

LB/TH/35/2025

TH5933

**DEVELOPMENT OF A RISK MANAGEMENT MODEL
IN TECHNOLOGICAL INNOVATIONS RELATED TO
THE TEXTILE AND APPAREL INDUSTRY**

K.A.U.P. Kumarapeli

188083R

MASTER OF PHILOSOPHY

Department of Textile and Apparel Engineering
Faculty of Engineering

University of Moratuwa
Sri Lanka

APRIL 2025

**DEVELOPMENT OF A RISK MANAGEMENT MODEL
IN TECHNOLOGICAL INNOVATIONS RELATED TO
THE TEXTILE AND APPAREL INDUSTRY**

K.A.U.P. Kumarapeli

188083R

Thesis submitted in partial fulfillment of the requirements for the degree
MASTER OF PHILOSOPHY

Department of Textile and Apparel Engineering
Faculty of Engineering

University of Moratuwa
Sri Lanka

APRIL 2025

DECLARATION

I declare that this is my own work and this thesis/~~dissertation~~ does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date: 17/04/2025

The above candidate has carried out research for the ~~PhD/MPhil/Masters~~ thesis/~~dissertation~~ under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Mrs. R.M.V.S. Ratnayake

Signature of the Supervisor:

Date: 17/04/2025

Name of the Co-Supervisor: Prof. T.S.S. Jayawardena

Signature of the Supervisor:

Date: 17/04/2025

DEDICATION

To my Amma, whose unwavering warmth, guidance, and care have shaped my
journey,

To my Thaththa, whose strength was my shield,

To my Nangi, who has been my super power,

To my Husband and Son, who have unconditionally believed in me.

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to my supervisory team, Mrs. Vijitha Ratnayake and Prof. Sanath Jayawardena, for their consistent support, compassion, and invaluable guidance throughout my MPhil journey. Their insightful responses and dedication to addressing all my inquiries have been instrumental in shaping this thesis. I am deeply indebted to them for their valuable feedback on my publications and their unwavering commitment to my success. This research would not have been possible without their assistance and active involvement in every step of the process. Our meetings and conversations were crucial in inspiring me to think beyond conventional boundaries, for which I am truly thankful. Besides my supervisors, I would like to express heartfelt gratitude to Dr. Ranga Abeysooriya for his assistance with statistical analysis and the rest of my progressive review committee, Prof. Asela Kulatunga and Prof. Gamini Lanarolle for the advices and motivation provided towards the successful completion of my research.

Furthermore, I am truly blessed to be surrounded by my loving family, whose unwavering support and trust have been the foundation of my journey. Though my parents are not here to witness the fulfilment of the dreams they nurtured for me, they went above and beyond to give me every opportunity to succeed. Their love continues to inspire me. I am deeply grateful to my amazing sister, for being my constant source of strength, and to my brother-in-law for his invaluable support in helping me reach this goal. Finally, I am profoundly thankful to my husband and son, who have stood by me through every high and low, giving me courage and teaching me perseverance. I am incredibly fortunate to have all of you in my life.

I would like to sincerely thank the managers and staff of the textile and apparel manufacturing factories involved in this study and to the experts who participated in the validation survey, their enthusiastic involvement and insightful contributions were crucial to the successful completion of this research. I am also profoundly grateful to the University of Moratuwa for granting me the opportunity to pursue this postgraduate research, and I acknowledge with appreciation the Senate Research Committee grant (SRC/LT/2019/25) that supported my work. Finally, I extend my heartfelt thanks to the Head of the Department of Textile & Apparel Engineering and all the staff for their continuous support during my research.

ABSTRACT

The Textile and Apparel industry, including Sri Lanka's, has grown significantly, offering substantial employment and economic benefits globally. Over the past four decades, Sri Lanka's apparel sector has experienced exceptional growth, becoming the nation's primary foreign exchange earner and employing thousands. Despite this success, Sri Lankan apparel faces higher costs and lead times compared to competitors, alongside a limited product range, which hampers its competitiveness. To stand out, it is crucial to leverage technological innovation for faster production, improved delivery times, precise research and development processes, and modern manufacturing techniques to reduce costs. However, technological innovation is fraught with uncertainty and a broad spectrum of risks, underlining the need for a robust risk management strategy. Due to varying organizational resources and product requirements, a generic risk management model is ineffective across different products and organizations. This situation necessitates a customized risk management approach, a need that current literature often overlooks. Furthermore, organizations are often hesitant to share confidential information with third parties, adding another layer of complexity. To address these issues, a risk management model was designed as a game, to solve the root causes of risk factors in technological innovations and effectively manage the associated risks. It integrates key elements from cooperative game theory, behavioral game theory, teamwork dynamics, psychological aspects of decision-making, visual problem-solving, and the board gaming concept. This model enhances resilience and agility while preserving the confidentiality of organizational strategies. 13 leading apparel manufacturers and 10 textile manufacturers were selected covering 145 factories. Data collection was conducted via questionnaires and structured/semi-structured interviews. The results present a flexible, customized risk management model that adapts to emerging risks while maintaining the strategic confidentiality of manufacturing organizations, addressing a significant gap in existing literature.

