UNCERTAINTY IDENTIFICATION IN NEW PRODUCT DEVELOPMENT

Mahesh Caisucar
Dr. Rajesh Prabhu Gaonkar

Abstract

The trend of the industry is to move towards the design and manufacture of more sophisticated products because of the customer satisfaction and global competition involved. New Product Development (NPD) is considered as one of the core functions of the corporate. New product development decisions contain considerable amount of uncertainty causing elements. This can confuse the decision-maker to reach the targeted performance. Uncertainty arises from both internal and external multiple sources including technical, management and commercial issues. A structured approach is required to be used that can facilitate practitioners and decision-makers to evaluate the relative importance among various elements and factors that affect NPD decisions. Hence the new product development is basically a Multi Attribute Decision Making (MADM) problem. This paper aims at investigating various factors affecting the new product development, and uncertainties associated with these factors, which are required to be tackled with multi attribute decision making approach.

Keywords – New Product Development (NPD), Multi Attribute Decision Making (MADM), Uncertainties.

1. INTRODUCTION

In an increasingly competitive global market, companies must be better at developing new products. The trend of the industry is to move towards the design and manufacture of more sophisticated products because of the global competition involved. The sophistication involves products with better and safer performance, more environmental friendliness, higher quality and reliability, and shorter time. Particularly for the companies with short product life cycle, development of new products fulfilling reasonable quality demands, performance and cost is of prime importance. At the early product design stage such multiple criteria have to be considered and assessed. But because of the limited reliable data available to measure and evaluate decision criteria, there is always difficulty in conducting the assessment at early design stage. Like all decision problems, new product development decisions contain considerable amount of uncertainty causing elements. This can confuse the

Figure 1: Factors affecting NPD
decision-maker to reach the targeted performance. Uncertainty arises from both internal and external multiple sources including technical, management and commercial issues. A structured approach is required to be used that can facilitate practitioners and decision-makers to evaluate the relative importance among various elements and factors that affect NPD decisions. Hence the New Product Development (NPD) is basically a Multi Attribute Decision Making (MADM) problem.

2. FACTORS AFFECTING NEW PRODUCT DEVELOPMENT DECISIONS

The stages of New Product Development involve consideration of many decision factors which are shown in Fig 1. Most of these decision factors require MADM approach, some of which are listed below:

1. Design Concept Evaluation
2. New Product Portfolio Selection
3. Product Project Screening
4. New Product Design Assessment
5. Sustainable Product Development
6. Quality Function Deployment
7. Group Decision
8. System Reliability
9. Material Selection

2.1 Design Concept Evaluation

A poor design concept can rarely be compensated at the later stages. Hence one of the most critical decision points when managing NPD is design concept evaluation. At early design stages up to 70% of the overall product development cost is committed. Successful design concept evaluation results in saving cost and time of product development. Design concept evaluation is a complex multi-criteria decision making (MCDM) problem which involves many factors ranging from task-related factors (e.g. product complexity, initial customer requirements impreciseness and information scarcity) to decision related factors (e.g. the expertise and diversity of DMs, and the method of aggregating judgments). At the same time design concept evaluation is also a group decision-making problem. The required data and information comes from design knowledge and experience at the earlier design stages and subjective judgments of Decision Makers (DM). Design information is deficient and imprecise at the earlier design stages. Lack of precision and the confidence levels on DMs' judgments contribute to various degrees of uncertainty. Coping with uncertain and vague characteristics of information is critical to the effectiveness of decision-making. Furthermore, the aggregation method of individual judgments in group decision making and the alternatives ranking method in the evaluation model are critical to the accuracy and effectiveness of design concept evaluation [1].

2.2 New Product Portfolio Selection

New-product portfolio selection is a crucial and vital decision for successful new-product development. Selecting a new-product portfolio for the future is an important problem faced by all companies that engage in NPD. Since a vast amount of information is incomplete and selection criteria are interdependent and often conflicting in nature, portfolio decisions are difficult because of the combinatorial complexity of allocating a limited resource over a multiplicity of new products. Portfolio management decision is usually made on the basis of product value, project risk and business strategies. The decision maker must allocate a limited set of resources to projects in a manner that balances risk, reward, and alignment with their respective strategies which may have non-numerical values. Due to both the nature and timing of new product development, portfolio selection is associated with uncertainty and complexity, and conventional evaluation methods cannot handle such decisions suitably and effectively [2].

