An ISM Framework for Agile New Product Development Process Risk Elements: Industry 4.0 Perspective

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1 Introduction

The global consumer behavior and a narrowing window of opportunity for businesses are forcing organizations for quick and efficient product development (PD). At the same time, it is necessary to maintain product quality, suitability to market needs, and high competitiveness. The NPD consists of series of steps that allow the creation of a product from ideation of concept through manufacturing, and here the majority of product goals are set [1]. Cooper [2] reported that approximately 40% of new creations are predicted to fail at the introduction to the market, despite all quality measures; only one from seven to ten new product ideas are commercially successful; whereas [3] mentioned that hardly 10% of businesses report that their NPD efforts help them to meet their annual profit goals proving that NPD is a risky activity with high failure costs. In the present era of Industry 4.0, organizations have started using emerging technologies like big data, rapid prototyping, cloud computing, industrial Internet of things, and cyber-physical systems to develop new products [4]. Arromba et al. [5] cited, in the scenario of Industry 4.0, these digital technologies have an impact on NPD performance, and [6] quoted organizations should make changes significantly, in their NPD procedure for smart invention. With the growth avenues presented by Industry 4.0 capabilities and the highly competing

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environment, leading-edge companies are attempting the ANPD process for physical product development, which originated in the software industry in the 1990s [7].

Simply adopting ANPD will not solve the current problems; instead, organizations should direct their efforts toward risk management resulting in fewer chances of failure [8]. To reduce their impact on the overall NPD process, risk factors emerge while ANPD adoption must be identified early in the process, followed by the creation of a risk management plan [3]. As a result, the authors have carried out the said research work with the following objectives:

i. To find out potential risk elements having a significant effect on decisions during ANPD;
ii. To evaluate and create interrelationships between possible risk elements using ISM; and
iii. To establish a risk element structural framework that takes into account both driving and dependence power.

This research has been divided into five sections including the current section. The ANPD literature is examined in the second section. Section three elaborates on the research methodology as well as a case application. Section four summarizes the above-mentioned research methodology's results and discussions; Section five discusses the research's conclusions, implications, as well as future scope.

2 Literature Review

This segment examines the ANPD concept, the associated risks, and the steps taken to model them using a hybrid ISM-MICMAC analysis.

2.1 ANPD Risk Elements

The majority of the organizations still use traditional PD processes such as stage-gate with structured timelines, rigid design evaluations, "gates" used while decision making, no interdisciplinary teams, and a new product creation which require a minimum of three years [9]. Industry 4.0 is a collection of advanced technologies for PD and manufacturing. Producing smart and connected products necessitate significant changes, particularly in the product development process. Organizations that create smart products must now use the most appropriate product development approaches [6].

Considering this, many organizations have attempted various alternate methodologies to enhance, speed up, and reconstruct their current PD methodology [2], agile new product development being one of them. It is understood as a collection of tools and strategies that allow for the rapid reconfiguration of products and related practices in response to changing customer needs [10]. With the increase in product variety, demand, complexity, as well as global competition, the emphasis on ANPD has increased, and ANPD risk management has thus become an important concern for organizations under the current circumstances [11]. For effective ANPD execution, the decision-maker must understand the various risk elements. A literature review on ANPD risk elements has been conducted and discussed in this section.

Park [12] has identified five different risks, performance factors of NPD, and presented a conceptual framework for risk and performance management along with lessons for effective risk management. Oehmen et al. [13] used empirical research to investigate the integration of risk management practices with NPD programs, as well as their relationship with different aspects of successful risk management. The findings suggested conducting more research about the impact of risk management practice on the success of the NPD program. Salvati et al. [14] discovered a positive relationship between the organization, market, technology, and commercial risk management and NPD performance metrics and recommended that NPD project team members must optimize the NPD process. Further [15] investigated medical device development process risks and developed an interaction model based on the relevant relationship among these risk sources. However, [11] reviewed the risks pertinent to agile project management practices adoption and identified the best response strategies. It is also recommended that the risks involved while using a hybrid methodology for NPD be pinpointed to assess the impact on project success.

