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DECISION MAKING IN PRODUCT DEVELOPMENT – A REVIEW OF THE LITERATURE

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ABSTRACT

For an effective product development process which identified the need of the customer, transferring the need to a product and making it producible, complex decisions are involved identifying reliable alternatives. In an intense market race, front loading of decision making is becoming more and more important to gain a strategic advantage position and to secure competitive power. It can be said that front loading of design decision making contributes greatly to the communication inside and outside a company when it practices a business philosophy and a business domain.(Kawarabayashi, et al, 2007) An important decision for many products is the specification of the product architecture which defines the primary modules and the interfaces between them. This decision not only affects the design of the product but also the process that will be followed during the rest of the product development project. Different processes launch different set of information-processing and decision making activities.

The focus of this paper is to study the available decision making models/tools which are proposed by the various researches for product development processes. A loosely structured method was adopted as a mechanism for surveying the literature. The research and literature review papers and essays related to the decision making in the design and product development of the engineering design, operational management and the apparel design and product development from the journals were reviewed.

It has acknowledged that the product development models are the usual approach to managing the product development organization, process, activities, tasks, and decision making in a sequential manner in order to decide the design of a product, how it should be manufactured and sold.

Key words – decision making, design, product development, models,

1. INTRODUCTION

As Ko(2010) believes traditionally, a product is designed based on the designer's experience and inspiration of artistic work and the final decision is made based on the manager's intuitive judgment of and subjective feeling. Further he outlines the following disadvantages. In intuitive approach

a) Right idea rarely comes at the right moment since it cannot be elicited at will
b) The results depends strongly on individual talent and experience
c) There is a danger that solutions will be circumscribed by one's special training and experience. (Ko, 2010)

The design problem (the consumer or the client) and the design solution (the finished product) which are interrelated is the important element about design thinking. The users' functional, aesthetical and economical requirements need to be understood by the designers. For an effective product development process which identified the need of the customer, transferring the need to a product and making it producible, complex decisions are involved

identifying reliable alternatives. As Almendra & Christiaans(2009) believe the designers and product developers have to make countless decisions which have a tremendous impact on the quality of the design solution and on the company's success on the market. Derelov(2009) highlights that decisions that are made in conceptual phase of the design process is crucial, since a decision made in the phase will act as a watershed for future activities of the process. He emphasis that a decision in the early phases of the design process has a relatively higher effect on the final result compared to a decision at the end of the design process since the ability to change the product becomes limited as design decisions are made. Adding more, he states that Decisions made early are the more important ones and should direct the work towards the most fitting alternatives in order to avoid unnecessary and time- consuming iterations

When examining the area of design decision making there have been traditionally, two main theoretical perspectives that could be adopted; the rationalistic and the naturalistic perspectives. Rational decision making is that one can generate a series of alternatives and use clear and discernible criteria to evaluate which of the solutions maximizes the utility and minimizes the cost. This emphasizes the importance of situational pressures and how people deal with complex cognitive functions in realistic settings. Naturalistic decision making is not realistic. (Hassard, Blandford, & Cox, 2009)

A company concentrates its strength in shortening a product development cycle, in order to develop the new products earlier and to timely introduce them to the markets. In an intense market race, front loading of decision making is becoming more and more important to gain a strategic advantage position and to secure competitive power. It can be said that front loading of design decision making contributes greatly to the communication inside and outside a company when it practices a business philosophy and a business domain.(Kawarabayashi, et al., 2007)

Hermann(2002) states that the poor decisions during product development leads to products that no one wants to buy and products that are expensive to manufacture in sufficient quantity and manufacturing firms understand that design decisions (though made early in the product life cycle) have excessive impact on the profitability of a product over its entire life cycle.

However there is no structured approach described in order to support decision making on generic fundamental decision making level. As Eriksson(2009) identifies the relationship between decision making success and product development process success is vital to clarify in order to create a decision- making system within a product development context. However it is not clear.

