Modified Approach to Risk Assessment — A Case Study on Product Innovation and Development Value Chain

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***Abstract*—Product Innovation is a key aspect of any company and central to the Innovation and New Product Development (NPD) process. Companies must take risks to launch new products speedily and successfully. The ability to diagnose and manage risk is very important activity in a high- risk environment. This paper examines a modified approach to risk assessment using Monte Carlo simulation for Product Innovation and Development (PID) value chain. Weighted Risk Assessment Table (WRAT) developed as risk assessment model and Monte Carlo simulation used to assess the project value at risk and its uncertainty. An overall Product innovation and Development Value Chain framework was also developed and the same is used to explore various risks, categorize them according to their sources, assesses those risks and their variability. The methodology was demonstrated using a case study on a new innovative home appliance.**

***Index Terms*—New product development, risk assessment, monte carlo simulation, innovation.**

I. Introduction

Risk is the potential that a chosen action or activity (including the choice of inaction) or actions from external world will lead to a loss (an undesirable outcome). Risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and impact of unfortunate events. Risk management and innovations are not opposed. The core competency of the most effective and successful innovator is risk management [1]. For these innovators the ability to identify, prioritize, and systematically eliminate risks is what drives innovation forward.

This paper aims to present a new PID value chain framework and a modified risk assessment methodology for this framework to bring new product or service to market. Any innovative products are of little value to a firm that cannot get to market, either on its own and/or through partnership. Find below are some of the essential requirements of a successful organizations.

- Imperative to innovate
- Emphasis on developing the capability and capacity to innovate and taking into market
- Culture of accountability and responsibility for delivering results
- Systematic organizational learning
- Risk management processes in decision making

This view of innovation from a market and institutional perspectives reveals that importance of innovation is related to the overall value delivery system which the organization possess intend to develop to bring innovative product / service to the market. An innovation value-chain framework was presented as a sequential, three-phase process that involves idea generation, idea development, and the diffusion of developed concepts mentioned in the literature [2]. Along with the value chain, the importance of one or more activities that a company can excels and one or more activities that a company struggles with — the firm's weakest links are detailed. Disruptive innovation framework capturing the essential characteristics and holistic success factors reported in the literature [3]. The service delivery system design characteristics and contingencies helps to understand service process was provided in the paper [4].

The modified risk assessment methodology for the product innovation and development value chain to assess risks available in the current product innovation and development system of organization are detailed in the following sections. This methodology will help organizations in making better decisions and to ensure corrective actions are in place to bridge the gap in the PID system and hence to bring innovation successfully to the market.

II. Proposed PID Value Chain Framework

A. Six Phases of PID Value Chain

Six phases value chain framework was developed for Product Innovation and Development (Fig. 1).

Phase 1: Scan

Keep your eyes open for new technologies/innovations that might assist you. A series of studies that tracks trends, technologies, competitor activities, substitution products, and innovations could influence or be leveraged as part of next generation products. The scope of this phase is the *Innovation/Technology Watch List*, which includes identified innovation/technologies, their trajectory in terms of performance and potential for adoption, along with major opportunities and limiting factors. The output of this phase may be white papers/summary reports on technology and market analysis leading to some high value adding innovation projects on all opportunities.

Phase 2: Screen

Evaluate the innovation against your strategy. Ask yourself

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if implementing this innovation/technology will help your company reach its strategic goals better or faster. Does it increase efficiency, reduce cost or act as a product differentiator? It is about detailed understanding about various technologies under consideration and identifying potential options.