Even though many researchers have worked in the field of risk identification and developing risk response strategies for the NPD domain, none have worked on identifying the interrelationships between them. The authors of this study attempted to identify various risk elements through a literature review, followed by brainstorming among the authors, and finally gathering expert opinion. The final list of risk elements is given in Table 1.

2.2 *Interpretive Structural Modeling and MICMAC Analysis*

ISM being a framework-oriented procedure that allows practitioners to develop frameworks for the interrelationships within a diverse set of elements in mixed circumstances [15]. The ISM-MICMAC process is carried out as discussed by [17]:

Step 1: The interrelationship between the risk elements i and j was described by using four fixed notations (V, A, X, O) to investigate REs for the development of the SSIM.

1. V- RE_i assists in obtaining RE_j;
2. A- RE_j will assist in achieving RE_i;
3. X- RE_i as well as RE_j will help for mutual attainment;
4. O- RE_i as well as RE_j has no relationship.

Table 1 ANPD risk elements

S. No.	Risk element	Code	Risk triggers	Reference
1	Human resource risk	RE1	Resistance to change, insufficient training for employee, difficulty in performing the tasks	[11, 16]
2	Financial support risk	RE2	Product development budget constraint, unstable product price	[17]
3	Ineffective planning risk	RE3	Fear of failure, unsatisfied stakeholder, variation in development time, costs	[13, 18]
4	Corporate incompatibility risk	RE4	Failure to meet the goals, insufficient resources for research and development, poor employee performance, poor communication across the organization	[11, 12]
5	Supply chain management (SCM) risk	RE5	Failure of a supplier, errors in supplier commitment, supply source inflexibility	[19]
6	NPD process risk	RE6	Inadequate identification of NPD scope, poor end-user involvement, improper competition assessment	[15, 20]
7	Advanced technology risk	RE7	Technology adoption, poor product design and development, system integration, intellectual property rights	[12, 14]
8	Competitiveness risk	RE8	Small market section, short product life because of changing customer requirements, competitor's market entry	[15]
9	Responsiveness risk	RE9	Creates adoption challenges, lower product development speed, poor customer satisfaction	[11]
10	Delay risk	RE10	Delay in new product introduction, product rejection, slow response to a shift in demand	[15]

Step 2: Transform the SSIM to a binary matrix that reflects the initial reachability matrix (IRM). SSIM notations (V, A, X, O) are converted into binary forms (0 and 1) as per the following:

- In SSIM if (i, j) = V, then in IRM (i, j) = 1 and (j, i) = 0
- In SSIM if (i, j) = A, then in IRM (i, j) = 0 and (j, i) = 1
- In SSIM if (i, j) = X, then in IRM (i, j) = 1 and (j, i) = 1
- In SSIM if (i, j) = O, then in IRM (i, j) = 0 and (j, i) = 0

Step 3: Following the preparation of the IRM, the next step is to remove transitivity. The fundamental constitution of ISM is relational transitivity. If a risk element RE1 is relevant with a risk element RE2, and RE2 is relevant with a risk element RE3, then RE1 must be relevant with RE3.

Step 4: Following the removal of transitivity, the next step is level partitioning. The reachability and antecedent sets are prepared. The intersection set having common risk elements of reachability and antecedent set are identified. Following the preparation of these three sets, the next step is to determine their levels.

Step 5: By referring to the level partitioning, a digraph is developed which shows the relationship between various risk elements and the hierarchy from bottom to top. The final step of ISM is to structure the REs at various levels by replacing codes in the digraph.

Step 6: In MICMAC analysis, the sixth step is used for quantification and distribution of the ANPD risk elements considering their driving and dependent power.

3 Research Methodology and Execution of ISM

This section discusses the methodology used to conduct research. It also goes over the various steps that must be taken during the execution of ISM-MICMAC analysis.