The focus of this paper is to study the available decision making models/tools which are proposed by the various researches for product development processes.

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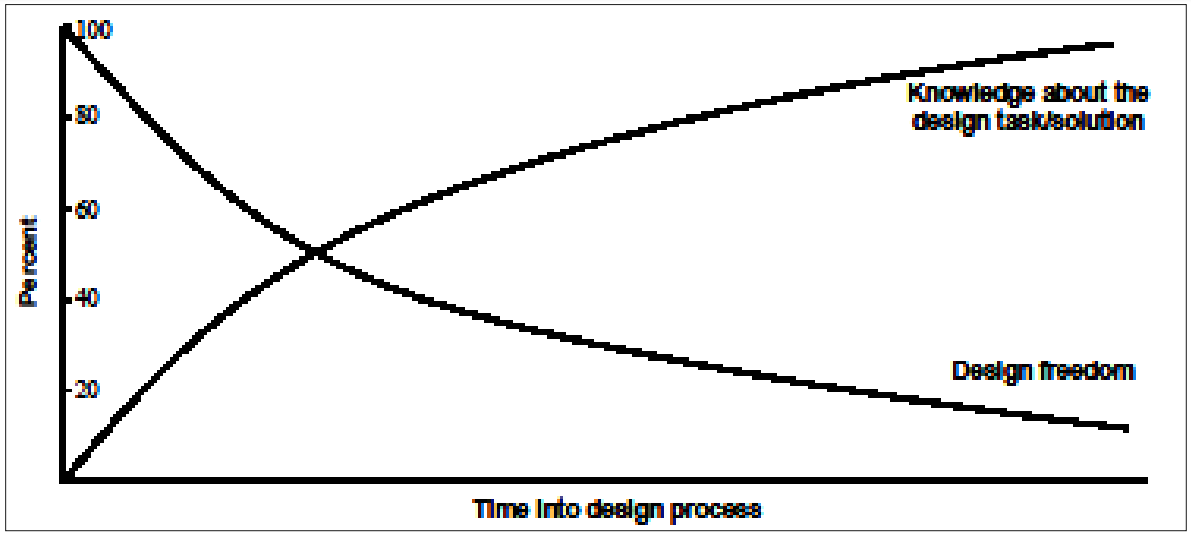

Fig 1- The ability to change the product with respect to time (adapted from Derelov 2009)

2. RESEARCH METHODOLOGY

A loosely structured method was adopted as a mechanism for surveying the literature. The research and literature review papers and essays related to the decision making in the design and product development of the engineering design, operational management and the apparel design and product development from the journals were reviewed. The books, thesis collections which were available on libraries as well as with the use of online data bases were used.

3. DISCUSSION

3.1Decision making in general

Drummond (1994) defines decision as resolving a specific choice or course of actions. Decisions vary in importance. They may be fundamental, intermediate or minor. Decisions may be under certainty, under risk, under uncertainty. A decision is a precise moment during a continuous process of evaluating alternatives. For practical purposes two broad categories of decisions exists. They are programmed and unprogrammed.

- Programmed decisions – a simple routine matter for which a manager has an established decision rule
- Un programmed decisions – anew complex decisions that require a creative solution

The decisions may be strategic or operational. The strategic decisions focus on organizational policy and directions while operational decisions focus on day to day management. Greenwood (1969) presented two decision frameworks; namely open and closed. In a closed decision framework a known set of alternatives and one or several courses of actions are selected by a rational selection process. Open decision frame work is more complex which is called adaptive. Decisions can be categorized into two types ; adaptive decisions and routine decisions. Derelov(2009) argued that there are at least three conditions should be fulfilled before making a decision.

a) There should be alternatives – the decision situation is defined by the selection between different alternatives.
b) The alternatives should lead to different consequences – The consequences must be determined and have no differ from each alternative
c) There should be desired consequences (goals) – For each decision, some consequences must be more preferable than others. Select the best to fulfill the desired consequences.