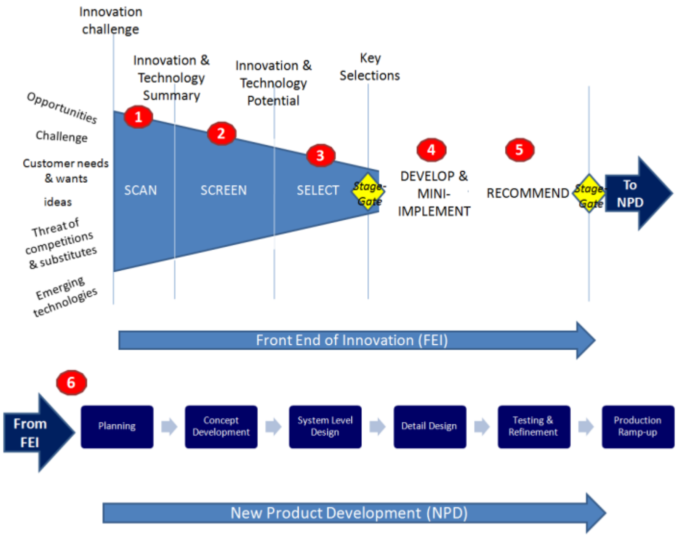

Fig. 1. The proposed product innovation & development value chain framework.

Phase 3: Select

During this phase, we will identify all the necessary requirements including business, functional, and technical. Based on focused stakeholder interviews, requirements technology options are categorized and prioritized. Each requirement weighted to provide a level of importance to the organization. In addition, this phase will evaluate the organization's current business product/process potentially affected by the technology change and begin to outline the future state of these product/ processes. This phase is all about selecting vital few options. An ANP based approach to evaluation is provided in the literature [5].

Phase 4: Develop and Mini-implement

Begin with a limited test of the innovation/technology by providing seed funding. A mini-implementation can help to evaluate innovation & new technologies within organization's own products, processes and services. This will serve as a proof of innovation/technology/concept to proceed further with development.

Phase 5: Recommend

Based on results from phase 4, further development as NPD will be recommended. This should include communications such as status on performance, timetables, phases, issue resolution and cost. It also should include how to communicate with employees, vendors or consultants assisting with the implementation. The phases 1 to 5 shall be termed as Front End of Innovation (FEI) or Fuzzy Front End.

Phase 6 – NPD Process

After completion of Fuzzy Front End, the NPD process shall be initiated to bring new product into the market. The phase 6 shows the generic new product development model adopted by many organizations [6]. A process-oriented approach to project management of NPD or any kind of project is given in [7].

III. Proposed Risk Assessment Methodology for PID Value Chain

Creativity and risk are inexorably linked; both are infinite in their variety with the result that their combination usually defies accurate description. The environment in which the conception and development of new products takes place is complex and involves creativity and risk at a number of levels in a wide range of situations [8]. Hence, systematic risk assessment methodology is essential for any PID process. The proposed risk assessment method helps to identify risks associating in delivering innovation value through all the six phases of PID. The companies could focus their effort in important delivery system aspects, so that the innovation value delivered as intended. The method consists of two phases. The Phase A is about development of Weighted Risk Assessment Table and Phase B is about Monte Carlo Simulation to handle uncertainties in risk sources.

A. Development of Weighted Risk Assessment Table

In this method, Risk Assessment Table (RAT) (widely used method by industries) has been suitably modified for assessing the risks in delivering innovation value. This modified RAT is called Weighted Risk Assessment Table (WRAT), which provides opportunity to estimate overall risk value of entire innovation project. The following steps were adopted for risk assessment.

1. Determine Risk Sources Categories: Identification of risk sources provides a basis for systematically examining the situation and ability of innovation project to meets its objectives. The risk sources are both internal and external to the PID project. Establishing categories for risk sources provides a mechanism for collecting and organizing risk.
2. Establish percentage importance for these risk sources: Based on strategic, organizational and risk management context, the team has to assign percentage importance. The summation of these percentages should be one.
3. Identify potential risk events and actions: Sit down and create a list of every possible risk event and opportunity you can think of. If you only focus on the threats, you could miss out the chance to deliver unexpected value to the customer or client. Ask your team to help you brainstorm during the project planning process, since they might see possibilities that you do not.
4. Determine Causes: By asking several "whys" (Five Whys) repeatedly will lead to root causes (deficiency or sources of variability) of risk events and actions.
5. Determine the Effects (consequences) of each risk event if it happens.
6. Determine Likelihood: What are the chances a certain risk will occur? Rate each risk with the probability from zero to one.
7. Determine impact on project value (%): What would happen if each risk occurred? Would your final delivery date get pushed back? Would you go over budget? Identify which risks have the biggest effect on your innovation project's outcomes, and estimate them in

terms of monitory value and calculate percentage value affecting.

