DESIGN CONCEPT SELECTION DECISIONS IN NEW PRODUCT DEVELOPMENT: A COMPARATIVE ANALYSIS

Mohit GOSWAMI
Operations Management Group
Indian Institute of Management Raipur, India
mgg123456@gmail.com

Abstract

Concept selection in new product development projects are a crucial task that need to be carried out effectively to maximize enterprise's profitability. A risk based design concept selection methodology was evolved by Goswami *et al.*(2014). In the context of this work, we aim to analyze the implications of this research by:

a) Comparing and validating the proposed methodology as devised by relevant existing measure(s) in current research literature and propose various improvement ideas that can either change the selection decisions or further improve them
b) Ignoring the interaction among the root nodes, evaluate whether selection decisions pertaining to various module instances is affected;
c) Assess whether selection decisions change across with respect to the size of the firm i.e. local vs global OEM.

Keywords: Design Concept Selection, New Product Development, Enterprise Network

1. INTRODUCTION

Choosing right design concept for further development and commercialization is a critical decision that manufacturers need to undertake at some stage during the course of new product development projects. Conventional approach warrants that manufacturers perform product performance tests, market validation activities and so forth on a number of design concepts simultaneously to ascertain whether the end product meets the technical, functional, statutory, and commercial objectives of the project. In doing so, manufacturers typically invest significant amount of resources such as number of man-hours spanned across respective functional agencies within the enterprises and monetary resources outside of the organization. However, a crucial downside to this kind of approach is that in case the project fails to take-off, the manufacturer loses the investments without realizing the end objective. Therefore a pragmatic methodology was required to be evolved that could help product managers at early stages of new product development to identify the least risk averse design concept. Goswami et al. (2014) devised a detailed analytical and predictive framework for a typical OEM (original equipment manufacturer) that could facilitate taking decisions regarding selection of product concept for developmental activities of the enterprise. By including key risk parameters (that are reflective of both enterprise and consumer), represented through a comprehensive Bayesian network, this research arrived at the optimal product design concept. In this research, we aim to extend further the research carried out by Goswami et al. (2014).

Goswami et al. (2014) addressed the problem of design concept selection decision from an enterprise centric perspective. Specifically in this research, six different internal agency within the enterprise was considered. Each of these six functional agencies had their own requirements in terms of the respective departmental objectives. Individual functional agencies within an OEM were represented by respective parent nodes. Further, each parent node had two different associated root nodes. Additionally, the parent nodes also among themselves had interdependencies in terms of varying risk propensities. The objective in the research was to choose a particular design concept in terms of the least value of enterprise risk index (ERI). The design concepts were populated based on the number of module instances of respective modules. In this research, we attempt to:

a) Analyze and validate the proposed methodology with relevant existing measure(s) in current research literature and propose various improvement ideas that can either alter the selection decisions or further improve selection decision;

Management Research and Practice
Volume 11, Issue 4 / December 2019

ISSN
2067- 2462

b) Ignoring the interaction among the root nodes, evaluate whether selection decisions pertaining to various module instances is affected;

c) Assess whether selection decisions change across different levels of OEM i.e. local vs global OEM.

A number researchers have addressed the issue of risk identification, assessment, evaluation and mitigation in context of enterprise processes and internal projects in context of new product development. In our critical literature review, we classify these research into two distinct categories: theoretical and empirical studies and analytical frameworks.

