A

DISSERTATION REPORT

ON

ANALYSING RISK IN NEW PRODUCT DEVELOPMENT PROCESS: A CASE STUDY

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

INDUSTRIAL ENGINEERING

BY

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(2014PIE5451)

UNDER THE GUIDANCE OF

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CERTIFICATE

This is to certify that the dissertation entitled **"Analysing Risk In New Product Development Process : A Case Study"** being submitted by **Madhubala Kushwah (2014PIE5451)** is a bonafide work carried out by her under my supervision and guidance, and hence approved for submission to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**. The matter embodied in this dissertation report has not been submitted anywhere else for the award of any other degree or diploma.

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **"Analysing Risk In New Product Development Process : A Case Study"** in partial fulfilment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my work carried out by me during a period of one year from July 2015 to June 2016 under the guidance and supervision of **Prof. (Dr.) A.P.S. Rathore** of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my work and has not been submitted anywhere else for the award of any other degree or diploma.

Madhubala Kushwah

(2014PIE5451)

It is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Prof. (Dr.) A.P.S. Rathore
Supervisor

Place: Jaipur
Dated: 30 June 2016

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Analysing Risk In New Product Development Process : A Case Study- M.Tech. Dissertation

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-Madhubala Kushwah

ABSTRACT

NPD is a key driver of progress and justifiable competitive gain, yet risks and threats are inherent in NPD in all businesses. Thus understanding, detecting, handling, and diminishing risk is imperative for organizations. Suitable risk management policies can considerably advance the chances of success of NPD. It is essential to have an organized and standard approach to NPD to accomplish an effective new product, and positively the fruitful performance of a new product into a business. At first, we present PD, NPD, FMEA, Fuzzy FMEA concepts and the major definitions. We start our study with the revision of the literature on the NPD risks and then deliver a fuzzy approach to FMEA to state priority of risks.

The analysis of failure modes and their effects generally requires dealing with uncertainty and subjectivity inherent in the risk assessment process. A review of the literature reveals that even if so many studies have scanned these concerns, none of them have clearly investigated the Smartphone industry. To tackle this problem, this report suggests applicability and efficiency of the Fuzzy FMEA tactic by an illustrative example of the Smartphone industry. This report offers NPD risk exploration technique using fuzzy FMEA after reviewing previous studies of the relevant field. There is a systematic case study on the Smartphone Development Process. It highlights key risk factors, their prioritisation and categorization on the basis of criticality. Finally it shows the development of a risk alleviation and mitigation model to suggest risk mitigation in Smartphone Industry. The proposed approach offers additional flexibility to the experts in making judgments and provides a better modeling of uncertainty.

The market becomes highly demanding and competitive in terms of costs and suspensions or delays, and at the same time expects a high level of quality. Then, to govern the best balance amid gains and risks, the firm has to continuously consider a risk management and its mitigation strategy. Considering all this we advise a decision-making tool to aid the managers pick the best way to cultivate success rate of the concerned project while monitoring the levels of risks. We suggest and frame a risk mitigation model for the aid of managers in the end.

KEY WORDS: NPD, FMEA, Fuzzy FMEA, risk analysis, risk factors, Smartphone industry.

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ABBREVIATIONS

NPD	New Product Development
RF	Risk Factor
FMEA	Failure Mode and Effects Analysis
O	Occurrence
S	Severity
D	Detection
Eq.	Equation
TFN	Triangular Fuzzy Number
E	Expert
SPD	Smartphone Product Development
RPN	Risk Priority Number
i.e.	that is
RM	Risk Management
PD	Product Development

CHAPTER 1- INTRODUCTION

The NPD process is an innovation process that is discovered from different functional perceptions, such as engineering, marketing, finance, and manufacturing, due to its inter-functional essence (Wittayapoom 2014). NPD is a vital process to keep a firm being competitive. However, NPD involves high risk along with a significant uncertainty due to its inherent features. To make sure a smooth procedure of NPD, the risks associated with the process need to be evaluated and the ambiguity should also be addressed properly. Without new products, companies cannot grow over time as their existing products would gradually get outdated against changing consumer needs and wants and new generations of products introduced by competitors (Thomas, 1995; Grunert & Trijp 2014).Companies have to invest continuously in NPD if not for the profit, then for their survival, since there is an enormous global competition, rapid technology change, and the world market opportunities are changing (Cooper & Kleinschmidt, 1988, 1991, 1995; Schmidt, 1995).Penetration strategy and market development strategy involves developing new products for existing markets and also plays a key role in the so-called diversification strategies where the company develops new products to enter new markets (Grunert & Trijp, 2014). Thus, NPD is regarded as the most crucial processes for survival, success and renewal of establishments, particularly for companies functioning in competitive markets and the markets likely to rapid product variations.

More time and money are involved than expected to reach the goals of the project (Coppendale, 1995; Cooper, 2003, Ahn et al., 2008). Globally, about 80% of manufacturer NPD projects flop before completion, and more than half of 20% of the otherwise active cases become unprofitable (Hoo-Gon Choi, 2011). It happens due to the lack of a structured process (Liberatore & Stylianou, 1995; Twigg, 1998).

High-risk proceedings may cause a substantial rise in the budget, disturbance of the schedule or deterioration of performance. Moderate risk makes some effect on cost, routine or performance. Low-risk events have slight or no influence on cost, schedule or conduct. Effective strategies are essential for reducing risk. The knowledge management systems are helpful in reducing risk (Cooper, 2003). If the new products are handled and managed properly, they can help in the significant growth of the company which, usually, cannot be achieved by the existing products (Cooper, 1999).

One can be prepared to react to unanticipated events, by proper planning, if they arise. By outlining risk management processes for one's firm, one marks success more likely by minimizing and removing risks so tasks can be completed on time. It enables one to meet one's budget and fulfil targeted objectives. When risk management strategies are absent in place, the projects face problems and their vulnerability increases. Efficient risk management strategies allow one to identify strengths, weaknesses, opportunities, and threats of one's projects. Thus, these strategies let one's company make the most of the profits and the least of expenses on events that don't harvest a return on investment. Assessing risk in NPD helps one understand risk, create risk mitigation scenarios, negotiate fair contracts, make better decisions and improve teamwork. Thus, by performing risk assessment and taking suitable steps to reduce risk, the chances of the success of the projected increase.

1.1 Background and Motivation

It is now obvious that NPD is a core purpose in any organization, and its adeptness mostly revises the accomplishment of the organization (Brown and Eisenhardt, 1995; Jensen and Harmsen, 2001). Some literature is available in the examination and investigation of risk in NPD. Former research indicated that there are some RFs, which have an impact on the NPD process in establishments and firms. But, little literature was presented explicitly exploring the RFs for NPD in the Smartphone Industry. Also, the analysis is essential to be commenced to recognise the extent of risk of these factors and their prioritising order so that relatively higher risks can be dealt first. It is achieved with the help of Fuzzy FMEA process. Hence, this study is carried out to offer a thorough understanding of the risk factors that can chiefly affect the projects concerning NPD, and also the prioritisation and categorisation of these factors in exercise within the Smartphone Industry.

Thus, the aim of this study is to discover the risk factors of NPD in the Smartphone Industry, to find out their causes and effects, arrange them as per their priority and to mitigate them.

1.2 Objectives of the Present Study

1. To identify the risk factors involved in the Smartphone product development process

2. To prioritise the obtained risk factors for identification of most severe factors and to categorize the risk factors by their criticality.
3. To propose a risk alleviation and mitigation strategy for the identified risks.

1.3 Structure of the Dissertation

This dissertation report is arranged into six chapters as shown in Figure 1.1. *Chapter 1* ponders the subject matter of the study, its background and motivation, and necessity of the study. It outlays the objectives of the research.

Chapter 2 delivers literature review on product development and NPD process, FMEA and fuzzy FMEA.

Chapter 3 contains the description of the research methodology. The design and organization of interview questionnaire are explained in this section. The detailed methodology of fuzzy approach to FMEA has been discussed.

Chapter 4 deals with the identification and corresponding explanation of risk factors in SPD process by the literature review along with expert opinions.

