Technology Selection for Product Innovation Using Analytic Network Process (ANP)–A Case Study

G. Thangamani, *Member, IACSIT*

***Abstract*—In today's competitive world, the strength of competitiveness of any particular industry is determined by their good innovative products based on new/emerging technologies and their technology development process. This paper describes a decision making methodology using Analytical Network Process (ANP) for technology selection for promising next generation clothes dryer technologies. A holistic decision making framework has been established with criteria such as strategic fit/leverage, performance feasibility, profitability, investment, technology risks and commercial risks. These criteria will also have several other sub-criteria to ensure the model is adequate in all respect. The technology selection by integrating above criteria and their dependencies modelled found to be very useful in evaluating technology options for consumer appliances industries.**

***Index Terms*—Analytic Hierarchy Process, Analytic Network Process, Consumer Appliance, Clothes Dryer, Technology Selection.**

I. Introduction

From late 1990s onwards, developments in home appliances focused on energy efficiency and environmental friendliness. Environmental awareness is at an all-time high and studies had found that home appliances were a major source of electricity consumption and greenhouse gas emissions. Many governments introduced a product labelling program, whereby the energy efficiency of an appliance was clearly displayed. This encouraged consumers to buy the most environmentally-friendly option available. Because of these, the strength of competitiveness of appliances industry is determined by their good technology innovation capability and technology development process meeting these energy/environmental requirements. In the international market and competitiveness of products or industry is directly proportional to its scientific and technological content meeting these needs [1].

This paper describes a technology selection for promising next generation clothes dryer technologies. Clothes dryer is the second most energy consuming household appliance after refrigerator. The purpose of this present paper is to evaluate competing technologies such as infrared heating (IR), microwave and induction heating for the clothe dryer since these are believed to have lower power consumption, reduced drying time, flexibility in drying temperature compared to the existing technology which is based on filament heating element. These new technology options may also have some limitations with respect to their ability to handle different type of clothes and safety in usage etc. The majority of technology selection framework addresses only the financial aspects and does not include other issues related to technology. This approach may be useful for industries where the financial constraint is the biggest since they cannot invest in all the competing technologies. Here, apart from financial aspects performance measures of technologies, strategic fit, performance achievability, technical and commercial risks are also taken into consideration in the selection process. The brief description of heating technologies with reference to clothes dryer is given below.

Manuscript received August 29, 2012; revised October 8, 2012.

G. Thangamani is with Indian Institute of Management Kozhikode (gtmani@iimk.ac.in).

II. Clothes Dryer Moisture Removal Technologies

A. Existing Technology

The clothes dryer or tumble dryer or drying machine is a household appliance that is used to remove moisture from a load of clothing and other textiles, generally shortly after they are cleaned in a washing machine. Traditional dryers continuously draw in the cool, dry, ambient air around them and heat it through filament heater before passing it through tumbler. This hot air removes moisture in the clothes thereby clothes are getting dried. The resulting humid air is usually vented outside to make room for more dry air to continue the drying process. This design makes no effort to efficiently transfer heat and/or recycle the heat put into the load, and thus is considered environmentally detrimental. Nevertheless, this design is simple, reliable, and cheap, and widely used as a result.

B. Microwave Heating Technology

Microwave heating is one of the technology candidates for clothes dryers. Most of the drying may be done using microwaves to evaporate the water, but the final drying has to be carried out by convection to remove water vapours from laundry. There are a number of advantages: shorter drying times (25% less), energy savings (17-25% less), lower drying temperatures. The problem of arcing and fabric damage must be definitively addressed before microwave dryers can be developed for the consumer market.

C. Infrared Heating Technology

In this technology, the back plate of rotating drum will be installed with heating system which comprises infrared lamps/heater each operable to emit infrared radiation with a wavelength ranging 1.2-6.5 micrometers. Dry hot air will also be circulated to remove moist air from the drum. There

DOI: 10.7763/IJIMT.2012.V3.298

several advantages like energy saving (up to 30% less), ability to handle different types of clothes and shorter drying time. Controlling infrared system and optimizing IR heating and hot air circulation could be a challenge in these systems.