Eriksson(2009) has identified criteria for achieving a high quality decisions. They are committed decision – maker, the right frame, the right alternatives, the right information, clear

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preferences, right decision procedures. Decisions can be divided into categories depending on the nature of the decision.

As Kihlander(2009) believes decision making is vast area that can be treated from several perspectives and scientific approaches such as psychology and cognition that deal with the human behavior and cognitive processes, or rational mathematical areas where decision making always strives for maximized and optimized utility. Decision making is the process of or the action of selecting the best among alternatives in order to solve problems. Therefore the orientation of decision making is the problem solving and what is involved in the decision making is the selection. Paryani(2007) defines the decision making as a process of choosing among alternative courses of actions or choices for the purpose of attaining a goal or goals. Drummond(1994) defined the decision making as creating events and shaping the future and the decision making process concerns events leading up to the moments of choice and beyond.

Decision theory helps to save time in the decision making process. That is because instead of wasting time on insignificant details it focuses on those points that matter. Decision theory is an interdisciplinary research area aimed at understanding decision making. It draws knowledge from mathematics, psychology, economics and other areas in order to better understand how to produce satisfactory outcome under certain conditions.(Tang ,2006) Simon (1959) outlines the decision making process as intelligence, design & choice. Intelligence is the search for understanding the problem, design is the development of alternatives and choice is the analysis of alternatives and choice of implementation. Marsh (1997)see the decision making process as Guesses about future consequences. Three distinct branches of scientific decision making theories . they are the Normative, descriptive & Prescriptive.

a. Normative – calculation of subjective value ,The outcome is not considered to be an evaluative factor to measure. Decision making process cannot be control and the influencing factors / forces cannot be control or oversee. Therefore the outcome is not appropriate for evaluative factor in decision quality.
b. Descriptive – how and why people decide. Difficulty, missed opportunities and good results are important factors of decision quality.
c. Prescriptive – mainly considered as decision analysis. This is concerned with application of normative and descriptive decision theory in real situation.

3.2 Decision making models in general

To provide information for decision making purposes decision making models, a simplified representation of reality, are used by decision makers. More over decisions models are used to provide insight about decision situations and to support the decisions made.

As Acar(2008) states that ,in the beginning of decision making models, models were used to minimize costs on continuous bas, introduction of new technologies, improving quality and concentrate on the companies, own competitive advantage. He reports four models outlined recent studies

a. Deterministic analytical models(Cohen & Lee,1989) - The deterministic analytical models attributed to this fact due to the simplicity of mathematical figures which formed as input.
b. Stochastic analytical models(Lee et al 1993) - Stochastic analytical models where figures on statistical data calculated in a normal distribution were used in a later stage.
c. Economic models (Christy & Grout, 1994) - Economic models were the last new typology an administer as a decision model.
d. Simulation models(Towill,1991) - The reason why simulation models were added was due to the technological development starting from the 1990's, were computers could be used to test the models in a real time environment (Acar, 2008)

Starkey (1992) outlined three general types of models as well as six specific types of models used in decision making,

General types of models

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a) ICONIC - physical representation os an item
b) ANALOGUE – used to demonstrate dynamic situations
c) SYMBOLIC – mathematical models

Specific types of models

a) Descriptive – represent functional relationship , do not recommend any course of action
b) Behavioral - represent the response to a system to an initial disturbance
c) Deterministic – functional relationship are known with certainty
d) Stochastic- based on probability
e) Simulation – imitative model used to analyze a specific problem
f) Optimization – used to select most appropriate strategy . they recommend course of action(prescriptive model) it contains 3 elements – decision variables/parameters, constraints, objective function (.....2)

Almendra & Christiaans (2009) identified three distinctive categorizations based on the nature of the approaches for decision making. First one is identified as *descriptive* which uses models and theories to describe human decision making behavior by studying the human beliefs. The second one is called *normative* that utilizes axioms to make optimal decisions ought to be made and the third one which is called *prescriptive* develops techniques and aids for supporting and improving human decision making. In addition to that, there is a distinctive difference between the descriptive and prescriptive models. The *descriptive* type represents functional relationships but does not recommend any course of actions while the *prescriptive* type recommend course of action to achieve objectives. (Starkey, 1992)

Descriptive models of decision making

a) Iconological model –
b) Bounded rationality
c) Organizational process
d) Implicit favorite
e) Political/ competitive (Bahl & Hunt, 1984)

However Harish and Raymond (1984) presented a general model of decision making.