Chapter 5 consists of the analysis of the responses of the experts. The results are generated and tabulated along with necessary graphs and diagrams using the fuzzy approach of FMEA. The inferences of the study and the overall outcomes of the study are discussed. A risk mitigation model has been designed.

Chapter 6 concludes the study and shows the limitations of the study. Further, it suggests the areas of explorations in the future.

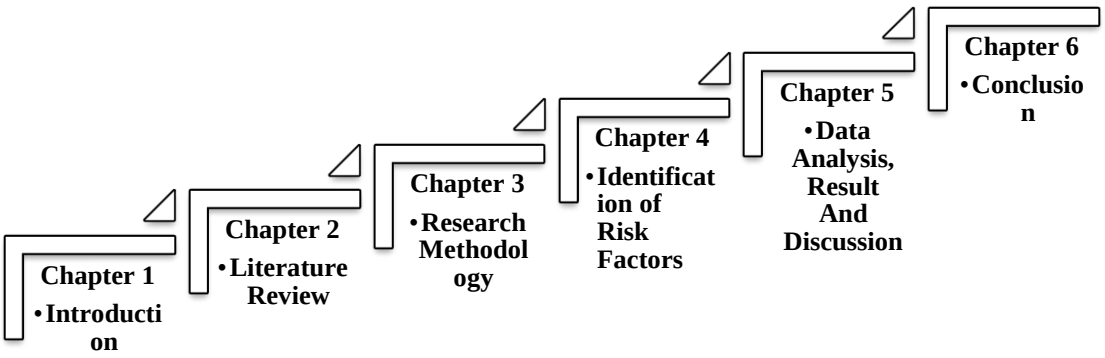

Figure 1.1 Structure of the dissertation

CHAPTER 2 - LITERATURE REVIEW

NPD has been playing a vital character in the feat of many companies in this competitive world (McCarthy, Tsinopoulos, Allen, & Rose-Anderssen, 2006). NPD is a relatively risky activity by nature (Kahraman et. al., 2007; Kayis et. al. 2006; Ozer, 2001) because of extreme market competition and advancement of product technology (Di Benedetto, 1999; Mullins & Sutherland, 1998; Srinivasan et. al., 2007). Because of some natural features, NPD decisions unavoidably come across a significant amount of uncertainties which may increase penalties (Kahraman et al., 2007; Kayis et al., 2006). Thus, it is important to manage all kinds of risks (Cooper, 2003; Kayis et. al.2007; Smith, 1999).

Risk handling in NPD projects in many establishments is done by consuming casual and disorganized approaches (Calantone et. al., 1999; Cooper, 2006; Gidel et. Al., 2005; Griffin, 1997) and thus their chances of failure rise. Risk management is the path of understanding future risks and making effective plans to alleviate, eradicate or take benefit of them (CIMA, 2002; Shaw et. al., 2005). Superior risk management, its enactment, and amalgamation of the executive systems signify an outstanding added value.

Thus, product development tasks should include risk assessment. It is a cycle by which an innovative organization regularly changes ideas into commercially feasible goods (or services), which is the goal of NPD.

2.1 PD and NPD process

Today there is a high competition in the market at global as well as local level. Thus, there is a need for design, quality, multi-company collaboration, productivity, optimal price levels and production process expectedness. The manufacturers have to retain and raise their positions in the market. The manufacturers have been refining their product development skills to fetch products to the marketplace quicker and diminish manufacturing bottlenecks. Firms have to devote more money to the management of product lifecycle and planning of resources (Riives et. al. 2012, Karjust et. al. 2010). The goal of engineering design is to fulfill individual requirements, mainly those who depend on the technological aspects. New idea (Figure 2.1) is the trigger or initiator for product development (Karnie, 2011).

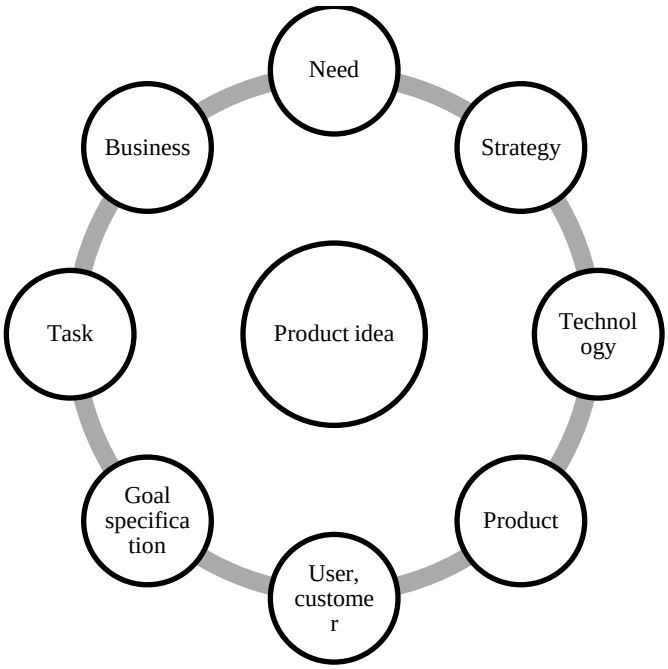

Figure 2.1 Dimensions of a product idea

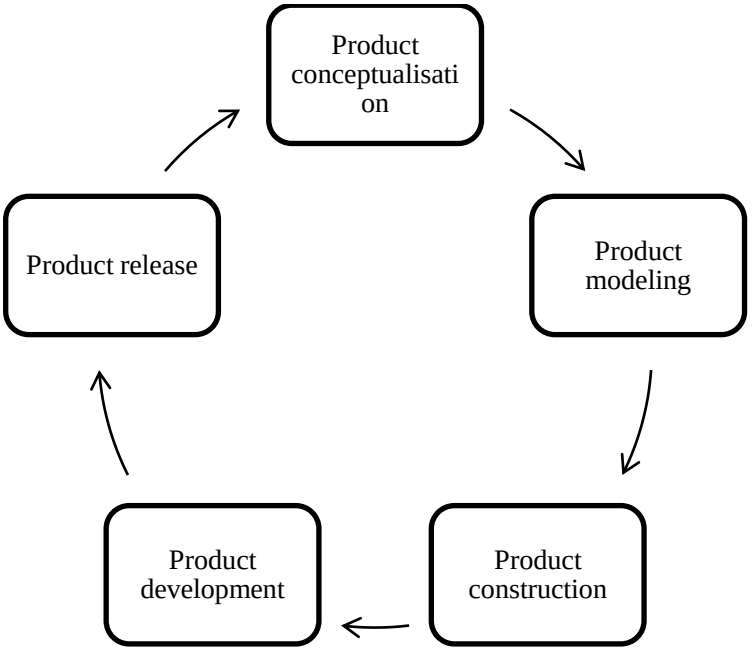

Figure 2.2 Product Development Process

New product development is the first stage in creating and commercializing fresh products within the whole planned process of product life cycle management which is used to sustain or cultivate market stake in business and engineering. New product development refers to the entire process of getting a new product to market. A product can be tangible or intangible. The most simple and traditional outlook to NPD is shown in Figure 2.3.