8. Calculate Percentage Value @ Risk: It is the multiplication of likelihood and impact of project value percentage.

The WRAT contains percentage importance for each risk source, which is not available in other forms of RAT. The WRAT for different innovation values of the product or service under consideration will help the organization in recommending corrective actions for overall delivery of innovation values. The various sources of innovation risks and their failure initiating events or actions for the case study are given in Table I. The excel model of the WRAT method is given in Table II. As per the methodology, Value @ Risk (%) guides the organization for better understand their product innovation and development system risk and providing scope for corrective action to deliver innovation without scarifying its value to market place. The case study detailed in this research to demonstrate the usefulness of this approach.

TABLE I: SOURCES OF RISKS AND THEIR FAILURE INITIATING EVENTS

Risk Sources	Failure initating Events & Actions
Market and Competition	Lack of Customer Understnding (needs and wants)
	Difficulty in building relationship with key customer
	Delay in developing new market
	Issue in product positioning
	Lack of proper portfolio
	Changes in sales forecasts
	Growing local competition
	Growing international competition
	Unscientific feasibility study
Strategy and Managerial	Difficulty in clarifying and agreeing on innovation
	Lack of coordination between functions / departments
	Late / delay in making decisions
	Frequent decision changes
Financial	Over running budget
	Incorrect pricing
	Inadequate sales expectation
	High initial costs
	Unpredictability of suppliers costs
	Cash flows issues
	High BoM cost
	Low IRR and NPV
Innovation	Poor in opportunity identification/ analysis
	Not many ideas
	Inadequate idea evaluation / short-listing
	Poor idea/concept development and prooving
	Confusing priorities
Technology	High technology development time
	Issue in linking technology with customer/business
	Unanticipated technology complexities
	Lack of competencies in technology development
	Not viable in price/performance
	High cost to acquire technology
	Huge funds to be invested in R&D
Design / manufacturing related	Quality issues
	Many iterations
	Too much waiting time for ID, prototypes
	Performance is not proven
	Issue in manufacture
	Too much material handling and transport
	Current design maturity level
	Materials issues
	Process capability issue
	Manufacturing and fabrication
	Very short time available to market
Suppliers	Too much dependance on components / services from
	Supplier component quality issues
	Inadequate capacity
IP	Research not sufficient to validate claims
	Delay in developing and protecting IP
	Legal issues with competitors
Legal and Compliance	Test compliance with standards issues
	Safety issues
	Compliance with any new requirements
Organizational	Lack of internal competencies
	Retention of key employees
	Internal organizational change
	Lack of commitment to innovation and product
	Commitment issues with leadership team