3.1 Research Methodology

The flowchart shows the steps followed for the conduction of this research work. The expert panel is made up of eight experts, six from industry, and two from academia. The ISM-MICMAC investigation procedure for this research work is carried out by collecting input from a panel of experts (Fig. 1).

3.2 ISM-MICMAC Analysis and Case Application

The short-listed risk elements were presented to the expert panel, and based on their opinion, ten risk elements for the ANPD process were selected as given in Table 1. The entire ISM process was explained to the experts, and the final VAXO analysis table is created (Table 2).

Table 3 shows the final level partition of the FRM.

Finally, each RE in ISM is to be placed at various stages via level partitioning of the FRM. The structural framework of RE that reflects the interrelationship between the risk elements is shown in Fig. 2.

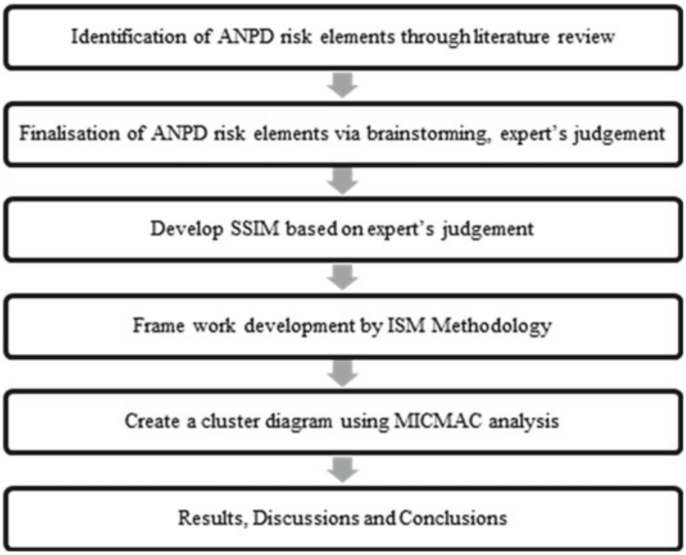

Fig. 1 Research methodology

Table 2 ANPD risk SSIM

Code	RE10	RE9	RE8	RE7	RE6	RE5	RE4	RE3	RE2
RE1	O	O	O	V	V	V	A	X	X
RE2	O	O	O	V	V	V	A	X	
RE3	O	O	O	V	V	V	A		
RE4	V	V	V	V	V	V			
RE5	V	V	V	X	X				
RE6	V	V	V	X					
RE7	V	V	V						
RE8	V	X							
RE9	V								
RE10									

By defining the partition levels, practitioners are often unable to make appropriate decisions for ANPD adoption; thus, understanding the driving as well as dependence power of REs used for the framework is required [17]. Finally, MICMAC analysis is added to address the aforementioned problem. Table 4 shows FRM with driving as well as dependence power.

As shown in Fig. 3, the ANPD risk elements are assigned to different quadrants based on the FRM information to analyze their driving as well as dependence power.

Table 3 Final level partition of FRM

Code	Reachability set	Antecedent set	Intersection set	Level
RE1	1,2,3,5,6,7	1,2,3,4	1,2,3	II
RE2	1,2,3,5,6,7	1,2,3,4	1,2,3	II
RE3	1,2,3,5,6,7	1,2,3,4	1,2,3	II
RE4	1,2,3,4,5,6,7,8,9,10	4	4	I
RE5	5,6,7,8,9,10	1,2,3,4,5,6,7	5,6,7	III
RE6	5,6,7,8,9,10	1,2,3,4,5,6,7	5,6,7	III
RE7	5,6,7,8,9,10	1,2,3,4,5,6,7	5,6,7	III
RE8	8,9,10	4,5,6,7,8,9	8,9	IV
RE9	8,9,10	4,5,6,7,8,9	8,9	IV
RE10	10	4,5,6,7,8,9,10	10	V