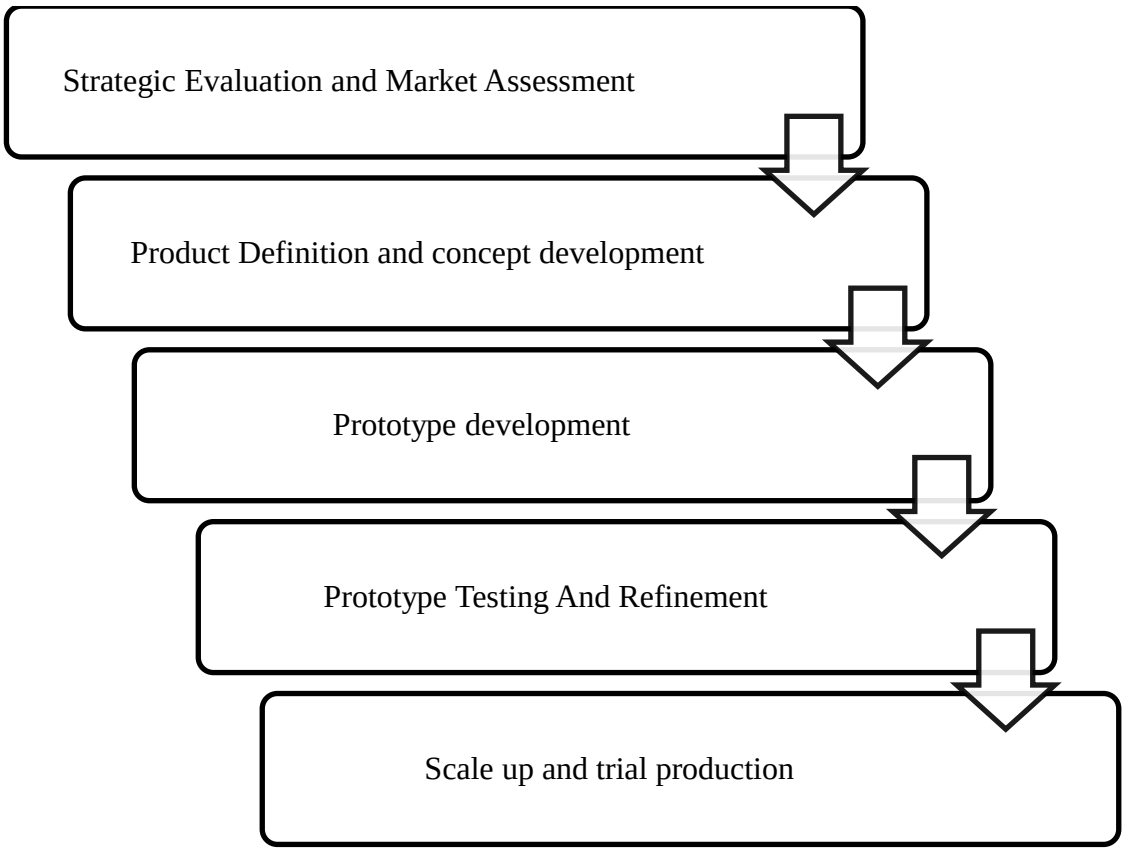

Figure 2.3 NPD process (Modified from Ulrich, 2009)

2.2 Failure Mode and Effects Analysis (FMEA)

2.2.1 Brief History of FMEA

FMEA was expounded (1949) by the US Armed Forces. It introduced Mil -P 1629 Technique for carrying out a failure mode effect and criticality analysis. The aim was to categorize failures "according to their impact on mission success and personnel/equipment safety" (Carlson, 2014). Apollo space program adopted it later on to reduce the risk for smaller sample sizes. The practice of FMEA became popular during the 1960s. In the late 1970s, after the Pinto affair, the Ford Motor Company familiarized FMEA to the automotive industry for the purpose of safety and regulatory consideration, improvement of production and design. The auto industry started executing FMEA by regulating the structure and means through the Automotive Industry Action Group, in the 1980s, At present, the FMEA method is widely used in a range of industries such as healthcare, foodservice, software, aeronautics, plastics, automotive, semiconductor processing and much more (Carlson, 2014).

2.2.2 Definition and objectives of FMEA

FMEA stands for Failure Mode and Effects Analysis. It is an engineering analysis which is carried out to determine the potential failure modes of a process, system, design or service, and their causes and effects on the end users or the system (Lin et al. 2014; Carlson, 2012). The risk accompanying these failure modes is assessed and evaluated using experts' opinions. Further, calculations are done to prioritize and identify the critical risk factors. Corrective activities are employed to check the risks in their order of priority. FMEA is a satisfactory problem inhibition procedure that can simply border with several engineering and reliability systems. FMEA establishes an active risk management environment (Ireson et al., 1995). FMEA is a very less expensive tool which is preventive in nature i.e. it helps to prevent problems in a product development process. If it is implemented correctly in the entire product life cycle, it reduces life cycle warranty costs as well as certain bottlenecks during product development. Thus, it improves safety, reliability, quality, cost and delivery. Hence, FMEA is widely used as a risk assessment and quality improvement tool (Islam and Tedford 2012; Tay and Lim, 2008).

ISO 14971 (2012) prescribes guidelines for the analysis of risk in Failure Mode and Effect Analysis to prioritize the risks (Li and Zeng, 2014). RPN is a mathematical grading of the risk of every potential failure mode which is calculated, traditionally, by multiplying the values of three elements i.e. O, S and D where O, S, D stands for likelihood of occurrence of the cause, severity of the effect and probability of detection of the object respectively (Zhang and Chu, 2011; Ireson et al., 1995). A higher RPN indicates higher risk and vice versa. Thus, the risk factors with higher RPN values are more important and are considered earlier than others (Mariajayaprakash et al. 2013). Hence, the risk with highest RPN value is ranked first and so on.

• Occurrence (O)

It refers to the likelihood of the number of times the failure mode or the risk occurs. It doesn't have an absolute value but relative. Its value depends on the criteria mentioned in the occurrence scale being referred.

• Severity (S)

It relates to the level of risk or the effect of a risk factor on the process. Its value depends on the criteria mentioned in the severity scale being indicated. It is also a comparative ranking.

• Detection (D)

It relates to the capability of strategic tests and assessments to eliminate defects or perceive failure modes or causes in time. A high value of detection number shows that the odds in favour of detection are little. It doesn't have an absolute value but comparative value.

These three factors are evaluated on a 10-point scale by the experts in the respective fields. The value of one of the factor is independent of the value of the other two factors.

The procedure for traditional FMEA is summarized as follows (Figure 2.4).

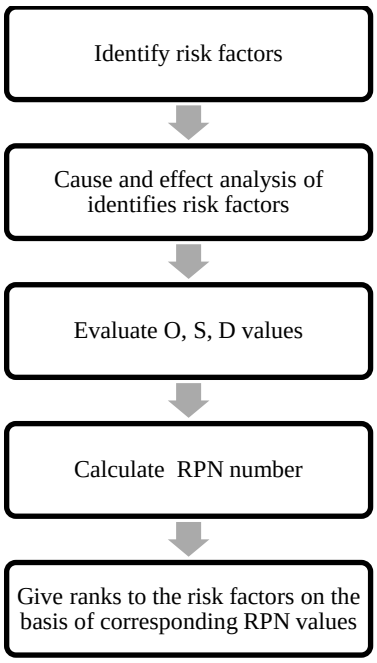

Figure 2.4 Procedure for traditional FMEA

2.2.3 Fuzzy FMEA

The fuzzy approach of FMEA is a potent tool for fitting in fuzzy expressions and indefinite data into decision context (Liu et al. 2014). O, S and D are the three top risk factors used in FMEA but practically it is not easy to get the exact assessment values of the risk factors. It occurs because of the presence of uncertainty in human judgments and inherent vagueness involved, since the values of O, S and D mostly

depends on the experience and expertise of the experts (Liu et al. 2014). Therefore, a fuzzy method for FMEA is widely applicable in the practical world, such as indefinite, vague, unspecific and fuzzy situations (Liu et al. 2013).

Advantages of Fuzzy FMEA over traditional FMEA (Liu et al. 2013):

- The combination of O, S and D factors of risks is possible in more realistic and flexible way. Also, the experience and expertise of experts are considered in the calculations of RPN values.
- Ambiguous and complex data can be dealt with in a reliable manner for the assessment of risk.
- The function of risk evaluation can be customized by nature of the process.
- In traditional FMEA the experts are asked to assign values to O, S, and D, for the risk factors and RPN is calculated directly by multiplying these values i.e. these three factors are considered equally important. It may result in false and unreliable results (Kumru and Kumru, 2013)

Drawbacks of Fuzzy FMEA (Liu et al. 2013):

- Complex calculations are involved while drawing inferences (Jin, 2000)
- Redefinition of the participation functions is required if any alteration is done in the number of linguistic terms and scale.
- They provide arbitrary RPN values or priority ranks to the failure modes even if their participation functions overlay (Mandal and Maiti 2014).
- A risk factor is an essential task to describe appropriate assistance function.