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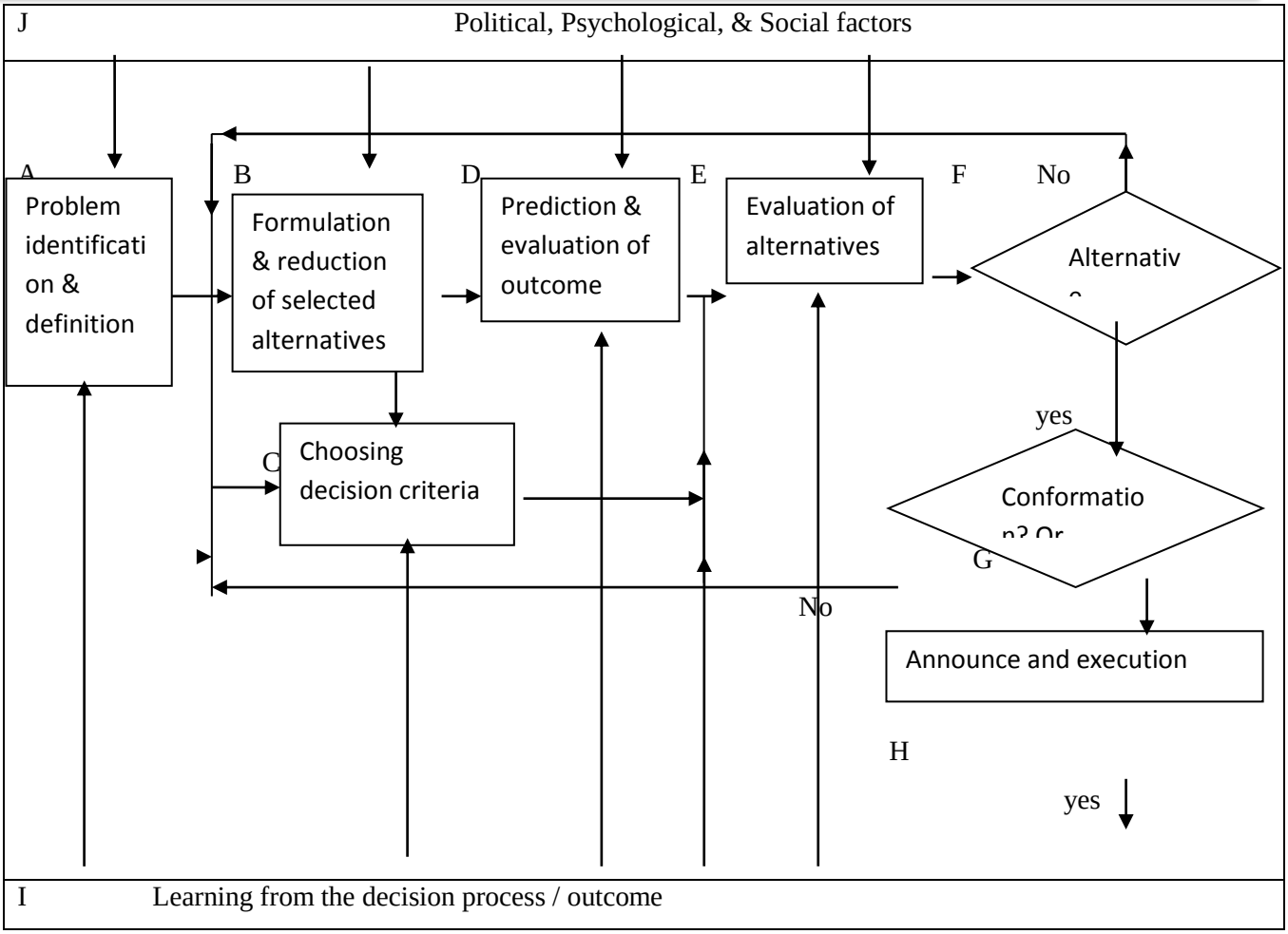