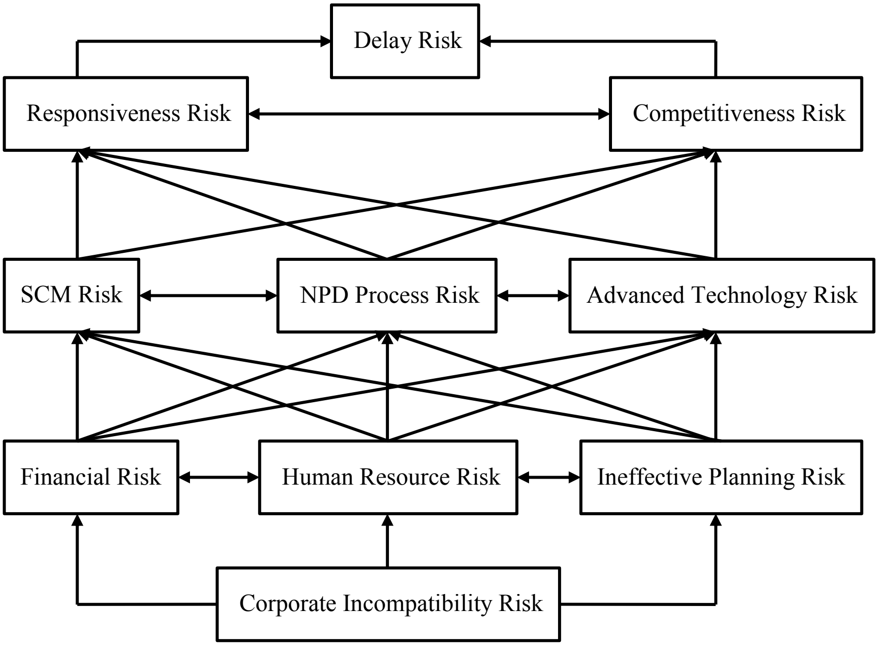

Fig. 2 Structural framework of REs

4 Results and Discussions

The model developed through the ISM approach depicts a structural framework of risk elements as well as their interrelationship. In this model, there are five levels. The results obtained are discussed below.

Table 4 ANPD risk elements FRM

Code	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	RE10	Driving power
RE1	1	1	1	0	1	1	1	0	0	0	6
RE2	1	1	1	0	1	1	1	0	0	0	6
RE3	1	1	1	0	1	1	1	0	0	0	6
RE4	1	1	1	1	1	1	1	1	1	1	10
RE5	0	0	0	0	1	1	1	1	1	1	6
RE6	0	0	0	0	1	1	1	1	1	1	6
RE7	0	0	0	0	1	1	1	1	1	1	6
RE8	0	0	0	0	0	0	0	1	1	1	3
RE9	0	0	0	0	0	0	0	1	1	1	3
RE10	0	0	0	0	0	0	0	0	0	1	1
Dependence power	4	4	4	1	7	7	7	6	6	7	