D. Induction Heating Technology

High-frequency electricity drives alternating current through a work coil. An intense and rapidly changing magnetic field is created within the area of the coil. A work-piece (or piece that will be heated) is placed within that space. The magnetic current flows through the work-piece creating eddy currents, which create the heat. How much heating can be done depends on the size and type of material the work-piece is made from. As of now, this technology is not fully leveraged for clothes dryer. The system design is very important to harvest the benefit of this technology.

All the above three technology options for clothes dryers are in experimental research studies in various research labs of appliance firms. Since firms can not invest in all the three technologies, they need select one promising technology meeting their needs.

This paper presents Analytic Network Process which structures this decision problem into a network with a goal, decision criteria, and alternatives. It uses a system of pair-wise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision. A brief theory about ANP is given below.

III. Analytic Network Process

The AHP, developed by Saaty [2], is an efficient multi-objective decision-making approach that employs pair-wise comparison to determine the weights and priorities of a variety of factors, attributes, elements and alternatives. The basic assumption is that decision makers are able to structure a complex problem in the form of a hierarchy where each element and alternative can be identified and evaluated with respect to other related elements. By making paired comparisons of the elements in a level in terms of the elements of the next higher level, it is possible to decide on an appropriate choice of that upper level [3]. The detailed explanations on AHP are available in [2]-[7].

The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP) as in [8]. ANP incorporates feedback and interdependent relationships among decision criteria and alternatives. It provides a general framework to deal with decisions without making assumptions about the independence of higher level elements from lower level elements or the independence of the elements within a level as in a hierarchy. This makes ANP more realistic compared with AHP. In fact, many real world decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements in a hierarchy on lower-level elements. Therefore, ANP is represented by a network, rather than a hierarchy.

ANP network is structured of clusters, elements, and links. A cluster is a collection of relevant elements within a network or sub-network with the elements in one cluster being connected to elements in another cluster (outer dependence) or the same cluster (inner dependence) [8].

The relative importance of elements with reference to a criterion is the central concept in ANP. The fundamental scale used in AHP is provided in Table I. The pair-wise comparisons are made systematically including all the combinations of element/cluster relationships. The fundamental comparison scale (1-9) is used in ANP which is similar to AHP. It is a scale of absolute numbers. The decision maker can express his preference between each pair of elements verbally as equally important, moderately more important, strongly more important, very strongly more important, and extremely more important. These descriptive preferences would then be translated into numerical values 1, 3, 5, 7, 9, respectively, with 2, 4, 6, and 8 as intermediate values for comparisons between two successive judgments. Reciprocals of these values are used for the corresponding transposed judgments.

After pair-wise comparison is completed, the ANP approach handles interdependence among elements by obtaining the composite weights through the development of a "Supermatrix". The complete ANP process was implemented in form of software called Super Decisions created (as in [9]) to alleviate the mathematical burden. This paper has used Super Decision software to analyze our technology selection problem. The Super Decisions software was selected for analysis since it implements the Analytic Network Process for decision making with dependence and feedback loops and it is developed by Saaty and his team.

TABLE I: THE FUNDAMENTAL SCALE OF THE AHP

Intensity of relative importance	Definition	Explanation
1	Equal importance	The two elements constitute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one element over another
5	Strong importance	Experience and judgment strongly favour one element over another
7	Very strong importance	An element is favoured very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjustment judgments	
Reciprocals of the above	If the element *i* has one of the above nonzero numbers assigned to it when compared with the element *J*, then *j* has the reciprocal value when compared with the element *i*	A reasonable assumption

IV. Literature Review

Some of the important literatures useful to this study are presented here. Reference [10] presented a detailed literature review of recent applications of the AHP and ANP decision making methodologies. Their finding showed that during the years 2005-2009, the use of the AHP technique had continued to increase exponentially and is expected that ANP will gain more popularity in the future. AHP integrated with mathematical programming, quality function deployment (QFD), meta-heuristics, SWOT analysis and data envelopment analysis (DEA) literatures are reviewed by [11].