Fig 2- A general model of decision making (adapted from Harish and Raymond. 1984)

3.3Decision making in product development

Almendra & Christiaans (2009) highlighted three substantive elements in decision making in design process. They are knowledge access and management, thinking and communication skills and use of strategy and provide solutions. Krishnan & Ulrich (2001) presented an idea on decision variables of product development in marketing, organizations, engineering design and organizational management. According to them decision variables in marketing are product attribute levels and price while in organizations they are product development team structure and incentives. In Engineering design the decisions variables are product size, shape, function, dimensions and configuration. Development process sequences and schedule and point of differentiation in production process are the decision variables in organization management. Krishnan & Ulrich (2001) made comparison of perspectives in the design and development communities.

An important decision for many products is the specification of the product architecture which defines the primary modules and the interfaces between them. This decision not only affects the design of the product but also the process that will be followed during the rest of the product development project. Different processes launch different set of information-processing and decision making activities. The framework which was presented by Hansen & Ahmed(2002) for engineering design decision making consists of two models, the decision map and the decision node. According to them, the decision map is the object of decision making and the decision node is a model of the interrelated decision making activities.

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Table 1- Perspectives in the design & development communities (adapted from Krishnan & Ulrich,2001)

	Marketing	Engineering design	Operation management	Organization
Perspective on product	A product is a bundle of attributes	A product is a complex assembly of interacting components	A product is a sequence of development / process steps	A product is an artifact resulting from an organizational process
Typical performance metrics	"fit with market" Market share , customer utility, profit	" form and function" Technical performance, innovativeness, cost	"efficiency" total cost several level lead time capacity utilization	" project success"
Dominant representational paradigm	Customer utility as a function of product attributes	Geometric models, Parametric models of technical performance	Process flow diagram, Parametric models of process performance	No dominant paradigm, organizational network some time used
Example decision variables	Product attribute levels, price	Product size, shape, configuration, function ,dimension	Development process sequence and schedule point of differentiation in production process	Product development team structure, incentives
Critical success factors	Product positioning and pricing, collecting and meeting customer needs	Creative concept and configuration, performance optimization	Supplier and material selection, design of production sequence	Organizational alignment, team characteristics

The decision made in the engineering design process can be categorized as . go or no go , single selection or structured design(Hatamura,2006) Engineers make many decisions related to various aspects of engineering design, such as manufacturing methods, materials, cost, quality and maintainability and testing. Engineering design decisions can be classified as design decisions and development decisions.

3.4 Decision making models in product development

However it is believed that product development process models are models of how to make decisions in a sequential manner in order to decide the design of a product, how it should be manufactured and sold. Product development models are the usual approach to managing the product development organization, process, activities, tasks, and decision making.

The manufacturability evaluation , especially in the early product development stage , is a typical vague and not- well defined process. A manufacturability evaluation decision model is formulated and analyzed based on fuzzy logic and multiple attribute decision making under the concurrent engineering environment. (Hsu & Hsing, 2003)