2.2.4 Defuzzification

Defuzzification of the fuzzy sets is the inverse process of fuzzification that refers to the transformation of fuzzy sets into crisp numbers i.e. it is a method of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. There are numerous techniques for defuzzifying a fuzzy set; some of the most popular methods are included in Fuzzy Logic.

There are several procedures for defuzzification, for example, the centre of gravity, semi-linear defuzzification, the centre of the area, the centre of gravity for singletons, left most maximum, random choice of maximum, right most maximum (Kumru and Kumru 2013) and mean of maximum. The mean of maximum produces better results about Centre of Area method (Lin et al. 2014).

CHAPTER-3 RESEARCH METHODOLOGY

3.1 Collection of Literature

A systematic literature review was conducted to understand the topic better. Primary sources of the literature are online databases of well-known publishers such as Science Direct, IEEE, Taylor and Francis, Google Scholar, etc.

The major search topics are new product development, risk factors, Smartphone industry, and Fuzzy FMEA. Based on these some keywords were made to explore literature. Their significance sieved the articles or journals found in the initial search based on the key words to the title. The most relevant articles were further reviewed. The keywords used for finding relevant articles were:

- Failure Mode and Effects Analysis
- Fuzzy Failure Mode and Effects Analysis
- New Product Development
- New Product Development in Smartphone industry
- Product Innovation
- Risk Assessment
- Risk Factors in New Product Development

3.2 Variables & Design of Interview Questionnaire

An interview questionnaire is conducted to obtain an evaluation of Occurrence, Severity, and Detection from experts. The applicant elements selected as variables for the questionnaire were listed by brainstorming with researchers and using previous literature. The Delphi questionnaire technique is used. Responses from engineers and managers, who are directly involved in various phases of NPD in Smartphone industries are obtained. It is presumed in the questionnaire that the respondents (experts) understand NPD better than anyone else, as they are involved in the real-world on a daily basis.

3.2.1 Design of the Questionnaire

The researchers and the experts helped in creating the draft of the questionnaire on the basis of the risk factors identified through literature review. All the risk factors are listed & grouped into following categories:

1. Consumer Risks
2. Competitive Risks
3. Technology Risks
4. Managerial Risks
5. Financial Risks
6. Human Resource Risks
7. Regulatory Risks
8. Supply Chain Risks
9. Marketing Risks

The questionnaire can be distinguished into two parts:

1. The first section of the questionnaire seeks basic information about the respondent, such as his/her name, organization, post and work experience.
2. The second part of the questionnaire covers the evaluation of risk factors associated with the Smartphone development process. The respondents were asked to encircle their responses in the table (Table 3.1) provided in the questionnaire. There was a provision for supplementary relevant comments at the end of the questionnaire

Table 3.1 – Linguistics for O, S, and D

	LINGUISTIC SCALE TERMS				
OCCURRENCE(O)	VL (very low)	L (low)	M (medium)	H (high)	VH (very high)
SEVERITY(S)	N (none)	S (slight)	M (moderate)	H (highly severe)	VH (very high severity)
DETECTION(D) (chances of detection)	EL (extremely likely)	H (high)	M (moderate)	L (low)	EU (extremely unlikely)

A trial study (an internal interview) was carried out with a limited research group comprising academicians and researchers in NPD field formed by convenient sampling. It was done to check the viability of the draft questionnaire. The suggestions gained after the internal interview was used to frame the final questionnaire. Several factors were customised to fit the Smartphone industry. The factors which were not appropriate to Smartphone were removed. The factors which represented similar function were clubbed together.

3.2.2 Organization of the Interview

The process used for collecting data was an offline interview with the questionnaire which was presented to the professionals in 7 Smartphone companies in India. These companies are prominent Smartphone companies having a bulbous customer base in India. The intended respondents were those managers involved in NPD process at the organization.

It took about three weeks duration to obtain final responses from the industry experts. A total of five out of these seven responses were further considered for analysis as they only these five responses were complete in all aspects.

3.3 Methodology of Fuzzy FMEA

The various steps involved in the Fuzzy FMEA methodology are given below (Kirkire et al., 2015) as depicted in Figure 3-1:

1. Obtain risk factors in NPD process.
2. Define fuzzy linguistic variables and terms for O, S, and D.
3. Evaluation of O, S, and D by experts for the risk factors using fuzzy linguistics (Lin et al. 2013).
4. Calculate O, S, and D using fuzzy linguistics (Eqs.)
5. Calculate RPN for each risk.
6. Arrange the risk factors in decreasing order of RPN number.

   The risk factor with highest RPN number is of most top priority.

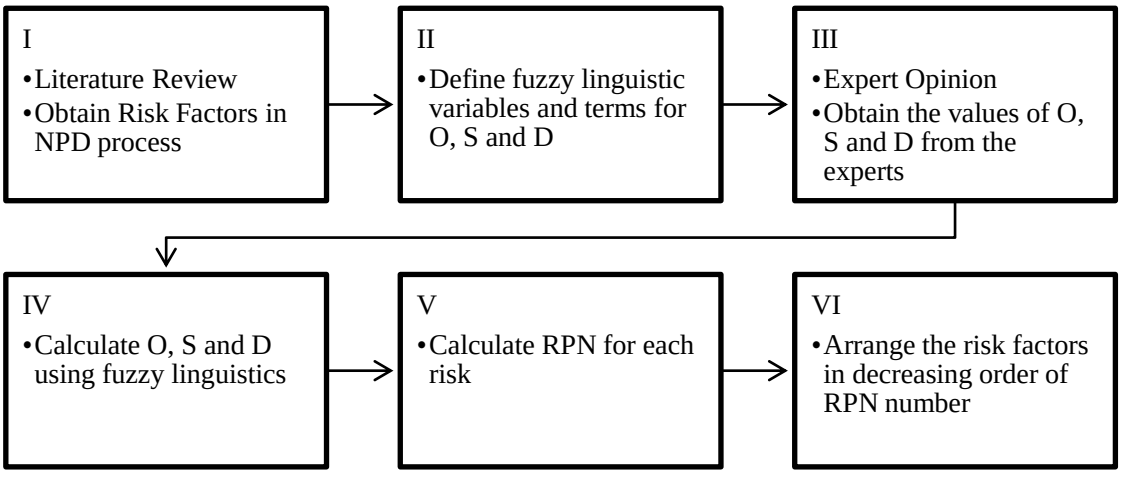

Figure 3.1 Flow diagrams for Fuzzy Analysis

CHAPTER-4 IDENTIFICATION OF RISK FACTORS IN SPD PROCESS

In literature review several articles and journals were found relevant to NPD and risk. Nevertheless, each scholar used a fairly different way to produce different factors. They shared a general study on effective NPD. Applicability of this general study is unclear when Smartphone industry is considered, due to its specific features. Thus, brainstorming with the researchers and the experts is required along with the literature review to identify the suitable risk factors relevant to the Smartphone industry.

In this study, a category of nine risk factors (Table 4.1) have been found from the available literature, and by brainstorming with the experts and the researchers.

Table 4.1 List of success factors identified through literature

S.No.	RISK FACTORS	SOURCES
1.	Consumer Market Risks	Nikolaos Pappas, 2016; Haryani etal.,2016; Weelden,2016; Stephen,2016; Syberg,2016; Rajshekhar et al,2015; Mihaela,2015; Rezaei ,2014; Dickson,2014; Montoya and Calantone, 1994
2.	Competitive Risks	Fornari et al,2016; Ozbugday,2016; Blasco,2016; Mahmutogullari et al,2016; Boco,2016; Poolton and Barclay, 1998
3.	Technology Risks	Ponce ,2016; Bearth,2016; Parks et al,2015; Visser,2015; Liu et al,2014; Kaul and Rao, 1995
4.	Managerial Risks	Boulton,2016; Iyeret al,2016; Akbar,2015; Xu et al,2015; Adam,2015; Ju et al,2014; Imhof,2014
5.	Financial Risks	Kim et al,2015; t Durucan ,2016; Iachini,2016; Guo,2016; Yang et al,2016; Ni et all,2015; Hammoudeh et al,2014; Chan,2015; Poledna et al,2015; Ahmed et al,2014; Poolton and Barclay, 1998
6.	Human Resource Risks	Becker et al,2016; Oborilová et al,2015; Cech et al,2016, Durrani,2015; Joncykz 2015; Hassini et al, 2015; Brown and Eisenhardt, 1995; Craig and Hart, 1992
7.	Regulatory Risks	Ramirez, 2015; *Wei,2015;* Ambituuni,2015; Sisodia et al,2015; Hanani ,2015; Harrison et al,2015
8.	Supply Chain Risks	Sherwin ,2016; Windelberg,2016; Aqlan,2016; Giannakis et al,2016; Cardoso,2016; Park ,2015; Fahimnia,2015
9.	Marketing Risks	Ejrami et al.,2016; Xu et al.,2015; Venkatesan,2015; Thomas and Wiley 1995; Clark and Fujimoto, 1991.