It is a known fact that supplier selection problems are multi-objective problems which have many qualitative and quantitative concerns. Reference [12] used ANP in vendor selection decisions. Reference [13] has presented a comprehensive method for evaluation and selection of supplier's offers in pharmaceutical industry using ANP. Reference [14] reviewed many literatures in supplier selection.

A decision tool using ANP to make informed decisions regarding in advanced manufacturing technologies is developed by [15]. This model is helping to select the most appropriate technology for adoption. Reference [16] introduced decision criteria of knowledge management (KM) strategies and applied ANP to strategy selection problem as a framework to guide KM managers. A new concept called Technology development envelope (TDE) was proposed by [17] and [18]. They have integrated AHP into the TDE framework to transform roadmapping approach to the level in which it is dynamic, flexible and operationalizable. Technology roadmapping is a needs driven technology planning process to help, identify, select, and develop technology alternatives to satisfy a set of product needs. It brings together a team of experts to develop a framework for organizing and presenting the critical technology planning information to make the appropriate technology investment decisions. TDE is a concept and methodology for identifying the optimum path in developing technology strategies and combining them with business strategies and/or policy decisions.

A. *Research Motivation*

From the review of research papers, it is found that most of the papers dealt with the applications of AHP and ANP. The application fields include education, logistics, e-business, IT, R&D, telecommunication industry, finance, banking, urban management, government, marketing and mining industry. To our best of knowledge, no single application was available for technology selection for consumer appliance industry. Also, there is no much of literature using holistic approach considering criteria such as strategic fit/leverage, performance feasibility, profitability, investment, technology risks and commercial risks. This motivated this research case study on prioritizing the best technology for next generation clothes dryer. Such research will help managers to make best decisions in their front end of innovations.

V. The Methodology for Technology Selection

The ANP methodology is explained in step-by-step approach as given below. The intricacies of the approach are not explained since detailed explanations are available in the literatures by [8], [9] and [19].

Step 0—Identify the objectives of decision model:

The objective of this model is to find the best technology suitable for next generation clothes dryer. Three technologies such as Infra red heating, Microwave heating nd Induction heating are indentified as potential candidates. The description of these technologies and their pros and cons are already provided.

Step 1—Identification of the selection criteria:

As a first step, the decision maker should identify a list of selection criteria for evaluating these technologies. The chosen criteria are given below.

- Strategic fit/leverage
- Key performance achievability
- Profitability
- Investment
- Technology risks
- Commercial risks

Step 2—Model construction:

Model construction provides structure to the problem to be evaluated. Each of the criteria is further divided into several sub-criteria. The list criteria and their sub-criteria are provided in the Table II. The objectives, criteria, sub-criteria and alternatives are clustered into clusters. Hence, in this model, one cluster for objective, one cluster for all the evaluation criteria and each of the evaluation criteria with their sub-criteria constitute clusters. The alternatives are grouped into one cluster. The overall ANP model is provided in the Fig. 1. The graphical look of the model in Super Decision is given in Fig. 2. Interdependencies are represented by straight arrows among the clusters and a looped arc within same cluster. The direction of the arcs signifies dependence between the clusters.