1.1. Theoretical frameworks

Thamhain (2013) employing the field study of 35 major product development projects spanning in 17 high-technology firms inferred that handling effectively with risk and uncertain events requires management insight that go beyond traditional quantitative tools and techniques. This study emphasized the role of collaboration across all facets of the cross functional project team. Marmier et al. (2013) on the basis of principles of a coherent process between risk and project management teams evolved a decision-making tool thus aiding the project managers to choose the ways that can improve the project success rate. This decision making framework was demonstrated employing a case study of aerospace industry. Mu et al. (2009) employing the survey data from Chinese manufacturers illustrated that risk mitigation strategies aimed at specific risk factors such as organizational and technological contribute both individual and interactively to influence the performance of new product development projects. Taha et al. (2015) employing the case study of screw design and utilizing Analytic hierarchy process (AHP) devised a methodology for selecting the best product design from a sustainability perspective. Oehmen et al. (2014) employing the empirical evidences from 291 product development programs investigated the association of risk management strategies with five disparate categories of performance related to product development programs namely: decision making quality, program stability, problem solving, product development success, and overall product success. Wu et al. (2015)'s contribution pertained to scenario planning and decision tree analysis for competitiveness of NPD programs.

1.2. Analytical studies

Patil et al. (2009) proposed a Business Risk in Early Design (B-RED) method for preliminary risk assessment based on the historical data from business failures. Wang et al. (2010) exploiting the properties of quality function deployment (QFD), transformed the organizational performance measures into project performance metric. A key contribution of this research was in terms of development of a systematic procedure for risk identification, assessment, response planning and control. Marle et al. (2013) consolidated a portfolio of risk clustering techniques and algorithm for risk assessment and evaluation of complex projects. A key contribution of this work was the consideration of relative interplays among risk factors that contribute towards the project performance. Shah et al. (2016) devised a value-risk based decision making tool for evaluating the performance of various manufacturing scenarios. This study derived the values and concerns from qualitative objective statements and qualitative risk statements. These statements were consolidated and subsequent analysis was done to obtain global indicators of value and risk. Zhou et al. (2014) developed an analytical framework that captured the notions of human uncertainties by developing two key metric namely: uncertain expected utility and uncertain risk premium.

2. RESEARCH SETTING

Our first objective seeks to compare and contrast OERI(overall enterprise risk index) proposed by Goswami et al. (2014) with a relevant measure reported in existing research literature. This measure relates to utility values obtained in the work of Chin et al. (2010). Through our analysis, we establish relationship between the utility value and OERI. Second objectives pertains to examination of the changes in module selection decisions, considering no interdependence among nodes. Finally, decisions pertinent to selection of different module instances within the product are investigated across different sizes of OEM by considering case of both local and global OEM. These module instances (for same module) can differ in their material specifications, product structure, manufacturing processes, operational/aesthetic features, expected quality, and reliability performance. However they can be used interchangeably within the product. Specifically OEMs operating in heavy construction equipment industry are considered for assessment of module selection decisions.Thus in this research, the rationality, flexibility and transparency of the decision analysis process for an industrial product design concept are examined. The required information and knowledge are collected from the industrial experts operating in their respective domains.

We employ the real life example of ROPS (roll over protection system) canopy of a heavy construction machinery. Figure 1 illustrates a typical ROPS.

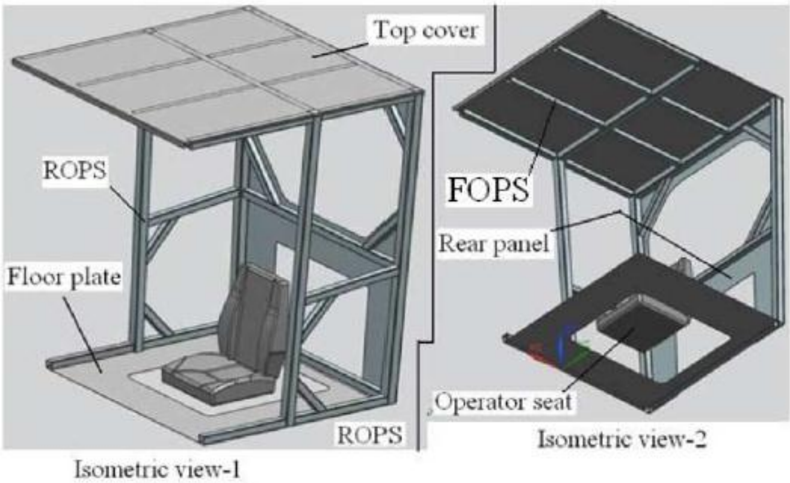

FIGURE 1 - ISOMETRIC VIEWS OF ROPS CANOPY (ADOPTED FROM GOSWAMI ET AL., 2014)

Table 1 enlists the feasible design concepts in terms of combinations of various module instances of respective modules. It is to be noted that these concepts are essentially MRPDCs (modular and repairable product design concept).