TABLE II: WEIGHTED RISK ASSESSMENT TABLE

Risk Sources	% Imporatnce	Failure initating Events & Actions	Cause(s)	Effect(s)	Likelihood	Impact on Project Value (%)	Value @ Risk (%)
Market and Competition	25.0%	Lack of Customer Understnding (needs and wants)	Not so good market understanding / research	Risk of business survival	0.8	80.0%	16.00%
		Difficulty in building relationship with key customer					
		Delay in developing new market					
		Issue in product positioning					
		Lack of proper portfolio					
		Changes in sales forecasts	Lack of market potential understanding and competition	Loosing competitive advantage			
		Growing local competition					
		Growing international competition					
		Unscientific feasibility study					
Strategy and Managerial	5.0%	Difficulty in clarifying and agreeing on innovation objectives	Lack of leadership and organizational culture	Risk of business survival	0.4	40.0%	0.80%
		Lack of coordination between functions / departments					
		Late / delay in making decisions					
		Frequent decision changes					
Financial	17.0%	Over running budget	Lack of awareness in overall cost	Hampered growth and return	0.5	75.0%	6.38%
		Incorrect pricing					
		Inadequate sales expectation					
		High initial costs					
		Unpredictability of suppliers costs					
		Cash flows issues					
		High BoM cost	Additional parts to ensure safety	Low profit margin			
		Low IRR and NPV					
Innovation	20.0%	Poor in opportunity identification/ analysis	Lack of structured "Front End for Innovation" Process	Less flow of innovations and hence hapered economic sustainability	0.6	60.0%	7.20%
		Not many ideas					
		Inadequate idea evaluation / short-listing					
		Poor idea/concept development and prooving					
		Confusing priorities					
Technology	15.0%	High technology development time	Lack of understanding on technical difficulty and uncertainty	Less flow of innovations and hence hampered economic sustainability	0.6	60.0%	5.40%
		Issue in linking technology with customer/business needs					
		Unanticipated technology complexities					
		Lack of competencies in technology development					
		Not viable in price/performance					
		High cost to acquire technology					
		Huge funds to be invested in R&D					
Design / manufacturing related	5.0%	Quality issues	Poor execution of NPD	Missing product launch & decline in market share	0.3	50.0%	0.75%
		Many iterations					
		Too much waiting time for ID, prototypes					
		Performance is not proven					
		Issue in manufacture					
		Too much material handling and transport					
		Current design maturity level					
		Materials issues					
		Process capability issue					
		Manufacturing and fabrication					
		Very short time available to market					
Suppliers	5.0%	Too much dependance on components / services from suppliers	Missing ESI in FEI	Not meeting sales targets and revenue reduction	0.3	30.0%	0.45%
		Supplier component quality issues					
		Inadequate capacity					
IP	2.0%	Research not sufficient to validate claims	Lack of understanding and structure in handling IP	Loosing market leadership	0.25	30.0%	0.15%
		Delay in developing and protecting IP					
		Legal issues with competitors					
Legal and Compliance	3.0%	Test compliance with standards issues	Lack of understanidng on countries policies, laws and regulations	Not meeting sales targets and revenue reduction	0.2	30.0%	0.18%
		Safety issues					
		Compliance with any new requirements					
Organizational	3.0%	Lack of internal competencies	Inability to attract talent	Mistrust and poor organizational culture	0.2	20.0%	0.12%
		Retention of key employees					
		Internal organizational change					
		Lack of commitment to innovation and product					
		Commitment issues with leadership team					

B. *Monte Carlo Simulation*

The project managers should find ways to handle uncertainties in project risk sources for successful completion of PID projects. The major constraints of PID projects are cost, schedule, scope and quality. All constraints will have impact on value of project. Monte Carlo approaches are very useful in determining impact of identified risks by running simulation over possible range of outcomes. A random sampling performed by using uncertain risk variable inputs to generate the range of outcomes with confidence measure for each outcome. A mathematical model is used for connecting input risk variable with that of output variable (in our example the entire project value at risk). This will help to prioritize various risk sources and to make informed decisions on project. The following steps were adopted for Monte Carlo Simulation.

1. Identify the project input risk variables
2. Establish percentage importance for these risk variables (the sum of these percentages must be equal to 1)
3. Establish output variables (in our case it is Value @ Risk; obtained through multiplying % importance, likelihood of occurring and Impact on project value by that variable)
4. Establish relationship for the correlated variables (if any)
5. Establish mathematical model connecting inputs and outputs. In our case, betaPERT distribution was used to model variations in input variables because of uncertainties. (The betaPERT distribution is a continuous distribution. It describes a situation where you know the minimum, maximum, and most likely values to occur. It is useful with limited data. It is similar to the triangular distribution, except the curve is smoothed to reduce the importance of peak. The betaPERT distribution is often used in project management models to estimate task and project durations. The parameters of the distribution are Minimum, Most Likely, Maximum).
6. Perform simulation runs for the identified variables and the correlations
7. Statistically analyze the results of the simulation run.

The steps 1 to 3 for the below mentioned case study are given in Table II and III. Steps 4 to 6 are given in the Table III. The simulation was carried out using the software package ModelRisk. The statistical results of simulation of the case study are given in Fig. 2-Fig. 4.