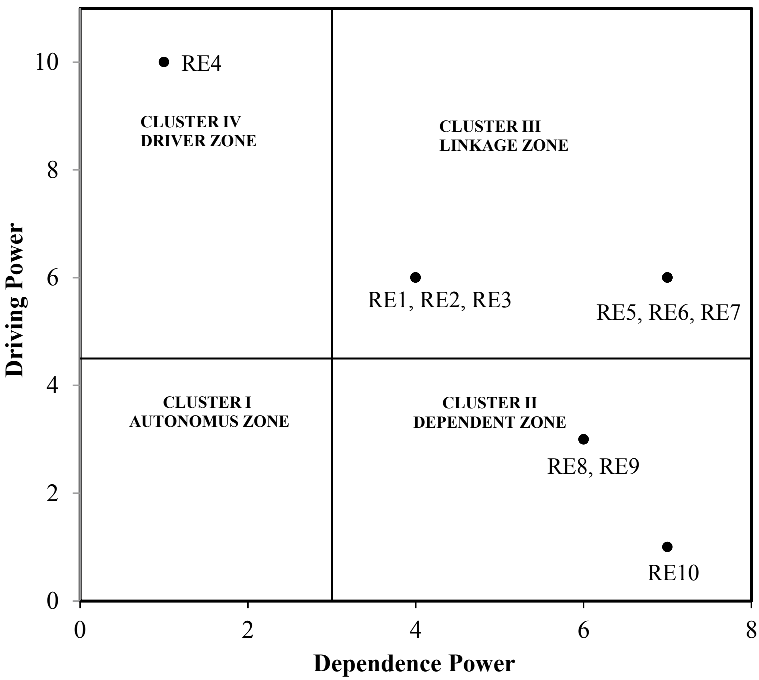

Fig. 3 Cluster diagram of ANPD REs

i. The bottom-most level is occupied by "corporate incompatibility risk", while "financial support risk", "human resource risk", and "ineffective planning risk" occupy the fourth level. Because such risk elements have a significant driving power, any variation in such risk elements will create a noteworthy effect across the remaining risk elements. Such risk elements should be ANPD practitioners' top focus.
ii. The third level includes three risk elements: "supply chain management (SCM) risk", "NPD process risk", and "advanced technology risk". These risk elements are linked to one another as well as to other risk factors, and they have a strong driving as well as dependence power. The particular findings imply that changes in pair of risk elements will have a direct influence on the other risk elements.
iii. The risk elements "responsiveness risk" and "competitiveness risk" are placed second from the top, indicating that they are influenced by certain risk elements.
iv. The model indicates that the risk element "delay risk" has been elevated to the first level. This risk element is highly dependent on other risk elements. Figure 3 shows the distribution of risk elements according to the clusters and is described below.
v. Cluster I: This cluster is made up of autonomous risk elements with low driving as well as dependence power. Such elements are somewhat detached from the system. None of the risk elements are recognized as autonomous elements in this case.
vi. Cluster II: It is composed of elements having high dependence but a little driving power, also termed as elements of criticality. In this case, the risk elements "competitiveness risk", "responsiveness risk", and "delay risk" are identified as the dependent elements. To address and mitigate these issues, a strategic plan is required.
vii. Cluster III: Linkage risk elements are having high driving as well as dependence power. Due to their unpredictable nature, any step performed on them may create an impact on the remaining risk elements along with the feedback effect. Risk elements like "human resource risk", "financial support risk", "ineffective planning risk", "supply chain management (SCM) risk", "NPD process risk", and "advanced technology risk" have been identified in this region. When decision-makers take action about them, it has the potential to have a significant impact on the ANPD process.
viii. Cluster IV: The driving risk element in the ANPD process is "corporate incompatibility risk", which has strong driving and weak dependence power. As a result, practitioners must conduct in-depth analysis to determine the root causes.

5 Conclusions and Future Scope

According to the literature review, the researchers identified several risks for various industries and countries. For the creation of the structural framework, ten potential risk elements related to ANPD are figured out in consultation with experts. The ISM–MICMAC methodology is used to investigate the interrelationships and related consequences of every risk element. The conclusions are as follows:

- Six risk elements have been identified as belonging to the linkage cluster. The significance of this third quadrant is that any alteration in the risk elements creates an impact on others. As a result of this circumstance, these risk elements are unstable.
- Organizations face a variety of risks as a result of globalization, technological advancement, and other factors. Although the risks associated with ANPD cannot be eliminated, their impact could be minimized by detecting, comprehending, and investigating the risk elements.
- Organizations, in particular, require a detailed strategy for ANPD implementation, and this article indicates a clear idea of ANPD risks, as well as the implications.
- The ISM model developed would aid ANPD practitioners and decision-makers in recognizing the most serious threats that necessitate immediate action.
- This study would help practitioners make decisions by assisting them in choosing risk management strategies to create a comprehensive and efficient ANPD process.
- In the future, potential risk elements, as well as sub-risk elements, can be recognized, evaluated, and ranked using various approaches. Although the ISM methodology was used to create an interrelationship structure between ANPD risk elements, this model is yet to be statistically validated. This model could be validated in the long term utilizing quantitative tools like structural equation modeling (SEM), etc.