TABLE II: List of Criteria, Sub-Criteria and Their Abbreviation

Clusters	Notation	Abbreviation
Evaluation Criteria	Strategy fit/leverage	SFL
	Key performance achievability	KPA
	Profitability	PRO
	Investment	INV
	Technology risks	TRS
	Commercial risks	CRS
Strategy fit/leverage	Business impact	BIM
	IP potential	IPP
	Platform for growth	PFG
Key performance	>= 30% energy savings potential	ESP
	Drying time reduction feasibility	DTR
	Able to handle all types of clothes	AHC
	Safe to use	STU
Profitability	Contribution to profitability	CTP
	Pay back period	PBP
	Time to market	TTM
Investment	R & D investment required	RDI
	R & D staff strength required	RDS
Technology risk	Technical gap	TGP
	Availability of competency	COM
Commercial risk	Market need and acceptance	MNA
	Regulatory impact	RIM
	Competitive intensity	CIN

Step 3—Performing pair-wise comparisons between the clusters/elements:

After formulating the model, the next step is to perform pair-wise comparison between clusters, criteria, sub-criteria and alternatives as per linkage provided in ANP model. To determine importance of the decision criteria with respect to the overall objective, pair-wise comparison is made. The scale used for this subjective judgment is provided in the Table I and the same is recommended by [5]. Several questions were posed to the decision maker to determine which criterion contributes more to the overall objective and the selection of the best technology alternatives. The sample question may be "With respect to the goal of selecting the best technology for clothes dryer, what is the relative importance of Strategy fit/leverage (SFL) to Key Performance Achievability (KPA). If the answer is (1/9) means the decision maker believes KPA is "Extremely important" relative to SFL. Table III illustrates the example of pair-wise comparison matrix of the criterion for the best technology for clothes dryer. It shows that KPA has the most influence on the best technology for clothes dryer with the priority of 0.350, followed by commercial risk (CRS) with 0.320. These local priorities are calculated using the procedure recommended by [5].

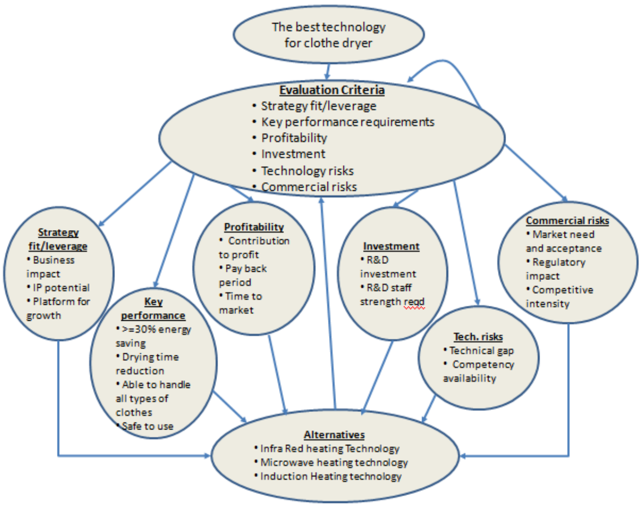

Fig. 1. The overall ANP model


Fig. 2. The overall ANP model construction in Super Decision

TABLE III: PAIR-WISE COMPARISON OF EVALUATION CRITERIA WITH RESPECT TO OBJECTIVE

	SFL	KPA	PRO	INV	TRS	CRS	Priorities
SFL		1/9	1/6	1/7	1/8	1/8	0.022
KPA			7	7	3	1	0.350
PRO				2	1/2	1/7	0.076
INV					1/7	1/7	0.055
TRS						1/2	0.177
CRS							0.320

Table IV shows the pair-wise comparison matrix for the alternatives with respect to business impact (BIM). In comparing the three technologies based on business impact, the decision maker was asked which technology is more preferred with respect to determining the best technology under business impact criterion.

Table III and IV are sample pair-wise comparison tables and their local priorities. The other comparisons are not provided because of page limitations. However these local priorities are available in the unweighted Supermatrix.

TABLE IV: COMPARING ALTERNATIVES WITH RESPECT TO BUSINESS IMPACT CRITERION

	IRT	MWT	IHT	Priorities
IRT		4	1	0.444
MWT			1/4	0.111
IHT				0.444

Step 4—Formation of the Unweighted Supermatrix:

In the Unweigted Supermatrix, the priorities of the elements are arranged both vertically and horizontally according to the clusters. The paired comparison provides vector will become part of the column in Supermatrix. This represents the impact, with respect to the control criterion of the elements of that cluster on a single element of the same or another cluster, listed at the top. The Supermatrix for our model is provided in the Table V.