TABLE 1 - FEASIBLE DESIGN CONCEPTS

MPRDC	Module intstance combination
P_1	$M_{1,1}/M_{2,1}/M_{3,1}/M_{4,1}$
P_2	$M_{1,1}/M_{2,1}/M_{3,1}/M_{4,2}$
P_3	$M_{1,1}/M_{2,1}/M_{3,1}/M_{4,3}$
P_4	$M_{1,1}/M_{2,2}/M_{3,2}/M_{4,1}$
P_5	$M_{1,1}/M_{2,2}/M_{3,2}/M_{4,2}$
P_6	$M_{1,1}/M_{2,2}/M_{3,2}/M_{4,3}$

3. THE ANALYSIS

3.1. Comparison of methodology

In order to compare and contrastthe devised framework by Goswami et al. (2014), we have compared OERI and calculated utility values employing framework devised Chin et al. (2009), where design alternative with higher calculated utility values is selectedfor different module instances enlisted in Table 1. Following the methodology proposed by Chin et al. (2009), utility values have been obtained by assigning the utility of product concepts in three states namely: High(H), Medium(M), and Low (L) such that Utility (H) = 0; Utility (M) = 0.5; Utility (L) = 1 and. Figure 2 illustrates this comparison.

Referring to Figure 2, it can be concluded that ERI and utility values have an inverse relationship implying that a module instance with lesser ERI value has a higher utility value, hence enterprise would benefit from selecting it for further development and commercialization.

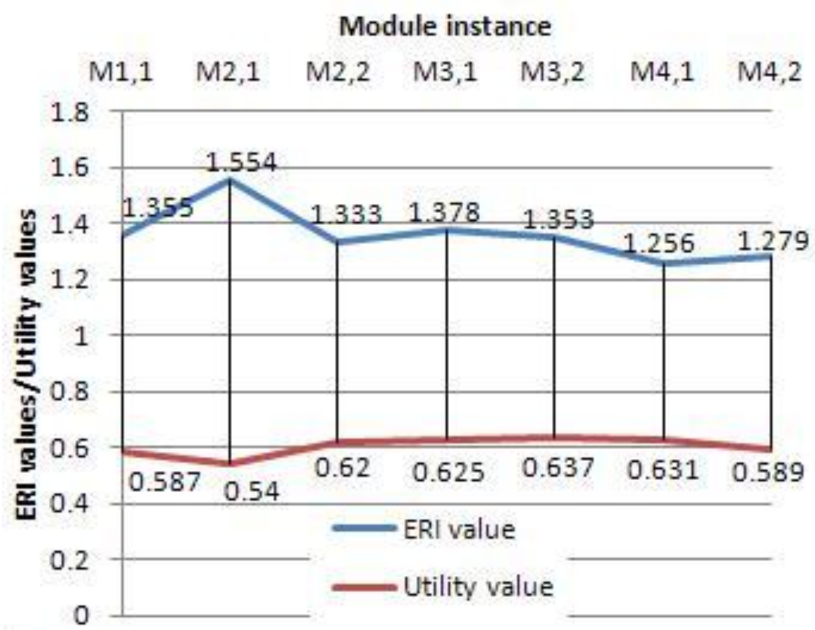

FIGURE 2 - ERI VS UTILITY VALUES FOR MODULE INSTANCES

3.2. Further improvement ideas

Referring to Figure 2, it can be inferred that module instance “M2,2” has been preferred over module instance “M2,1” for final module selection in the product.