Risk factors in smartphone development process are obtained from literature review and discussion with experts.

All the obtained risk factors are grouped into following categories:

1. Consumer Risks:

   Consumer risks include customer satisfaction and enjoyment, strong brand loyalty, saturated market, decreasing new user market base.

2. Competitive Risks:

   Competitive Risks include the large presence of imitations & substitutes, new entrants, the risk of damage to corporate brand bargaining power of buyers, information management system and loss of confidential information to competitors, price wars, rumours about the product by other competitors, poaching of important personnel.

3. Technology Risks

   Technology Risks include rapid technological advancements, product differentiation, risk related to systems, risk related to intended work performed by the product, availability of reliable vendors, availability of adequate human resources with relevant knowledge, expertise and experience, effective product support infrastructure, firewall programs to prevent hacking of confidential knowledge of firm as well as its customers, innovation, availability of backup plan to keep company running if any accident occurs, research and development

4. Managerial Risks

   Managerial Risks include inadequate or failed procedures, systems or policies, employment practices and workplace safety, the arrangement of assets.

5. Financial Risks

   Financial Risks include high capital requirements, high sunk costs, higher cost of production because of smaller economies of scale, bargaining power of buyers, bargaining power of suppliers, backup capital plans for shortage time, customers can default on invoices (credit risk), rise in cost of raw materials (commodity price risk), rise and fall in international and national currency (exchange rate risk), rise in rate of interests (interest rate risk), asset price risk for example plunge in the value of stocks or real estate one pledged as collateral could cause the bank to cut ones credit lines, cost of advertising and promotion.

6. Human Resource Risks

Human resource risks include the availability of adequate human resources with relevant knowledge, contacts, temperament expertise and experience; team work and coordination, risk related to recruitment, motivation and retention of right partners, risk related to poaching of human resources by competitors.

7. Regulatory Risks

   Regulatory risks include risk related to intellectual property rights, risk related to services involving copyright, tax compilations, and disputes arising from poorly structured agreements.

8. Supply Chain Risks

   Supply chain risks include access to the distribution channel, bargaining power of suppliers, inventory management.

9. Marketing Risks

   Marketing risks include pricing strategies, identification of target market, promotion, advertising, research, and development.

CHAPTER-5 DATA ANALYSIS, RESULT AND DISCUSSION

The qualitative and quantitative analysis of the collected data for the research has been done. Qualitative analysis is done using Cause and Effect process while the quantitative analysis is conducted using Fuzzy FMEA method. Calculations of the process have been carried out using Microsoft Excel software.

5.1 Qualitative Analysis

FMEA is a step-by-step approach for identifying all possible failures in design, manufacturing or assembly process, or a product or service. FMEA originates during the original theoretical points of design and lasts all over the existence of the product or service. "Failure modes" refers to the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual. "Effects analysis" refers to studying the consequences of those failures (Ahmed et. al., 2013; Karuppusami and Gandhinathan, 2006). Cause and Effect Analysis of the identified Risk Factors in SPD process are shown in Table 5.1.

Failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones.

Table 5.1 - Cause and Effect Analysis of the identified Risk Factors in SPD process

Risk Factor	**Failure Mode**	**Causes**	**Effects**
RF1	Customer Risks	Demand and preference of clients not met. Consumers are satisfied with their existing products.	Loss of interest of customers. Decrease in profit potential.
RF2	Competitive Risks	Multiple substitute products, Presence of already accepted big brands and saturated market.	Low demand of than expected. Consumers are not willing to switch their present brand.
RF3	Technological Risks	Lack of compatibility with changing software (OS), Lack of security software, Web Security, Data confidentiality,	Obsolescence of the product, Less consumer response

		Physical Security, Data confidentiality	
RF4	Managerial Risks	Inadequate or failed procedures, systems or policies. Lack of resources or their improper management.	Bottlenecks, delays, confusion
RF5	Financial Risks	Lack of required capital, developing and implementing new technology and personnel require high capital	Lack of money to develop and implement new technology, lack capital slowdowns the new product development process
RF6	Human Resource Risk	Lack of highly intellectual and trained personnel	Very slow or no innovation at all
RF7	Regulatory Risks	Best methods are patented. Tax problems. Different laws in different places.	Cannot do desired development at low cost
RF8	Supply Chain Risks	Risk related to supply chain management	Delays, increase in total cost (storage cost), bad goodwill, shortages
RF9	Marketing Risks	Making a product is easier than its marketing. Lack of proper plans for price fixation and customer expectations. Lack of advertising and promotion of the product.	Customers will not know about the product; they may not satisfy with the price of the product.

5.2 Quantitative Analysis

The problems of the fuzzy phenomenon in the real world can be solved using fuzzy linguistic theory. This theory helps in fitting in fuzzy expressions and rough or vague data into decision framework (Liu et al. 2014). The fuzzy linguistic scale used in this research for the evaluation of O, S and D is with TFNs (Triangular Fuzzy Numbers) (Figure 5.1) which can be easily understood using Table 5.2.

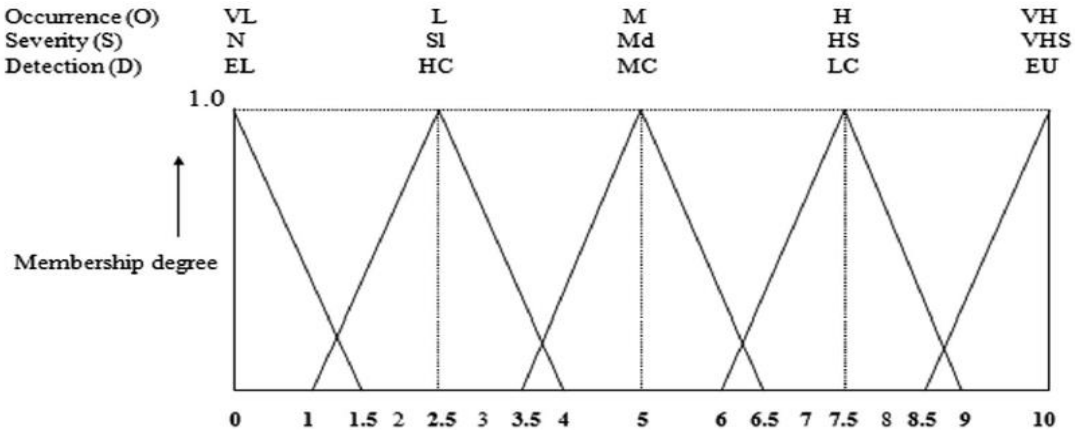

Figure 5.1 – Fuzzy linguistic scale for O, S, and D for SPD process risk factors (Lin et al. 2013)

Table 5.2 – Fuzzy lingustics for O, S, D and their corresponding fuzzy numbers

LINGUISTIC SCALE TERMS

OCCURRENCE(O)	VL (very low)	L (low)	M (medium)	H (high)	VH (very high)
SEVERITY(S)	N (none)	S (slight)	M (moderate)	H (highly severe)	VH (very high severity)
DETECTION(D) (chances of detection)	EL (extremely likely)	H (high)	M (moderate)	L (low)	EU (extremely unlikely)
Corresponding Fuzzy Numbers	0, 0, 1.5	1, 2.5, 4	3.5, 5, 6.5	6, 7.5, 9	8.5, 10, 10

The evaluation of O, S, and D of the nine identified risk factors during SPD process, using fuzzy linguistic terms, by the five experts (E) is presented in Table 5.3.