Step 5—Formation of the weighted Supermatrix:

The weighted priorities at the clusters priority matrix are used to weight all the elements in the block of column priorities of the Supermatrix corresponding to the impact of the elements of that cluster on another cluster. This process is repeated for all the clusters resulting in the weighted Supermatrix. The weighted Supermatrix are provided in the Table VI.

Step 6—Formation of limiting matrix:

Now, we want to obtain final influence of an element on the highest goal. The limiting matrix and the system's solution derives from multiplying the weighted Supermatrix (step 5) by itself, which accounts for variable interaction, until the system's raw values converge to the same value for each column of the matrix. This "power method" process yields the limiting matrix, which provides the relative importance weights for every element in the model. The limiting matrix is provided in the Table VII.

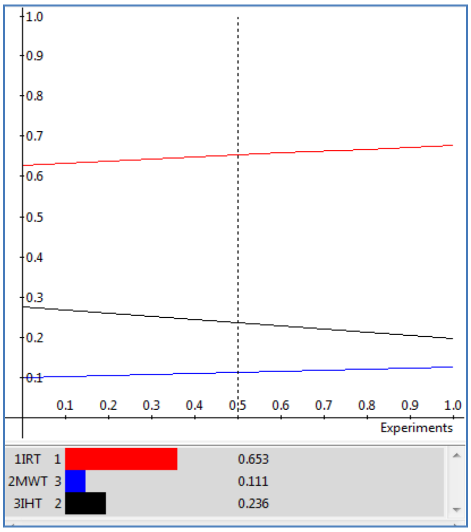

Fig. 3. Sensitivity graph for energy saving potential

Step 7—Sensitivity analysis on the final outcome:

One can do the sensitivity analysis to determine whether the final answer is stable with respect to changes in the inputs either judgments or priorities. We would be interested, if there is any change in the alternatives because of input changes. Fig. 3 shows the sensitivity graph of the technology selection model for Energy Saving Potential (ESP). The priorities of alternatives are plotted on the Y axis, with respect to the different experiments of the element (X axis) i.e. changes in priorities of ESP. The graph shows that no matter what the value of priorities of ESP, IRT remains the dominant alternative. Performing similar sensitivity analysis for other control criteria led to the conclusion that the outcome is very stable and does not change the overall ranks.

TABLE V: UNWEIGHTED SUPERMATRIX

		1Goal	2Criteria						3Sub-criteria - SFL			4Sub-criteria - KPA				5Sub-criteria - PRO			6Sub-criteria - INV		7Sub-criteria - TRS		8Sub-criteria - CRS			9Alternatives		
		The best technology for dryer	1SFL	2KPA	3PRO	4INV	5TRS	6CRS	1BIM	2IPP	3PFG	4ESP	5DTR	6AHC	7STU	8CTP	9PBP	10TTM	11RDI	12RDS	13TGP	14COM	15MNA	16RIM	17CIN	1IRT	2MWT	3IHT
1Goal	The best technology for dryer	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2Criteria	1SFL	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.068	0.057
	2KPA	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.447	0.414	0.383
	3PRO	0.076	0.000	0.127	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.114	0.244
	4INV	0.055	0.000	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.058	0.065	0.076
	5TRS	0.177	0.000	0.272	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.184	0.147	0.120
	6CRS	0.320	0.000	0.548	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.208	0.193	0.120
3Sub-criteria - SFL	1BIM	0.000	0.733	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2IPP	0.000	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3PFG	0.000	0.199	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4Sub-criteria - KPA	4ESP	0.000	0.000	0.246	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5DTR	0.000	0.000	0.189	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6AHC	0.000	0.000	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	7STU	0.000	0.000	0.431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5Sub-criteria - PRO	8CTP	0.000	0.000	0.000	0.528	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	9PBP	0.000	0.000	0.000	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	10TTM	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6Sub-criteria - INV	11RDI	0.000	0.000	0.000	0.000	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	12RDS	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7Sub-criteria - TRS	13TGP	0.000	0.000	0.000	0.000	0.000	0.857	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	14COM	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8Sub-criteria - CRS	15MNA	0.000	0.000	0.000	0.000	0.000	0.000	0.729	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	16RIM	0.000	0.000	0.000	0.000	0.000	0.000	0.163	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	17CIN	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9Alternatives	1IRT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.260	0.717	0.682	0.773	0.467	0.287	0.725	0.696	0.649	0.778	0.725	0.778	0.725	0.641	0.467	0.550	0.000	0.000	0.000
	2MWT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.327	0.088	0.216	0.139	0.067	0.078	0.125	0.075	0.072	0.111	0.125	0.111	0.125	0.067	0.067	0.210	0.000	0.000	0.000
	3IHT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.413	0.195	0.103	0.088	0.467	0.635	0.150	0.229	0.279	0.111	0.150	0.111	0.150	0.293	0.467	0.240	0.000	0.000	0.000