Considering the dynamic and uncertainenvironment of new product development (NPD), new evidences will come out from time to time. One of the mostimportant features of Bayesian network is its ability to updateknowledge in light of new evidence. After comparing two alternative module instances, we can further improve the concepts with the Bayesian methodology toeither improve the rejected module instance “M2,1” in certain weak areas sothat it may reverse the selection decision, or further improve module instance “M2,2” in its weaker areas so as to achieve a betterfinal solution. Employing the pairwise comparison matrix approach as illustrated by Chin et al. (2009), prior probabilities for the two module instances are generated. These values are listed in Table 2.

TABLE 2 - PRIOR PROBABILITIES FOR THE TWO MODULE INSTANCES CORRESPONDING TO DIFFERENT RISK STATES OF ROOT NODES

	State	CPD	RDC	CSC	SES	MDC	CMP	SRC	SER	TTR	FFR	QAC	QIR
M21	H	.625	.312	.758	.8	.427	.575	.412	.381	.342	.234	.385	.234
	M	.335	.297	.231	.15	.323	.215	.376	.573	.239	.654	.475	.654
	L	.04	.391	.011	.05	.25	.21	.212	.046	.419	.112	.14	.112
M22	H	.342	.234	.8	.197	.316	.197	.516	.525	.425	.234	.412	.381
	M	.239	.654	.15	.312	.246	.312	.237	.385	.321	.654	.448	.507
	L	.419	.112	.05	.491	.438	.491	.247	.09	.254	.112	.376	.573

The definitions of the risk states are taken from Goswami et al.(2014). Referring to Table 2, it can be inferred that at high risk state, values prior probabilities of CSC, SRC, SER, TTR, QAC, and QIR are higher for module instance “M2,2”; while values prior probabilities of CPD, RDC, SES, MDC, and CMP are higher for module instance “M2,1”. In order to achieve superior results, either M2,1 can be improved so that it gets preference over “M2,2” or “M2,2” can be further improved so that the preferential gap for selecting “M2,2” improves further. We now propose two sets of ideas that corresponds to improving “M2,2” further and improves “M2,1”, so that it supersedes M2,2 in final selection. These two ideas have been termed as Idea set-1 and Idea set-2 respectively.

Idea set-1

- Improving CPD and RDC: These two ideas correspond to improving complexity of product design and research and development capability as far module instance "M2,2" is concerned. In context of M2,2, a number of steps can be taken to reduce the complexity of design such as increasing the bend radius, reducing the number of bends, relaxing the tolerances on linear dimensions and so forth. On the research and development capability front, design engineers can be educated to provide a much simpler alternative to existing "M2,2", so that RDC value can reduce further.
- Improving SES: Efforts can be initiated to enhance the similarity to existing supply. In context of "M2,2", this can include commonizing thickness (2.5 mm) of plates that forms entire assembly with that already existing with company either in-house or with company's suppliers.
- Improving MDC and CMP: This idea directly relates to improving the manufacturing capability and reducing the complexity of manufacturing process involved. For M2,2, this can translate to number of steps including rationalizing the bend radii, reducing the number of bends, changing the manufacturing process to die based process rather than fabrication process and so forth.
- Improving FFR: Improving the FFR value of module instance "M2,2" would entail relaxing some features and functionality that the module is supposed to provide. For instance, relaxing the flatness tolerance on the flat face of "M2,2".

