrix by the weight of its criteria and adding the resulting super matrices. By solving Strategy Selection Problem through ANP, it gives weightage to 0.28 (strategy1), 0.322 (strategy 2), 0.0.20 (strategy 3), and 0.189 (strategy 4). It implies that strategy 2 is best for ABC Company which is Product Market Development Strategy. For achieving the objectives, marketing criteria is more important than Technical and Organization. ABC Company can implement this and gain competitive advantage.

Fig-5. Final score of Strategies



5. IMPLEMENTATION ISSUES

The successful implementation of the strategy invariably requires some degree of change in the organization. If the organization is able to comprehend the present and future better than its rivals, it can manage change better. In a habitat that is changing at a very fast pace, there is a

requirement of unconventional thinking that outsmarts, outpace and outperform the competition. It entails adopting novel approaches of core competence based strategy to source, manufacture, distribute and market a product.

Once strategies have been formulated, the following factors need to be taken care of:

- The top management should cooperate by forming cross functional teams and have effective communication, thereby gaining advantages through synergy. It should achieve business success by building a worldwide community of shared understanding and commitment. It needs to be ensured that right information is provided to all employees in a timely and effective manner.
- The vision and related action plan is to be understood by whole organization.
- Sufficient resources are to be allocated for execution of the strategies.
- Skill of employees needs to be developed through in-house and external training to carry out the action plan efficiently.
- The organization must have a decentralized customer driven structure to cope with the fast changing environment and differing needs of the customers globally. There is a need of more flexible approach wherein managers may have key decision-making power, as they are the people who could best see how individual employees are performing.
- A dedicated team is to be assigned work of value innovation.
- The management processes including performance evaluation, rewards, career management, product development and logistics need to match with strategic plan.
- There has to be a focus on strategic control that requires organization to establish a clear understanding of division of responsibility between the centre and the divisions. The performance management should be everyone's responsibility and the development areas must be reviewed to ensure employees continue to grow and contribute to the organization. The people must be educated and allowed to take different roles.
- Short-term milestones for execution of plan in terms of product launch or profit figures are to be set to create short-term wins.
- Strategy formation to cope with discontinuities in environment and efficient implementation has to be an ongoing process of the organization.
- A self-assessment policy must follow to identify strategic and tactical areas for improvement; also some strategic teams should be formed and made responsible for driving the overall improvement. It must formulate a quality policy for customer to deliver the highest quality products, services and solutions that ensure value and contribute to organization's success

6. CONCLUSION

The SWOT analysis based Strategy presented above aims at generating sustainable competitive advantage in order to develop market and customer awareness. The gap between the

existing and evolved strategy have been identified. The feedback from the organization provided additional information for devising the control actions and filling the gaps. The proposed strategy emphasizes ' Market development', 'Product development through new technology or R&D effort' and 'Cost reduction through analysis of value chain in the ABC Company and be customer focused. Seven strategies are formulated for ABC Company in DPG areas. But ABC Company cannot take all at a time. AHP and ANP Techniques have been used to analyze the appropriate strategy which will help in attaining customer satisfaction and increased market value.

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