TABLE III: VARIABLES USED IN MONTE CARLO SIMULATION

						BetaPERT Distribution Parameters				
Risk Sources	% Importance	Likelihood	Impact on Project Value (%)	Value @ Risk (%)		Most likely Value @ Risk (%)	Best Case	Worst Case		Simulated Sample Value (%)
Market and Competition	25.0%	0.8	80.00%	16.00%		16.00%	10.00%	25.00%		14.03%
Strategy and Managerial	5.0%	0.4	40.00%	0.80%		0.80%	0.20%	2.00%		0.85%
Financial	17.0%	0.5	75.00%	6.38%		6.38%	2.00%	10.00%		4.26%
Innovation	20.0%	0.6	60.00%	7.20%		7.20%	5.00%	15.00%		8.14%
Technology	15.0%	0.6	60.00%	5.40%		5.40%	4.00%	15.00%		7.16%
Design / manufacturing related	5.0%	0.3	50.00%	0.75%		0.75%	0.50%	3.00%		0.78%
Suppliers	5.0%	0.3	30.00%	0.45%		0.45%	0.20%	3.00%		1.04%
IP	2.0%	0.25	30.00%	0.15%		0.15%	0.10%	0.20%		0.14%
Legal and Compliance	3.0%	0.2	30.00%	0.18%		0.18%	0.00%	0.20%		0.14%
Organizational	3.0%	0.2	20.00%	0.12%		0.12%	0.00%	1.00%		0.31%
Total Project Value @ Risk (%)						37.43%				36.83%
						Single Point Estimate				Simulated Sample Estimate

IV. CASE STUDY: INFRARED TECHNOLOGY BASED CLOTHES DRYER

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

Clothes dryer is the second most energy consuming household appliance after refrigerator. This paper is to evaluate risk associated with infrared heating (IR) based heating for the clothe dryer since these are believed to have lower power consumption, reduced drying time, flexibility in drying temperature compared to the existing technology based on filament heating element. This new technology option may also have some limitations with respect to their ability to handle different type of clothes and safety in usage etc. The majority of risk assessment framework addresses the financial aspects and does not include other issues related to technology/innovations. The implementation of Weighted Risk Assessment Table (WRAT) was provided in the Fig. 3. Value @ Risk (%) numbers were developed for the clothes dryer (refer simulation step 3). The simulation results are available in Fig. 2 to Fig. 4.

The comparative analysis of various risk sources is provided in the Fig. 4. From this analysis, it is evident that company has to work on market & competition, innovation and technology aspects of clothes dryer to minimize risk. The approach mentioned in this paper is useful for industries who want ensure success through product innovation and development.

Variable Name Variable Type Simulation #	Total Project Value @ Risk Output Sim: 1
Location	
Mean	0.409727479
Minimum	0.289214963
Maximum	0.557904283
# of Errors	0
# of Filtered	0
Spread	
St. dev.	0.04051644
Variance	0.001641582
CofV	0.098886314
Shape	
Skewness	0.169940134
Kurtosis	2.888581058
Percentiles	
1.00%	0.3214
5.00%	0.3444
15.00%	0.3674
25.00%	0.3814
35.00%	0.3932
45.00%	0.403
55.00%	0.4139
65.00%	0.4244
75.00%	0.4367
85.00%	0.4519
95.00%	0.4802
99.00%	0.5074

Fig. 2. The simulation statistics.

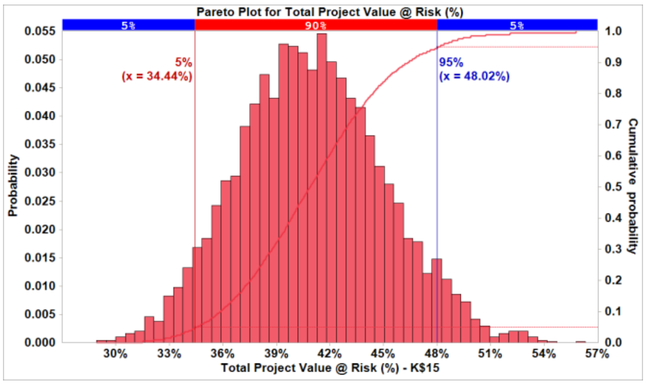

Fig. 3. Pareto plot for total project Value @ Risk.