Idea set-2

- Improving CSC: In order to improve module instance "M2,1" in terms of its prior probability of CSC, the two subassembly plates can be subcontracted to a single supplier or all related manufacturing activities can be kept in-house, so that the associated complexity of its supply chain reduces, thereby improving the prior probability.
- Improving SRC and SER: This idea directly relates to improving the service capability and increasing the similarity with existing service aggregate(s) within the company. Efforts can be initiated to enhance the similarity of module instance "M2,1" with that existing in the component product line existing with after sales and service department
- Improving TTR: In order to improve the time to market risk associated with module instance "M2,1", the two subassembly can be purchase off the shelf from commercial market base and completing in welding processes in-house. This will have higher chances of meeting the time to market requirements.
- Improving QAC and QAR: This idea pertains to improving the quality assurance capability and reducing the quality assurance risk associated with module instance "M2,1" by devising quality assurance and inspection methods that guarantees closeness to the final functional requirement module instance "M2,1"

3.3. Bayesian network without node interdependency

In the work devised by Goswami et al. (2014), we have evolved a Bayesian network that captures the interdependencies of entire related nodes in terms of strong, medium and weak negative relations. This is an ideal setting across enterprises where-in each department involved fully understand the interactions amongst different parameters reflective of their business goals. However across different industries and even with large OEMs, different functional agencies don't understand how their considerations are related to considerations of other department.

In order to mimic this situation, we simplify the Bayesian network proposed in Figure 3, where-in no interaction exists amongst different root and parent nodes.