References

1. Leite M, Baptista AJ, Ribeiro AMR (2016) A road map for implementing lean and agile techniques in SMEs product development teams. Int J Prod Dev 21(1):20–40
2. Cooper RG (2018) The drivers of success in new-product development. Ind Mark Manag 76(January):36–47
3. Chauhan AS, Nepal B, Soni G, Rathore APS (2018) Examining the state of risk management research in new product development process. EMJ Eng Manag J 30(2):85–97
4. Wijewardhana GEH, Weerabahu SK, Nanayakkara JLD, Samaranayake P (2020) New product development process in apparel industry using industry 4.0 technologies. Int J Product Perform Manag
5. Arromba IF et al (2020) Industry 4.0 in the product development process: benefits, difficulties and its impact in marketing strategies and operations. J Bus Ind Mark 36(3):522–534
6. Barrane FZ, Ndubisi NO, Kamble S, Karuranga GE, Poulin D (2020) Building trust in multi-stakeholder collaborations for new product development in the digital transformation era. Benchmarking 28(1):205–228

7. Cooper RG, Sommer AF (2018) Agile–Stage-Gate for manufacturers: changing the way new products are developedintegrating agile project management methods into a stage-gate system offers both opportunities and challenges. Res Technol Manag 61(2):17–26
8. Conforto EC, Amaral DC (2015) Agile project management and stage-gate model—a hybrid framework for technology-based companies. J. Eng Technol Manag JET-M 40(2015):1–14
9. Cooper RG, Sommer AF (2016) Agile-Stage-Gate: new idea-to-launch method for manufactured new products is faster, more responsive. Ind Mark Manag 59:167–180
10. Gurumurthy A, Kodali R (2012) An application of analytic hierarchy process for the selection of a methodology to improve the product development process. J Model Manag 7(1):97–121
11. Galli BJ, Lopez PAH (2018) Risks management in agile new product development project environments. Int J Risk Conting Manag 7(4):37–67
12. Park YH (2010) A study of risk management and performance measures on new product development. Asian J Qual 11(1):39–48
13. Oehmen J, Olechowski A, Robert Kenley C, Ben-Daya M (2014) Analysis of the effect of risk management practices on the performance of new product development programs. Technovation 34(8):441–453
14. Salavati M, Tuyserkani M, Mousavi SA, Falahi N, Abdi F (2016) Improving new product development performance by risk management. J Bus Ind Mark 31(3):418–425
15. Rane SB, Kirkire MS (2017) Interpretive structural modelling of risk sources in medical device development process. Int J Syst Assur Eng Manag 8:451–464
16. Yadav G, Desai TN (2016) Lean six sigma: a categorized review of the literature. Int J Lean Six Sigma 7(1):2–24
17. Yadav G, Desai TN (2017) Analyzing lean six sigma enablers: a hybrid ISM-fuzzy MICMAC approach. TQM J 29(3):488–510
18. Yadav G, Mangla SK, Luthra S, Rai DP (2019) Developing a sustainable smart city framework for developing economies: an Indian context. Sustain Cities Soc 47(February):101462
19. Narkhede BE, Raut RD, Roy M, Yadav VS, Gardas B (2020) Implementation barriers to lean-agile manufacturing systems for original equipment manufacturers: an integrated decision-making approach. Int J Adv Manuf Technol 108(9–10):3193–3206
20. Yadav G, Luthra S, Huisingh D, Mangla SK, Narkhede BE, Liu Y (2020) Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies. J Clean Prod 245:118726