TABLE VI: WEIGHTED SUPERMATRIX

		1Goal	2Criteria						3Sub-criteria - SFL			4Sub-criteria - KPA				5Sub-criteria - PRO			6Sub-criteria - INV		7Sub-criteria - TRS		8Sub-criteria - CRS			9Alternatives		
		The best technology for dryer	1SFL	2KPA	3PRO	4INV	5TRS	6CRS	1BIM	2IPP	3PFG	4ESP	5DTR	6AHC	7STU	8CTP	9PBP	10TTM	11RDI	12RDS	13TGP	14COM	15MNA	16RIM	17CIN	1IRT	2MWT	3IHT
1Goal	The best technology for dryer	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2Criteria	1SFL	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.068	0.057
	2KPA	0.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.447	0.414	0.383
	3PRO	0.076	0.000	0.064	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.114	0.244
	4INV	0.055	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.058	0.065	0.076
	5TRS	0.177	0.000	0.136	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.184	0.147	0.120
	6CRS	0.320	0.000	0.274	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.208	0.193	0.120
3Sub-criteria - SFL	1BIM	0.000	0.733	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2IPP	0.000	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3PFG	0.000	0.199	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4Sub-criteria - KPA	4ESP	0.000	0.000	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	5DTR	0.000	0.000	0.094	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	6AHC	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	7STU	0.000	0.000	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5Sub-criteria - PRO	8CTP	0.000	0.000	0.000	0.528	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	9PBP	0.000	0.000	0.000	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	10TTM	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6Sub-criteria - INV	11RDI	0.000	0.000	0.000	0.000	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	12RDS	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7Sub-criteria - TRS	13TGP	0.000	0.000	0.000	0.000	0.000	0.857	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	14COM	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8Sub-criteria - CRS	15MNA	0.000	0.000	0.000	0.000	0.000	0.000	0.729	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	16RIM	0.000	0.000	0.000	0.000	0.000	0.000	0.163	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	17CIN	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9Alternatives	1IRT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.260	0.717	0.682	0.773	0.467	0.287	0.725	0.696	0.649	0.778	0.725	0.778	0.725	0.641	0.467	0.550	0.000	0.000	0.000
	2MWT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.327	0.088	0.216	0.139	0.067	0.078	0.125	0.075	0.072	0.111	0.125	0.111	0.125	0.067	0.067	0.210	0.000	0.000	0.000
	3IHT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.413	0.195	0.103	0.088	0.467	0.635	0.150	0.229	0.279	0.111	0.150	0.111	0.150	0.293	0.467	0.240	0.000	0.000	0.000