Management Research and Practice
Volume 11, Issue 4 / December 2019

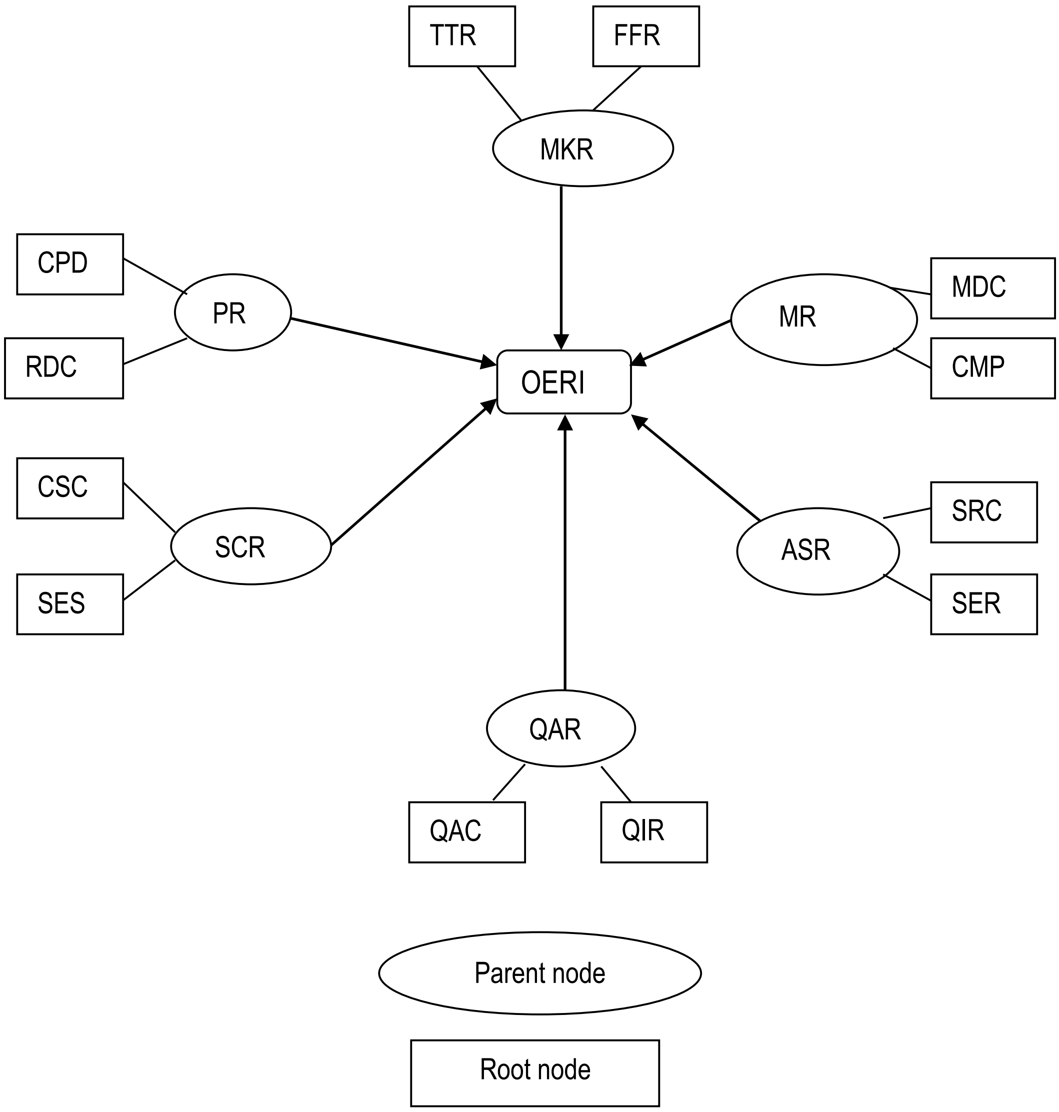

FIGURE 3 - ROOT, PARENT AND ENTERPRISE NODE WITHOUT ANY INTERDEPENDENCY

For the network depicted in Figure 3 and using the methodology proposed in Goswami et al. (2014), OERI values for all the MRPDCs have been calculated. These values are compared against those obtained in case of network having independencies. Figure 4 illustrates with comparison.

From Figure 4, it can be inferred that both plots (i.e. network with interdependency and network without interdependency) follow similar trends. However in case of network with interdependency, the most preferred MRPDC is P5 (lowest OERI of .57); while with network without interdependency the most preferred MRPDC becomes P4. In both the cases MRPDCs P1, P2, P3, and P6 are not desirable product design concepts to be developed. This consistency holds for both type of enterprise network. Thus it can be reasonably concluded that both types of enterprise network yield similar results as far eliminating the undesirable product design concepts is concerned. However for final convergence at a particular concept, the two networks can give different solutions, in which case the one resulting from network with interdependency should be adopted.

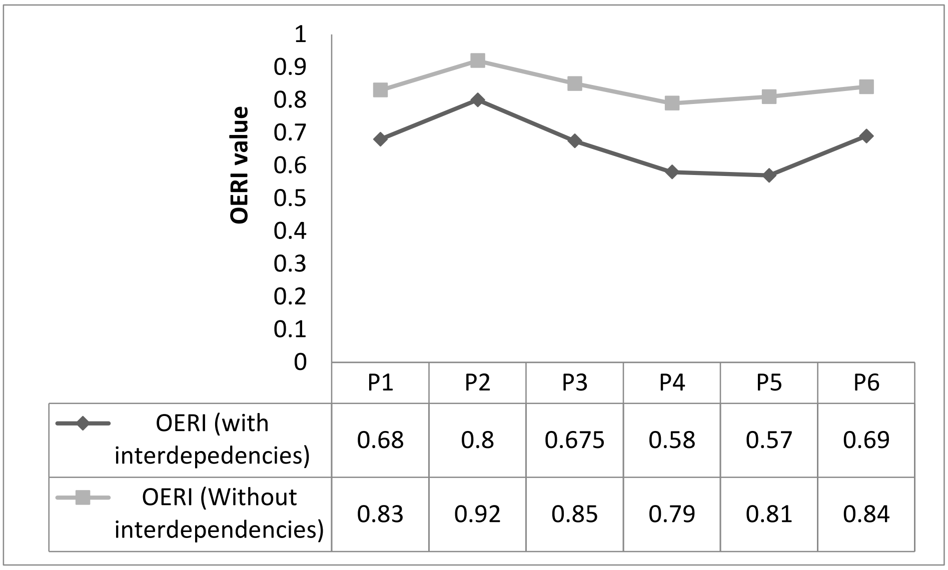

FIGURE 4 - COMPARISON OF OERI VALUES FOR TWO DIFFERENT ENTERPRISE NETWORKS

3.4. Influence of size of OEM on selection decisions

In this sub-section, the primary focus is to empirically analyze the module selection decisions across two different sizes of OEM namely local and global OEM. In context of our research, a local OEM is defined as one having market and operations primary focused in just one country, unlike a global OEM having market and operations across continents. Table 3 lists the major differences between the two sizes of OEM in terms of major functional attributes within the organization.