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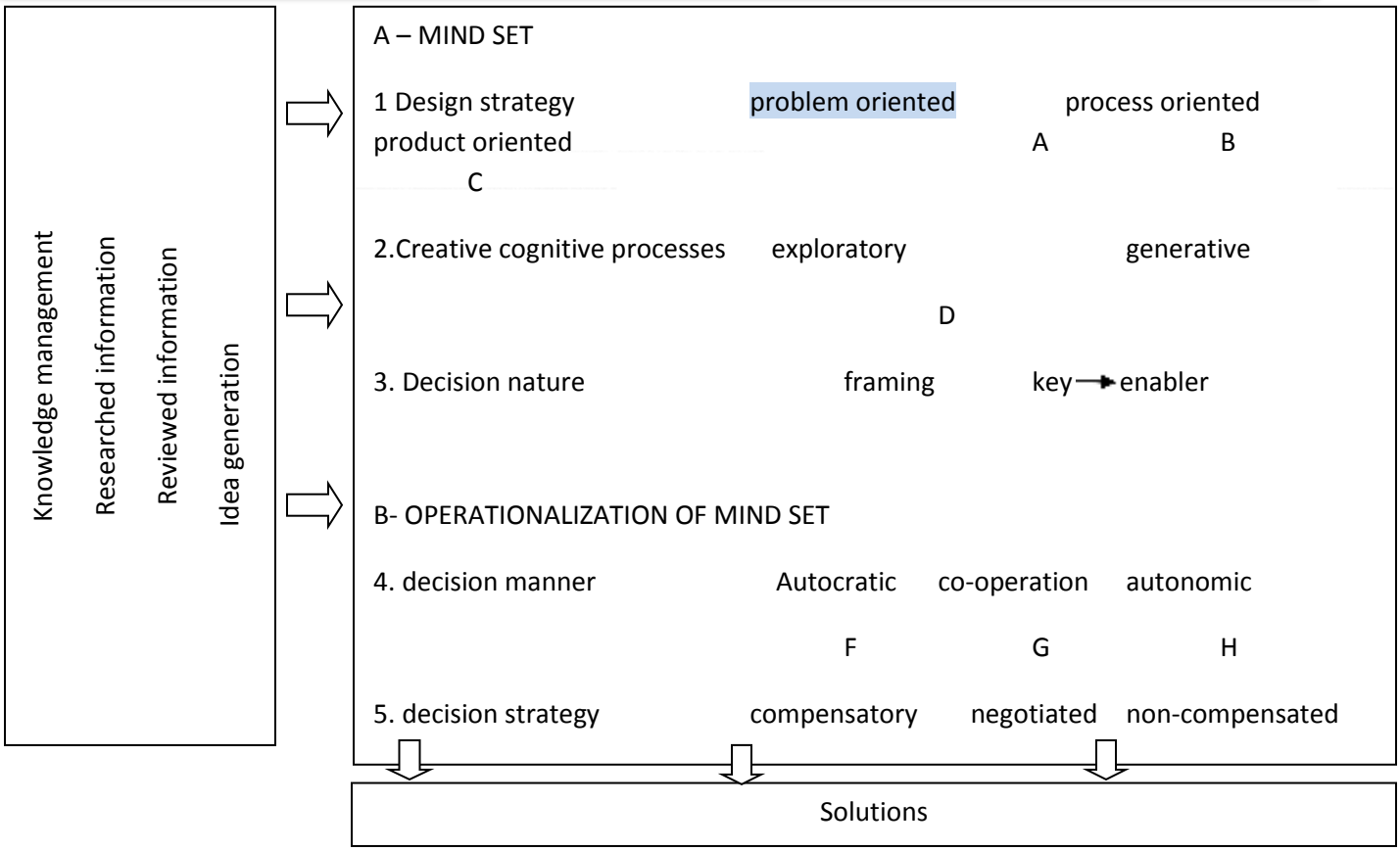

Fig 3- Design decision making descriptive model (adapted from Almendra, Cristiaans , 2009)

The decision making tools/ models used in product design & development identified and presented by the various researchers which can be found in the literature are integrated with the design process itself. Some researchers have concentrated on one aspect and some have considered different aspects when developing decision making tools / models can be summarized as follows.

Table 2 - The decision making tools/ models identified/ presented in product design & development by researches.