2.3 Product Project Screening

The rate of NPD project failure is around one-third or even higher, although it varies from industry to industry. There are usually numerous new product ideas during the early stage of project development. Some of the ideas have high probability of success, while majority of them could be unfeasible. Project screening helps to eliminate the ideas that have high probability of failure. Thus, it is imperative to conduct project screening, as selecting a right project for commercialization is the first step to the success of NPD. NPD project screening helps to eliminate projects that have high potential of failure and allocate the development resources to the projects that have the highest potential of success. As a result, the growth of companies can be sustained and the overall NPD failure rate can be reduced. Ranking, checklists, scoring models, and numerical weighting methods are some of the methods available for NPD project screening. However, the methods are too simple to tackle complex problems. Hence the growing complexity of NPD requires the use of more sophisticated management science decision support techniques [3]. Incomplete data or lack of data and imprecise judgments are the two ways by which uncertainty are induced at project screening. A very little reliable information is available to make judgments against screening criteria. Examples such as the lack of financial and engineering data make decision making difficult and unreliable. Most of the screening approaches are based on judgments of managers. Inability of human in making reliable judgments is another cause of uncertainty. 

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The experience of the managers may be limited to a small number of projects, and the managers' ability to judge the importance of screening criteria and compare potential projects may also be limited. The involvement of multidisciplinary NPD team members in the decision making process is an additional characteristic of NPD. Team members from different functional units jointly make decisions to screen and select projects. However, the members usually do not have expertise or knowledge in all the aspects of the screening criteria. Hence in the given situation, they may not be able to make accurate judgments on some aspects that are not related to their functional expertise. Since NPD always involves new issues including new design, new manufacturing processes, new suppliers, etc., it is not practical to make judgments based fully on past experience or information. It is therefore a big challenge for product managers and experts to move from experience-based decision making to scientific NPD project screening decision making. MADM methodology helps manufacturers in handling uncertainties and group-based decisions in the early NPD project screening stage [3, 4].

2.4 New Product Design Assessment
Researchers and practitioners have emphasized the need to enhance product design assurance in early design stages. Determining the best product design among a lot of feasible alternatives is a key issue in successful new product development. It is advocated that the entire product attributes of performance, quality, reliability, safety, maintainability, serviceability, manufacturability, etc., are build during the product design process. Hence, the product design process becomes an increasingly complex decision-making problem. One must simultaneously cater, for many interrelated criteria of both quantitative and qualitative nature. The design decision analysis has to be conducted on the basis of both precise numbers and subjective judgments, which are imprecise and vague (fuzzy) in nature. These uncertainties are incurred due to a lack of evidence and understanding or human's inability of providing accurate judgments at early design stage of novel new products. This reveals that a better decision-making methodology is needed to facilitate product design assessment in situations where several performance measures like product functions and features, manufacturability and cost, quality and reliability, maintainability and serviceability, etc., must be accounted for, but conventional approaches cannot be applied with confidence [5].

1.5 Sustainable Product Development
Environmental Impact Assessment (EIA) problems are characterised by environmental factors that are qualitative in nature and can be assessed only on the basis of human judgments. Such judgements inevitably involve various types of uncertainties such as ignorance and fuzziness. Hence EIA problems have to be modelled and analysed using methods that can handle uncertainties [6]. The framework which aims at the integration of economic, environmental and social considerations into product development is known as Sustainable Product Development. The major challenge is the holistic analysis and improvement of products regarding their impact on surrounding systems. The product needs to be analyzed along its complete lifecycle for a valid assessment. The principle of sustainable development requires the consideration of multiple design targets at the same time. For example reduction of hazardous waste against higher material cost. Design engineers need to foresee diverse interrelations between a product's characteristics and its economic, social and environmental impacts while developing sustainable products. A wide range of design methods has been developed in order to support this complex task. Life Cycle Sustainability Assessment (LCSA), which is a retrospective analytical method, requires a large amount of information and is thus utilized when important design decisions are already made, whereas prospective methods are rather generic and too broad to be helpful in concrete design decisions. For shifting multi-criteria quantitative analysis to earlier development, the integration of discrete decision trees with LCSA is used [7, 20].

2.6 Quality Function Deployment
Quality function deployment (QFD) is a method to help transform customer needs (the voice of the customer [VOC]) into engineering characteristics (and appropriate test methods) for a product or service. It helps create operational definitions of the requirements, which may be vague when first expressed. It often involves a group of cross-functional team members from marketing, design, quality, finance and production and a group of customers. Each member and customer demonstrates significantly different behavior from the others and generates different assessment results which may be complete and incomplete, precise and imprecise, known and unknown, leading to great uncertainty in the QFD process. Significant number of subjective judgments is required from both customers and QFD team members for the successful implementation of QFD. Selected customers assess the relative importance of customer expectations or requirements (WHATs). The QFD team is set up to identify customer wants, map them into relevant engineering requirements, which are often called the HOWs, develop the relationship matrix between WHATs and HOWs and the interrelationship matrix between HOWs, and prioritize the HOWs [8, 21]. The analytic hierarchy process (AHP), a well-known and commonly used multi-criteria decision-making method, and its variants: fuzzy AHP, analytic network process (ANP) and fuzzy ANP have been suggested and
widely applied to prioritize customer requirements (WHATS). The weighted sum method, fuzzy weighted average (FWA), fuzzy outranking approach and grey model have all been suggested for prioritizing engineering design requirements [8, 9]. Since fuzziness is involved in the process of QFD, MADM techniques are required to deal with it and also to address the issue of how to deal with incomplete, imprecise and missing (ignorance) information in QFD, which is essentially inherent and sometimes inevitable in human being’s subjective judgments.