TABLE 3 - DIFFERENCES BETWEEN GLOBAL AND LOCAL OEM IN TERMS OF FUNCTIONAL ATTRIBUTES OF ORGANIZATION

Functions agencies	Global OEM	Local OEM
Design	• Strong product design, validation, and testing capabilities • Strong inter-functional collaboration at product design stage	• Moderate product design, validation, and testing capabilities • Weak to moderate inter-functional collaboration
Supply chain	• Global network of multi-tiered suppliers • Strong leverage with supplier base • Responsive and coherent supply chain network	• Local network of suppliers • Limited leverage with supplier base
Quality assurance	• Involved at every stage of manufacturing/assembly • Truly serve as agency that ensures quality assurance.	• Role limited mainly to quality inspection activities.
Marketing	• Competent system in place for understanding, analyzing customer needs and converting them into engineering requirements	• Weak to moderate marketing capabilities
Production	• Strong in-house manufacturing capabilities	• Moderate in-house capabilities • Reliant more on tie-up, collaborations, and joint venture for advanced manufacturing processes
Aftersales support	• Robust aftersales and dealer network • Quick availability of replacement parts	• Weak to moderate aftersales support capabilities

Our aim is to investigate both in local as well global OEM, the module selection decisions. For this purpose, experts belonging to different functional areas provided their inputs and using the methodology devised by

Goswami et al. (2014). ERI values are calculated in case of both local and global OEM. We have specifically considered the case of heavy construction machinery industry. Table 4 provides ERI values for selected module instance for both the cases. It is to be noted that the module instance yielding minimum value of ERI is selected in the final product.

TABLE 4 - SELECTED MODULE INSTANCES IN CASE OF BOTH TYPE OF OEM

Modules	OEM			
	Local		Global	
	ERI value	Module instance	ERI value	Module instance
1	0.73	M1,1	0.68	M1,1
2	0.67	M2,2	0.72	M2,1
3	0.79	M3,2	0.82	M3,1
4	0.71	M4,3	0.76	M4,2

Referring to the Table 4, for module 4 in case of local OEM, module instance “M4,3” is selected, while in case of global OEM, module instance “M4,2” is selected. M4,3 is metallic cover, while M4,2 is molded cover. This decision can be interpreted by a few rationales. Firstly in case of global OEM, the production volumes are often much higher compared to those in a local OEM. Since molding process involves costly initial set-up in the form of development of dies. Hence in case of local OEM, metallic cover is being preferred over molded cover. Secondly, manufacturing a molded item requires more technical knowhow compared to manufacturing a metallic item. Hence local OEM with relatively limited technical knowhow has preferred metallic cover. Finally, suppliers dealing in the molded items are relatively fewer than those dealing in metallic item. Hence global OEM having relatively more access to supplier network have preferred a molded cover over metallic cover.

4. CONCLUSIONS

This research analyzes in detail the devised product concept selection framework devised by Goswami et al. (2014). The analysis has been performed from three major perspectives. Firstly, the devised product concept selection framework has been validated by comparing the OERI with an existing measure of utility developed by Chin et al. (2009). Further, a number of ideas have been proposed that either will improve the product concept selection decision or change it. This comparison infers that OERI holds inverse relationship with utility i.e. lower values of OERI implies higher value of utility. Secondly, investigation has been carried out by comparing the OERI values yielded by both the Bayesian networks i.e. with and without interdependency. This comparison results in minor variations observed during the course of module instances selection decision. Finally, module instance selection decisions have been analyzed vis-à-vis both global and local OEMs. This analysis confirms that global OEM can undertake development of relatively more risky products as far as developmental risks are concerned.