Table 5.3 – Evaluation of O, S, and D by experts using Fuzzy linguistics

Risk Factor	Expert	Occurrence(O)	Severity(S)	Detection(D)
RF1	E1	VH	VHS	LC
	E2	M	VHS	HC
	E3	H	VHS	HC
	E4	H	Md	HC
	E5	H	Md	HC
RF2	E1	VH	VHS	VHS
	E2	VH	HS	EL
	E3	M	HS	MC
	E4	H	VHS	MC
	E5	VH	HS	HC
RF3	E1	H	Md	MC
	E2	H	Md	MC
	E3	M	Md	EL
	E4	H	HS	HC

	E5	M	HS	MC
RF4	E1	M	Md	MC
	E2	H	Md	MC
	E3	M	SL	HC
	E4	M	Md	MC
	E5	L	HS	MC
RF5	E1	H	HS	LC
	E2	L	HS	EL
	E3	VH	Md	HC
	E4	H	Md	MC
	E5	H	HS	MC
RF6	E1	M	Md	MC
	E2	H	Md	MC
	E3	M	SL	HC
	E4	M	Md	HC
	E5	M	SL	HC
RF7	E1	VH	VHS	VHS
	E2	L	VHS	EL
	E3	VH	Md	HC
	E4	H	HS	HC
	E5	M	HS	EL
RF8	E1	H	HS	HC
	E2	VH	SL	LC
	E3	H	Md	HC
	E4	M	Md	HC
	E5	H	Md	HC
RF9	E1	M	Md	MC
	E2	VH	VHS	LC
	E3	VH	HS	MC
	E4	H	HS	MC
	E5	H	Md	HC

The aggregated fuzzy information for the nine risk factors for the SPD process is presented in Table 5.4. Fuzzy occurrence, severity, detection and fuzzy RPN of each risk factor in the SPD process have been calculated using Eqs. (1)–(4) (Lin et al. 2013), respectively. Table 5.4 shows the RPN values for all the nine identified risk factors during SPD process using Eq. 4.

$$\mathrm{D}O = \left\{\frac{[(OU-OL)+(OM-OL)]}{3}\right\} + OL \qquad \text{Eq. 1}$$

$$DS = \left\{\frac{[(SU-SL)+(SM-SL)]}{3}\right\} + SL \qquad \text{Eq. 2}$$

$$DD = \left\{\frac{[(DU-DL)+(DM-DL)]}{3}\right\} + DL \quad \text{Eq. 3}$$

Where,

L, M, U respectively denote lower, medium and upper limit.

DO, DS and DD are fuzzy Ocurrence, Severity, and Detection respectively.

RPN is calculated using DO, DS and DD as follows:

$$RPN = DO * DS * DD \quad \text{Eq. 4}$$

Table 5.4 - Aggregated Fuzzy information for nine risk factors and corresponding RPN values

Expert	FACTOR 1									Fuzzy RPN	Rank
	O			S			D				
	OL	OM	OU	SL	SM	SU	DL	DM	DU		
E1	8.5	10	10	8.5	10	10	6	7.5	9		
E2	3.5	5	6.5	8.5	10	10	1	2.5	4		
E3	6	7.5	9	8.5	10	10	1	2.5	4		
E4	6	7.5	9	3.5	5	6.5	1	2.5	4		
E5	6	7.5	9	3.5	5	6.5	1	2.5	4		
AVERAGE	6	7.5	8.7	6.5	8	8.6	2	3.5	5		
FUZZY	7.4			7.7			3.5			199.43	III
	FACTOR 2										
E1	8.5	10	10	8.5	10	10	8.5	10	10		
E2	8.5	10	10	6	7.5	9	0	0	1.5		
E3	3.5	5	6.5	6	7.5	9	3.5	5	6.5		
E4	6	7.5	9	8.5	10	10	3.5	5	6.5		
E5	8.5	10	10	6	7.5	9	1	2.5	4		
AVERAGE	7	8.5	9.1	7	8.5	9.4	3.3	4.5	5.7		
FUZZY	8.2			8.3			4.5			306.27	I
	FACTOR 3										
E1	6	7.5	9	3.5	5	6.5	3.5	5	6.5		
E2	6	7.5	9	3.5	5	6.5	3.5	5	6.5		
E3	3.5	5	6.5	3.5	5	6.5	0	0	1.5		
E4	6	7.5	9	6	7.5	9	1	2.5	4		

E5	3.5	5	6.5	6	7.5	9	3.5	5	6.5		
AVERAGE	5	6.5	8	4.5	6	7.5	2.3	3.5	5		
FUZZY	6.5			6			3.6			140.4	VI
	FACTOR 4										
E1	3.5	5	6.5	3.5	5	6.5	3.5	5	6.5		
E2	6	7.5	9	3.5	5	6.5	3.5	5	6.5		
E3	3.5	5	6.5	1	2.5	4	1	2.5	4		
E4	3.5	5	6.5	3.5	5	6.5	3.5	5	6.5		
E5	1	2.5	4	6	7.5	9	3.5	5	6.5		
AVERAGE	3.5	5	6.5	3.5	5	6.5	3	4.5	6		
FUZZY	5			5			4.5			112.5	VIII
	FACTOR 5										
E1	6	7.5	9	6	7.5	9	6	7.5	9		
E2	1	2.5	4	6	7.5	9	0	0	1.5		
E3	8.5	10	10	3.5	5	6.5	1	2.5	4		
E4	6	7.5	9	3.5	5	6.5	3.5	5	6.5		
E5	6	7.5	9	6	7.5	9	3.5	5	6.5		
AVERAGE	5.5	7	8.2	5	6.5	8	2.8	4	5.5		
FUZZY	6.9			6.5			4.1			183.885	IV
	FACTOR 6										
E1	3.5	5	6.5	3.5	5	6.5	3.5	5	6.5		
E2	6	7.5	9	3.5	5	6.5	3.5	5	6.5		
E3	3.5	5	6.5	1	2.5	4	1	2.5	4		
E4	3.5	5	6.5	3.5	5	6.5	1	2.5	4		
E5	3.5	5	6.5	1	2.5	4	1	2.5	4		
AVERAGE	4	5.5	7	2.5	4	5.5	2	3.5	5		
FUZZY	5.5			4			3.5			77	IX
	FACTOR 7										
E1	8.5	10	10	8.5	10	10	8.5	10	10		
E2	1	2.5	4	8.5	10	10	0	0	1.5		
E3	8.5	10	10	3.5	5	6.5	1	2.5	4		
E4	6	7.5	9	6	7.5	9	1	2.5	4		

E5	3.5	5	6.5	6	7.5	9	0	0	1.5		
AVERAGE	5.5	7	7.9	6.5	8	8.9	2.1	3	4.2		
FUZZY	6.8			7.8			3.1			164.424	V
	FACTOR 8										
E1	6	7.5	9	6	7.5	9	1	2.5	4		
E2	8.5	10	10	1	2.5	4	6	7.5	9		
E3	6	7.5	9	3.5	5	6.5	1	2.5	4		
E4	3.5	5	6.5	3.5	5	6.5	1	2.5	4		
E5	6	7.5	9	3.5	5	6.5	1	2.5	4		
AVERAGE	6	7.5	8.7	3.5	5	6.5	2	3.5	5		
FUZZY	7.4			5			3.5			129.5	VII
	FACTOR 9										
E1	3.5	5	6.5	3.5	5	6.5	3.5	5	6.5		
E2	8.5	10	10	8.5	10	10	6	7.5	9		
E3	8.5	10	10	6	7.5	9	3.5	5	6.5		
E4	6	7.5	9	6	7.5	9	3.5	5	6.5		
E5	6	7.5	9	3.5	5	6.5	1	2.5	4		
AVERAGE	6.5	8	8.9	5.5	7	8.2	3.5	5	6.5		
FUZZY	7.8			6.9			5			269.1	II

The fuzzy RPNs thus obtained are ranked in Table 5.4 and 5.5. Greater the RPN of the risk factor higher is its risk. Thus, the risk factor with highest fuzzy RPN has been ranked 1, with second highest 2 and so on to ensure that the risk factors with higher risks are dealt earlier.