2.7 Group Decision
The process of NPD is multidisciplinary in nature. It requires the participation of a group of people from different departments in making decisions. A problem of judgment synthesis arises because of this group approach. Each group members may present different judgments about project screening decisions because of differences in technical backgrounds, departmental goals and constraints etc. The reliability of the decisions may depend on the way the diverse judgments are synthesized [3]. Group decision involves reduction of different individual preferences on a given set to a single collective preference. The most important characteristic of group decision is that all individuals involved in decision making belong to some organization (family, firm, government). Their opinions may differ in their perception of the problem and they may have different interest, but they are all responsible for the organization’s well-being and share responsibility for the implemented decision [10]. The group discussion involves focusing on what actions and criteria to be considered, what weights and other necessary parameters will be appropriate. Once all the individual information has been gathered and the discussion is closed, a technique is used for obtaining values of these model parameters which represents the collective opinion. With this information, the multicriteria decision model gives us the group ranking. Group consensus (GC) is a pivotal factor to reach a final solution accepted by almost all or at least most of the group in the group decision analysis (GDA) [11].

2.8 System Reliability
Reliability analysis aims at the quantification of the probability of failure of the system and focuses on safety. Many researchers have developed various reliability prediction techniques. An accurate product reliability prediction model can offer useful information for managers to take follow-up actions to improve the quality and cost of system. Most of these models are developed using the following: Bayesian statistical, Linear or nonlinear multiple regression, Neural networks, Support vector machine (SVM) and Autoregressive integrated moving average (ARIMA). But these models suffer from number of drawbacks such as lack of suitable models, exceptional assumptions of prediction model, and difficulty to validate. Also accuracy and speed are hampered [14]. A fundamental issue in reliability analysis based on the failure data is the uncertainty in the failure occurrence and consequence. For a complex engineering system, many reliability analysis problems involve quantitative data and qualitative information, as well as various types of uncertainties such as incompleteness and fuzziness. Under these circumstances, there is a need to develop a new reliability analysis method using multiple attribute decision analysis (MADA) which can deal with various types of uncertainties efficiently [12,13].

2.9 Material Selection
For diverse engineering applications, selection of proper materials for different components is a challenging task in the design and development of new products. During the entire design and manufacturing process materials play a crucial and important role. A wrongly selected material results in huge cost involvement. It may even lead to premature component or product failure. New materials are available to meet the demands of cost reduction and better performance which now a days are been used to replace older materials. Normally a trial and error method based on previous experimentation are used while choosing a new material. Large number of factors such as mechanical, electrical and physical properties and cost considerations of the materials are required for the selection. The designers and engineers have to take into account a large number of material selection criteria. A large number of available alternative materials, having complex relationships with various selection parameters (criteria), make the material selection process a challenging task. Decision making in the presence of multiple, generally conflicting criteria requires the use of multiple criteria decision making (MCDM) [15, 16].

3. LIMITATION OF THE STUDY
All the above listed factors show that MADM approach is a must for NPD process. The literature review shows that most of the published work does not consider all forms of data e.g. imprecise, vague, incomplete, uncertain etc. For this, studying the existing MADM methods and checking whether group based MADM methods can give better result is required. Also MADM methods have not been used for factors such as Design for Manufacturing (DFM), Design for Assembly (DFA) and Design for Maintainability and Serviceability which also affect the new product development. Lastly in today’s competitive market, managing NPD becomes crucial for survival of small and medium sized enterprises (SMEs). Many SMEs face a dilemma in NPD. While the SMEs realize the need for NPD, focus to work in this area is frequently driven out by other
immediate priorities. Understanding the key performance criteria of NPD for SMEs and devising a self assessment model for NPD performance is the need of the hour.

3. CONCLUSIONS
In this study various factors affecting New Product Development are projected in the form a flowchart. A brief study of each factor is done and it was observed that there is lot of uncertainties, incompleteness, vagueness, impreciseness in the data, associated with this factors. To tackle these problems it is felt that MADM methods are a must. Even grouping of some MADM methods may give a better result. It is also felt that self assessing model for NPD for SMEs has to be devised.

REFERENCES

AUTHORS

Mahesh Caisucar, Research Scholar, Mechanical Engineering Department, Goa College of Engineering, Farmagudi, Ponda, Goa - 403 401
E-mail: maheshc@gec.ac.in

Dr. Rajesh Prabhu Gaonkar, Professor & Head, Mechanical Engineering Department, Goa College of Engineering, Farmagudi, Ponda, Goa - 403 401
Email: rpg@gec.ac.in