TABLE VII: LIMIT SUPERMATRIX

		1Goal	2Criteria						3Sub-criteria - SFL			4Sub-criteria - KPA				5Sub-criteria - PRO			6Sub-criteria - INV		7Sub-criteria - TRS		8Sub-criteria - CRS			9Alternatives		
		The best technology for dryer	1SFL	2KPA	3PRO	4INV	5TRS	6CRS	1BIM	2IPP	3PFG	4ESP	5DTR	6AHC	7STU	8CTP	9PBP	10TTM	11RDI	12RDS	13TGP	14COM	15MNA	16RIM	17CIN	1IRT	2MWT	3IHT
1Goal	The best technology for dryer	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2Criteria	1SFL	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	2KPA	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
	3PRO	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
	4INV	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
	5TRS	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
	6CRS	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
3Sub-criteria - SFL	1BIM	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
	2IPP	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3PFG	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
4Sub-criteria - KPA	4ESP	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
	5DTR	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	6AHC	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
	7STU	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
5Sub-criteria - PRO	8CTP	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
	9PBP	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
	10TTM	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
6Sub-criteria - INV	11RDI	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
	12RDS	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
7Sub-criteria - TRS	13TGP	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
	14COM	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
8Sub-criteria - CRS	15MNA	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
	16RIM	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
	17CIN	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
9Alternatives	1IRT	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199
	2MWT	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
	3IHT	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080

VI. RESULTS AND DISCUSSION

The priority vector for the alternatives in the network is provided by Super Decision software after doing pair-wise comparison. The synthesized priority vector for the alternatives over all the subnets is calculated. Table VIII provides the weights of the subnets. The "Normalized by cluster" refers to the weights of each alternative in each top level cluster. The "Limiting" refers to total weights of each alternative. From Table VII, the decision makers can understand which criterion needs more attention and which alternative is better than others under certain criterion.

The priorities provided by the current evaluation of technologies are 0.64 for infrared heating, 0.256 for induction heating technology and 0.104 for microwave heating technology. From this analysis, it is very clear that the firm has to focus on infrared heating technology for their next generation clothes dryer. The various priorities of criteria and sub-criteria shall be obtained from Table VIII.

TABLE VIII: THE PRIORITIES OF VARIOUS SUB-NETS

Name	Normalized By Cluster	Limiting
1SFL	0.030	0.011
2KPA	0.352	0.133
3PRO	0.125	0.047
4INV	0.062	0.023
5TRS	0.183	0.069
6CRS	0.248	0.094
1BIM	0.733	0.008
2IPP	0.068	0.001
3PFG	0.199	0.002
4ESP	0.246	0.016
5DTR	0.189	0.013
6AHC	0.135	0.009
7STU	0.431	0.029
8CTP	0.528	0.025
9PBP	0.140	0.007
10TTM	0.333	0.016
11RDI	0.800	0.019
12RDS	0.200	0.005
13TGP	0.857	0.059
14COM	0.143	0.010
15MNA	0.729	0.068
16RIM	0.163	0.015
17CIN	0.109	0.010
1IRT	0.640	0.199
2MWT	0.104	0.032
3IHT	0.256	0.080

VII. CONCLUSION

This paper analyses the characteristics of the technology selection for the next generation clothes dryer. It uses a comprehensive and objective methodology for selection process. Six major criteria and 17 sub-criteria are used in the ANP model. Inner dependence of criteria themselves and alternatives influence over criteria are considered. The priorities of various criteria and alternatives are obtained. Sensitivity analysis is also carried out for few criteria. One of the major limitations of ANP approach is that if the number of criteria and alternatives increases, one has to perform several pair-wise comparisons which increase the effort. Clustering of criteria and alternatives will help to lessen the effort to certain extent. The proposed holistic ANP approach for technology selection for clothes dryer can be used as a methodology for other technology comparisons for consumer appliances to order for the firm to short list their technology options to bring innovations in their products.

REFERENCES

[1] B. Li and R. Bi, “Using ANP to evaluate technology innovation,” in *Proc. 2009 International Conference on Future BioMedical Information Engineering,* 2009, pp. 272-275.

[2] T. L. Saaty, *The analytic hierarchy process,* New York: McGraw-Hill, 1980.