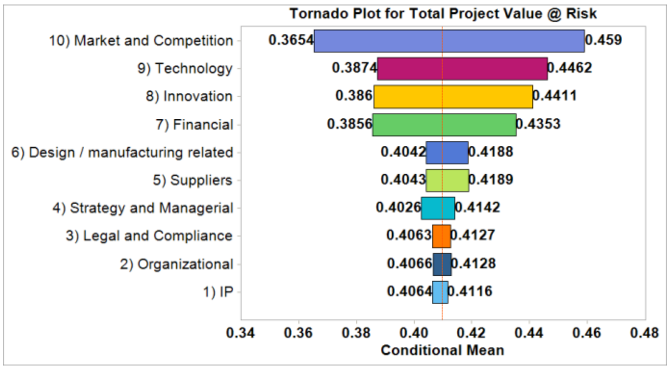

Fig. 4. Tornado plot for total project Value @ Risk (sensitivity analysis).

V. Results and Discussion

There were 10 risk sources identified for this case study. They are market and competition, strategy and managerial, financial, innovation related, technology, design and manufacturing related, suppliers, IP, legal and compliance and organizational. More than 58 failure initiating events and actions were brainstormed. This, almost exhaustive list is provided in the Table I and II. Based on experts' opinion, the Value @ Risk for each of the risk sources were estimated. For example, the market and competition risk source, the value @ risk was estimated as 16% (refer Table III) which was estimated from Table II. BetaPERT distribution describes the situation where expert judgements were used to model variability in the input variables (in our case Value @ Risk for various risk sources). It is a continuous distribution using minimum, maximum, and most likely values for Value @ Risk. For market and competition, most likely value at risk is 16%, best case is 10% and the worst case is 25%. This means any risk event in market and competition happens the value generated by this innovation project will reduce by 16% (most likely), the best-case value reduction is 10% and worst-case value reduction is 25%. Hence, the value at risk is having variability 10 % to 25%. Monte Carlo simulation was applied for this range to determine its uncertainty as per betaPERT. One sampled value of simulation is 14.03%. Likewise, the simulation was carried with random sample of 5000 for each the 10 risk sources; and based on their relationship the final simulation statistics were derived. These statistics are provided in the Fig. 2. For this project, the total project Value @ Risk is coming as 40.97% with the standard deviation of 0.0405, minimum value as 28.92% and maximum value as 55.79%. Fig. 3 Pareto plot also indicates that 41% of value of project is under risk because of various sources. As per chart, the value at risk cannot exceed 48.02% at 95% confidence level. This shall be interpreted as, the value of project will come down by 48.02% (at 95% confidence level) if the risk events happen and response actions are not implemented. Tornado diagram (Fig. 4) is useful for deterministic sensitivity analysis - comparing the relative importance of variables. For each variable/uncertainty considered, you will need estimates for what the low, base, and high outcomes would be. The sensitive variable was modeled as uncertain value while all other variables was held at baseline values (stable). This allows us to test the sensitivity/risk associated with one uncertainty/variable [9]. For example, Market and Competition risk source can increase Value @ Risk of the project from 41% to 45.9%. Similarly, if it can reduce the Value @ Risk to 36.54% in the lower end. As per Tornado diagram, Market and Competition, Technology, Innovation and Financial are important sources of risks (having very high-risk value). For this innovative project, the Value @ Risk is very high and hence corrective actions should be placed appropriately to minimize project Value @ Risk. This modified risk assessment methodology was proved as one of the best method to estimate value at risk for any innovative project. Monte Carlo simulation methodology using betaPERT distribution was found to be very effective in handling uncertainties associated with risk events.

VI. Conclusion

Risk assessment study conducted for the IR clothes dryer generates proactive solutions for managing different sources of risks associated with product innovation and development effectively. A company can also use these methodologies to find out their weaknesses in their PID value Chain. This will help organizations to develop necessary learning and increase their innovation capabilities, which lead to innovation success.

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