REFERENCES

Agard, B. and Basseto, S., 2013, “Modular design of product family for quality and cost”, *International Journal of Production Research*, 1(6), 1648-1667.

Chin, K., Tang, D., Yang, J., Wong, S., and Wang, H., 2009, “Assessing New Product Development Project Risk by Bayesian Network with a Systematic Probability Generation Methodology.” *Expert Systems with Applications* 36 (6), 9879–9890.

Chin, K., Tang, D., Yang, J., Wong, S., and Wang, H., 2009, “Assessing new product development project risk by Bayesian network with a systematic probability generation methodology”, *Expert Systems with Applications*, 36(6), 9879-9890.

Clark, K.B., and Wheelwright, S.C., 1993, “Managing New Product and Process Development”, Free Press, New York.

Cooper, R. G., 2006, “Managing technology development project”, *Research Technology Management*, 49(6), 23–31.

Goswami, M., and Tiwari, M. K., 2014, "A predictive risk evaluation framework for modular product concept selection in new product design environment", *Journal of Engineering Design*, 25(1-3),150-171.

Kayis, B., Arndt, G. and Zhou, M., 2007, "A risk mitigation methodology for new product and process design in concurrent engineering projects", *CIRP Annals Manufacturing Technology*, 56(1), 167–170.

Kayis, B., Arndt, G., Zhou, M., Savci, S., Khoo, Y., B., and Rispler, A., 2006, "Risk Quantification for New Product Design and Development in a Concurrent Engineering Environment" *CIRP Annals Manufacturing Technology*, 55(1), 147-150.

Marmier, F., Gourc, D., and Laarz, F., 2013, "A risk oriented model to assess strategic decisions in new product development projects", *Decision Support Systems*, 56(2013), 74-82.

Mu, J., Peng, G., and Maclachlan, D., L., 2009, "Effect of risk management strategy on NPD performance", *Technovation*, 29(2009), 170-180.

Patil, R., Grantham, K., and Steele, D., 2012, "Business Risk in Early Design: A Business Risk Assessment Approach", *Engineering Management Journal*, 24(1), 35-46.

Ringen, G., Holtskog, H. and Martinsen K, 2012, "User Friendly Framework for Measuring Product and Process Novelty in the Early Stages of Product Development", *procedia, CIRP*, 3(2012), 513 –518.

Schmitt, R., and Linder, A., 2013, "Technical complaint management as a lever for product and process improvement", *CIRP Annals Manufacturing Technology*, 62(1), 435-438.

Shah, L., A., Etienne, A., Siadat, A., Vernadat, F., "Decision-making in the manufacturing environment using a value-risk graph", *Journal of Intelligent Manufacturing*, 27(3), 617-630.

Taha, Z., Salaam, H., A., Phoon, S., Y., Ya, T., M., Y., S., Mohamad, M., R., 2015, "APPLICATION OF INTEGRATED SUSTAINABILITY ASSESSMENT: CASE STUDY OF A SCREW DESIGN", *International Journal of Industrial Engineering*, 22(1), 1-10.

Thamhain, H., 2013, "Managing Risks in Complex Projects", *Project Management Journal*, 44(2), 20-35.

Wang, J., Lin, W., Huang, Y., H., 2010, "A performance-oriented risk management framework for innovative R&D projects", *Technovation*, 30(11-12), 601-611.

Wang, Y., and Tseng, M., M., 2011, "Integrating comprehensive customer requirements into product design", *CIRP Annals Manufacturing Technology*, 60(2011), 175-178.

Wu, J., Z., Lin, K., S., Wu, C., Y., "INTEGRATION OF SCENARIO PLANNING AND DECISION TREE ANALYSIS FOR NEW PRODUCT DEVELOPMENT: A CASE STUDY OF A SMARTPHONE PROJECT IN TAIWAN", *International Journal of Industrial Engineering*, 22(1), 171-182.