[3] A. S. Alidi, “Use of the analytic hierarchy process to measure the initial viability of industrial projects,” *International Journal of Project Management*, vol. 14, pp. 205-208, 1996.

[4] T. L. Saaty, “How to make decision: The analytic hierarchy process,” *European Journal of Operational Research*, vol. 48, pp. 9-26, 1990.

[5] T. L. Saaty, *Decision making for leaders: The analytic hierarchy process for decisions in a complex world,* Pittsburgh, PA: RWS publications, 1995.

[6] T. L. Saaty, “Decision making with the analytic hierarchy process,” *International Journal of Services Sciences,* vol. 1, no. 1, pp. 83-98, 2008.

[7] T. L. Saaty, *Fundamentals of Decision Making with the Analytic Hierarchy Process*, Pittsburgh, PA: RWS Publications, 2000.

[8] T. L. Saaty, “Fundamentals of the analytic network process”, in *Proc. ISAHP, Kobe, Japan*, August 12-14, 1999.

[9] T. L. Saaty, *Super Decisions Software,* Pittsburgh, PA: RWS Publications, 2004.

[10] S. Sipahi and M. Timor, “The analytic hierarchy process and analytic network process: an overview of applications,” *Management Decisions,* vol. 48, no. 5, pp. 775-808, 2010.

[11] W. Ho, “Integrated analytic hierarchy process and its applications – A literature review,” *European Journal of Operational Research,* vol. 186, pp. 211-228, 2008.

[12] O. Bayazit, “Use of analytic network process in vendor selection decisions,” *Benchmarking: An International Journal*, vol. 13, no. 5, pp. 566-579, 2006.

[13] K. Kirytopoulos, V. Leopoulos, and D. Voulgaridou, “Supplier selection in pharmaceutical industry: An analytic network process approach,” *Benchmarking: An International Journal*, vol. 15, no. 4, pp. 494-516, 2008.

[14] H. Jun and J. Peng, “Application of supplier selection based on the AHP theory,” in *Proc. IEEE International Symposium on Knowledge and Acquisition and Modelling Workshop,* December 21-22, 2008.

[15] S. M. Ordoobadi, “Application of ANP methodology in evaluation of advanced technologies,” *Journal of Manufacturing Technology Management*, vol. 23, no. 2, pp. 229-252, 2012.

[16] S. Percin, “Use of analytic network process in selecting knowledge management strategies,” *Management Research Review,* vol. 33, no. 5, pp. 452-471, 2010.

[17] N. Gerdsri, “An analytic approach to building a technology development envelope (TDE) for roadmapping of emerging technologies,” *International Journal of Innovation and Technology Management*, vol. 4, no. 2, pp. 121-135, 2007.

[18] N. Gerdsri and D. F. Kocaoglu, “Applying the analytic hierarchy process (AHP) to build a strategic framework for technology roadmapping,” *Mathematical and computer modelling,* vol. 46, nos. 7/8, pp. 1071-1080, 2007.

[19] T. L. Saaty, *Theory and Applications of the Analytic Network Process. Decision Making with Benefits, Opportunities, Costs and Risks*, Pittsburgh, PA: RWS Publications, 2005.

G. Thangamani is working as a faculty in Indian Institute of Management Kozhikode. He obtained his Ph.D. from IIT Madras and his thesis is entitled "Models for assessment of Reliability Measures for Complex Systems". He earned his Bachelor degree in Mechanical Engineering with Honours for scholastics achievements and did his M.E in Industrial Engineering from Anna University, Chennai. He started his career as a faculty in Pondicherry Engineering College, Pondicherry for 4 years. Later on, he was associated with some of the best companies in the world such as Whirlpool and GE. His research interests are in Complex System Reliability Prediction, Business Process Modeling, Analysis & Reengineering, Six Sigma, Lean approaches in manufacturing / service systems and product innovation and technology management. He has several publications in international journals and conferences.