Purpose	Decision making model/ tools developed
Idea screening -	1. Fuzzy synthetic evaluation method (FSEM) based on fuzzy set theory (Yao Tsung Ko, etal.2010)
Product concept evaluation	1. Extended house of quality & mixed integer non-linear programming considering product life cycle factors and resource constraints (Johg-Ho Shin,etal.2011) 2. Monte Carlo simulation 3. Analytical network process

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	4. Pugh's evaluation matrix
To identify customer requirements	1. QFD (quality function deployment) to identify the customer attributes and transfer to engineering attributes 2. AHP(analytic hierarchy process) 3. FAHP(Fuzzy analytic hierarchy process) 4. AHP and Fuzzy logic to determine target values of product characteristics 5. Non liner mathematical programme to determine engineering characteristics under concerns of cost and life cycle constraints 6. FQFD (Fuzzy quality function deployment) to determine the target value s of design characteristics(Ming – Chyuan.... 2008)
Design for Manufacture/ assembly	1. Fuzzy logic 2. Multiple attribute decision making (MADM) 3. Fuzzy Multiple attribute decision making (FMADM) 4. MADM & activity based costing (ABC)
Suitable design solutions	1. TOPSIS 2. AHP & TOPSIS -. (Ming – Chyuan.... 2008) 3. DM (decision matrix) , 4. Robust design (RD), 5. value analysis/ engineering (VA/VE) 6. design for X (DFX) 7. axiomatic design (AD) (Goncalves 2006) 8. Integrating - QFD & Value analysis (VA) & data envelopment analysis (DEA) (Ignacio 2007)
Supplier evaluation/ selection	1. Data envelopment analysis(DEA) -Mainly focuses on the system efficiency Efficiency = weighted sum of output / Weighted sum of input 2. Mathematical programming models 3. Analytic hierarchy process (AHP) 4. Cased based reasoning (CBR) 5. Analytic network process (ANP) 6. Fuzzy set theory 7. Simple multi- attribute rating technique (SMART) 8. Genetic algorithm 9. Criteria based decision making methods (ELECTRE, PROMETHEE) (Prince Agrawal, Manjari Sahai.....2011)

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Cost management	1. Integrating – QFD , value engineering (VE) & target costing - mathematical programming approach (Jariri 2008)

3.4.1.Idea screening

New product concept screening decisions are associated with complexity, uncertainty and imprecision for the following reasons (Cooper et al.; Ahn and Dyckhoff ,1997)

a) At the time of decision, usually only uncertain and complete information is available
b) The competitive environment is marked by uncertainty and rapid changes in technologies and markets
c) The criteria for new product screening are not always quantifiable or comparable and criteria may directly conflict or interact with one another.
d) Multiple functional groups , each with a different perspective, may be involved in the evaluation decision. (Ko, 2010)

Yao Tsung Ko,(2010) presented a decision making model to idea screening based on fuzzy set theory. The model is called "Fuzzy synthetic evaluation method (FSEM) "

3.4.2.To identify customer requirements

QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical attributes (TA) for each stage of product development and production. The major benefits of using QFD .

a) Helps companies to make key trade-offs between what the customer demands and what the company can afford to produce
b) Improves effective communication between company divisions and enhances teamwork
c) Is built in upstream
d) Increases customer satisfaction by making sure that customer demands are brought into the product development process
e) Shorten the time to market (Zegordi & Jariri, 2008)

3.4.3.Design for Manufacture/ assembly

Fuzzy logic is a very powerful tool that can deal with decisions involving complex, ambiguous and vague phenomena that can only be assessed by linguistic values rather than numerical terms. (Ko, 2010)

5. CONCLUSION

However the decision making tools/ models used in product design & development identified and presented by the various researchers which can be found in the literature are integrated with the design process itself, it is clear that of all of them not only affects the design of the product but also the process that will be followed during the rest of the product development project.

This study highlighted that the decision making is an essential component of successful product development process.

Further it is expected to explore more on best practices in product development to enhance and nourish the product development decision making.

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