Table 5.5 Summary of RPN values and corresponding ranks of risk factors

	RISK FACTOR	**FUZZY RPN**	**RANK**
R1	Consumer Risks	**199.43**	**3**
R2	Competitive Risks	**306.27**	**1**
R3	Technology Risks	**140.4**	**6**
R4	Managerial Risks	**112.5**	**8**
R5	Financial Risks	**183.885**	**4**
R6	Human Resource Risks	**77**	**9**
R7	Regulatory Risks	**164.424**	**5**

R8	Supply Chain Risks	**129.5**	**7**
R9	Marketing Risks	**269.1**	**2**

The risks during SPD process have been categorized as negligible risks(NR), lower risks(LR), moderate risks(MR) and high or critical risks(HR) as per the RPN values obtained (Figure 5.2 and 5.3). Experts helped in categorizing the risks in these categories.

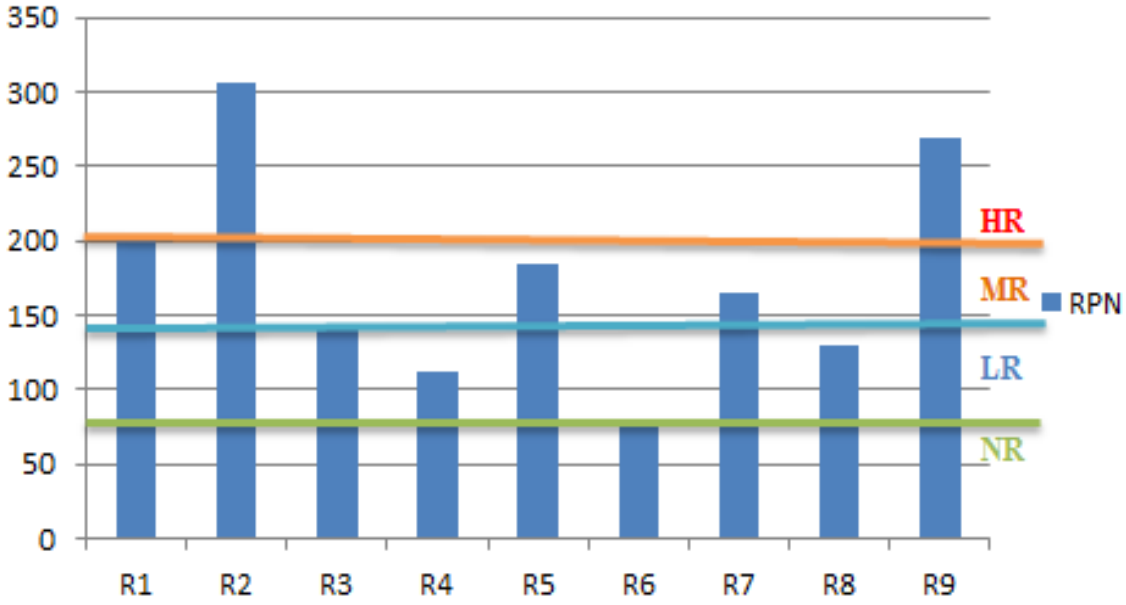

Figure 5.2 Categorization of risk based on RPN values

HR	High Risk Factors		R2							R9
MR	Moderate Risk Factors	R1				R5		R7		
LR	Low Risk Factors			R3	R4				R8	
NR	Negligible Risk Factors						R6			

Figure 5.3 Scatter of risks by their category

From Figure 4.2 and 4.3, it is clear that R2 (Competitive Risks) and R9 (Marketing Risks) are the factors with high risks and thus it is required to remove or minimize them first. R1 (Consumer Risks), R5 (Financial Risks) and R7 (Regulatory Risks) should be treated next. Low Risk Factors R3 (Technology Risks), R4 (Managerial Risks) and R8 (Supply Chain Risks) can be avoided by taking required preventive measures. There is no need to spend much time, labour and money on the negligible

risk factor R6 (Human Resource Risks). Keeping these things in mind a risk alleviation model has been designed in the next chapter.

5.3 Model for Risk Alleviation and Mitigation

In earlier chapters, the risk factors have been identified, prioritized and categorized. In this chapter, a model to mitigate or alleviate the risks is suggested with the help of the experts (Table 5.6). A model for risk mitigation (Figure 5.6) is also developed as per the recommendations of the experts. It shows the risks identified and the strategy for their mitigation as suggested by the experts. The model has a reasonable flow. SPD process risks are presented on the left-hand side of the model. High, moderate, low level and negligible risks are denoted in their decreasing order of criticality. Common strategies for risk mitigation by their criticality are given away on the right-hand side of the model. Some risks remain after applying the mitigation strategy. These are shown as the residual risks in the model. Calculation of the tolerable level of every residual risk should be carried out for better results.

Table 5.6 Recommended risk treatment and mitigation

Risk Category	Risk factor	Risk treatment and management	Risk mitigation strategy
High risk	R2 Competitive Risks	Proper information management system. The motivation of employees.	Formulate and install the risk response proposal or plan as soon as possible.
	R9 Marketing Risks	Invest in marketing and advertising. Generate the need of product and justify this need properly to the prospective buyers.	
Moderate risk	R1 Consumer Risks	Flawless definition of the end user or customer. A detailed collection of customer demands and	Take necessary action to a short passage of time to escape future risks.

		requirements. Involvement of experts to finalize required strategy.	
	R5 Financial Risks	Minimize cost. Minimize waste. Utilise available resources optimally.	
	R7 Regulatory Risks	Complete know how of escaping regulatory risks wisely and legally. Avoid poorly structured agreements.	
Low risk	R3 Technology Risks	Adopt latest and user friendly technology. Product differentiation. Acquire well qualified employees and experts. Keep back up. Promotion of team work.	Keep an eye on these risks and make a precautionary action plan.
	R4 Managerial Risks	Division of labour. Proper allocation of available resources. Effective decision making.	
	R8 Supply Chain Risks	Manage inventory. Avoid bottlenecks. Avoid full dependence on suppliers.	
Negligible risk	R6 Human Resource Risks	Training of employees. The motivation of employees.	Take action if concerns arise another time in future.

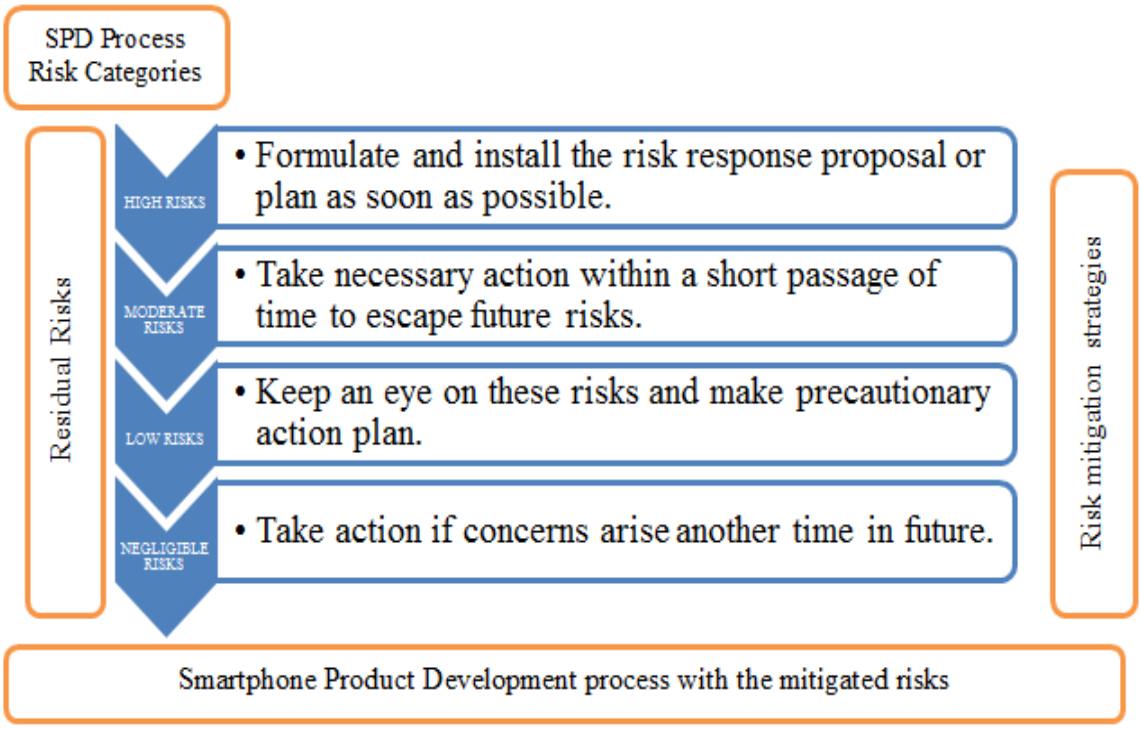

Figure 5.4 SPD Risks Mitigation Model

Most of the investigation and study on RM has emphasized on identification and analysis of risk. A case study of SPD is presented here in this dissertation in which a total of nine risks are discovered. These risks are classified as Consumer Risks, Competitive Risks, Technology Risks, Managerial Risks, Financial Risks, Human Resource Risks, Regulatory Risks, Supply Chain Risks and Marketing Risks, by brainstorming with experts. RPN is calculated for each risk using fuzzy FMEA. The risks are further characterized as high, moderate, low level and negligible risks by their RPN and the criticality. The fuzzy FMEA gives 36.36 % HRs, 34.61 % MRs, 24.16 % LRs and 4.87% NRs out of total risks (Figure 5.5).

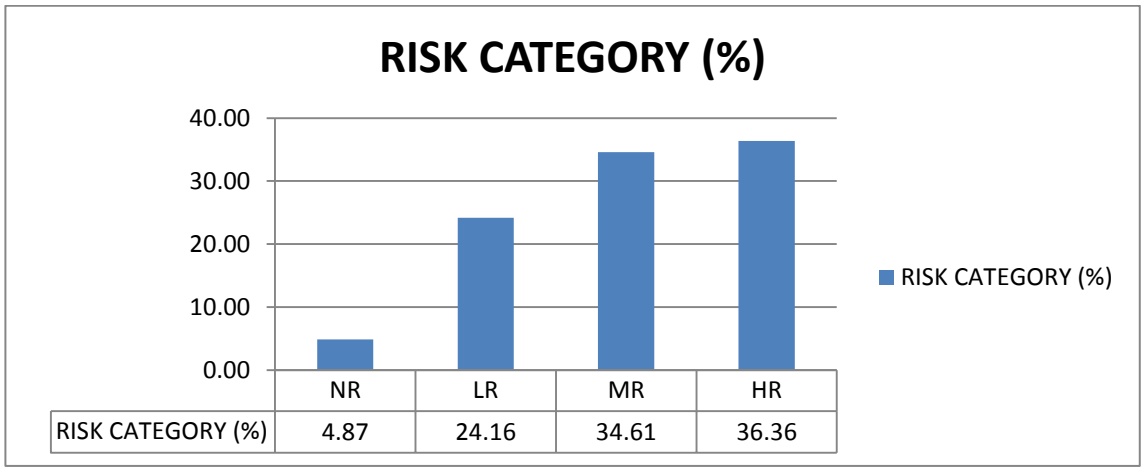

Figure 5.5 Distributions of Risk Categories

The study provides a detailed methodology for the developers, managers and researchers to explore SPD process risks and perform risk management using fuzzy FMEA approach. The risks identified here may be specific in nature, but they provide a guideline for development processes of other similar products and devices. Also, the procedure of a fuzzy approach to FMEA is discussed here in detail. The model of risk mitigation developed here will serve as a generic model for risk alleviation and mitigation.

CHAPTER -6 CONCLUSION

These days, the industrial processes are more complex and rapid. The market has become exceedingly challenging relative to costs and blockages or delays and at the same time demands a high level of quality. Then, to govern the best balance amid gains and risks, the firm has to continuously consider a risk management and its mitigation strategy. So, the choices and decisions are more sophisticated. Therefore here is extreme importance of new topics about identifying risks, managing risks and avoidance of risks. It is essential to have an organized and standard approach to NPD to accomplish an effective new product, and positively the fruitful performance of a new product into a business. At first, we present PD, NPD, FMEA, Fuzzy FMEA concepts and the major definitions.

We have worked on the topic based on the activities and experiences of experts and researchers who are familiar with the product development practice of somewhat sophisticated products. The study has offered NPD risk exploration technique using fuzzy FMEA after reviewing previous studies of the relevant field. A systematic case study on the Smartphone Development Process is done. Nine key risk factors were identified, namely Consumer Risks, Competitive Risks, Technology Risks, Managerial Risks, Financial Risks, Human Resource Risks, Regulatory Risks, Supply Chain Risks and Marketing Risks, with help of brainstorming with the experts and the review of the previous literature. The risk factors have been prioritised and categorized on the basis of their criticality. The results show 2 high, 3 moderate, 3 low and 1 negligible risk factor which can be easily seen in Figure 5.2 and 5.3. The Competitive Risks and Marketing Risks were the significant risks which need to be eliminated first, followed by other seven categories in the similar order. Consequently, a risk alleviation and mitigation model has been drawn (Figure 5.4) to suggest risk mitigation in Smartphone Industry. The managers can pick the best way out of this model for the success their project in the relevant field while monitoring the levels of risks. The model suggests risk mitigation plans for the aid of managers.

This research report marks a noteworthy contribution to the product development study as it shows how fuzzy FMEA can be utilized to analyze risk factors and how we can relate them to the system dynamics in new product development.

6.1 Limitations and Future Scope

This case study has numerous advantages and some limitations as well. It is designed for Smartphone industry & discloses the risks specific to this industry. Therefore, the results are limited to Smartphone industry & its results can't be directly applied to other circumstances. Thus, additional methods for risk analysis which are more generic should be used and linked to the results stated here. However, the framework of the methodology can be applied to examine the same problems in another segment of industries. A key limitation of this study is that the opinions of the experts were majorly taken as per the Indian market. A detailed survey of the smartphone product development companies will be useful in drawing statistics-based conclusions.Generalization could be increased by gathering data on other countries. Other cases can be studied to increase with similar methodology to make this study wider.

The data is collected from the experts in the concerned field by assuming that they are accustomed to NPD process & hold the required understanding, expertise & experience. So, the bias of the expert who is judging the identified risk factors might have influenced the ultimate results. It is a limitation of validity & reliability of the results.

Phase-wise distribution of risks can be performed in Future to examine the significance and connection of several risks at different stages or phases of NPD process.

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APPENDIX – SURVEY QUESTIONNAIRE

Interview questionnaire for Risk Analysis in Smartphone Product Development Process

NAME: _____DESIGNATION:_____

EXPERIENCE: _____ORGANISATION:_____

Evaluate the following risk factors associated with Smartphone development. Encircle your responses in the table below. The linguistics scale for evaluation is provided below the table.

S. No.	FAILURE MODE	OCCURRENCE (O)					SEVERITY (S)					DETECTION(D)				
1	Consumer Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
2	Competitive Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
3	Technology Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
4	Managerial Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
5	Financial Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
6	Human Resource Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
7	Regulatory Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
8	Supply Chain Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU
9	Marketing Risks	VL	L	M	H	VH	N	S	M	H	VH	EL	H	M	L	EU

LINGUISTIC SCALE TERMS

OCCURRENCE(O)	VL (very low)	L (low)	M (medium)	H (high)	VH (very high)
SEVERITY(S)	N (none)	S (slight)	M (moderate)	H (highly severe)	VH (very high severity)
DETECTION(D) (chances of detection)	EL (extremely likely)	H (high)	M (moderate)	L (low)	EU (extremely unlikely)

Lingustics for O, S, and D