Keywords: Textile and Apparel Industry, Technological Innovations, Risk Management Model, Risk Factors and Root Causes, Game Theory

TABLE OF CONTENTS

Declaration of the candidate and the supervisor	i
Dedication	ii
Acknowledgement	iii
Abstract	iv
Table of Contents	v
List of Figures	ix
List of Tables	xii
List of Abbreviations	xiii
List of Appendices	xv
1. Introduction	1
1.1 Sri Lankan textile and apparel industry	1
1.1.1 Innovations in the Sri Lankan textile and apparel industry	2
1.2 Research gap	3
1.3 Research problem	4
1.3.1 Aim of the research	4
1.3.2 Research objectives	4
1.3.3 Scope of the research	4
1.3.4 Research design	5
1.4 Outline of the thesis	5
2. Literature Review	6
2.1 Introduction	6
2.2 Challenges in the textile and apparel industry	6
2.3 An overview of different innovation concepts	9
2.4 Different approaches to the innovation process	12
2.4.1 Different innovator types in textile and apparel industry	14
2.5 Role of technological innovations in textile and apparel industry	15
2.6 Risk in innovation process	15
2.7 Risk management in the technological innovation process	16
2.7.1 Risk factors related to the technological innovation process	16
2.7.2 Root causes related to risk factors of technological innovation	17

2.8	Interconnections between different factors	20
2.9	Classification techniques	21
2.9.1	Artificial neural networks for data classification	22
2.10	Consistency of the data classification	23
2.11	Dealing with large data sets	23
2.12	Root cause analysis methods	24
2.13	Prioritization techniques of root causes	25
2.14	Methods used in risk management models	25
2.14.1	Visual representation in problem-solving	26
2.14.2	Validation	26
3.	Research Methodology	28
3.1	Introduction	28
3.2	Interconnections of innovation concepts	28
3.2.1	Detailed analysis of the interpretation of innovation concept	29
3.2.1.1	Visualization of inter-connections of innovation concepts	31
3.3	Classification of innovation concepts	32
3.3.1	Classification of innovation concepts using Grounded	32
3.3.2	Validation of the consistency of the classification	33
3.3.2.1	Statistically proving the consistency of the classification	34
3.4	Core innovation concepts	35
3.4.1	Deriving core innovation concepts from three main phases using Grounded Theory	36
3.5	Base for the risk management model	38
3.6	Risk factors associated with technological innovations	39
3.6.1	Refined list of risk factors associated with technological innovations	42
3.7	Classification of risk factors into main phases of innovation process	46
3.7.1	Intra-organizational innovation phase (P1)	47
3.7.2	Peripheral innovation phase (P2)	47
3.7.3	Sustainable innovation phase (P3)	47
3.8	Validation of the consistency of risk factor classification	48
3.9	Root causes associated with technological innovations	48
3.10	Different innovator types	54

3.10.1	Innovator type of the organization	54
3.10.1.1	Structuring the Neural Network	55
3.10.1.2	Hidden layers and the nodes	56
3.10.1.3	Output of the Neural Network	56
3.11	Priorities of root causes and risk factors	57
3.11.1	Priorities of risk factors related to different innovator types	58
3.11.2	Priorities of root causes on risk factors	59
3.12	Limitations in developing a customized risk management model	62
3.13	The rationale for the risk management model	62
3.13.1	Methodology for forming the game	64
3.14	The risk management model	70
3.14.1	Pitch Making Phase	72
3.14.2	Kick Start Phase	72
3.14.3	Unsolved risk factors	73
3.15	Validation of the risk management model	78
4.	Results and Discussion	80
4.1	Interconnections of different innovation concepts	80
4.1.1	Visualization of interconnections of innovation concepts	82
4.2	Classification of innovation concepts	82
4.2.1	Validation of consistency of classification	83
4.2.2	Statistical validation of consistency of classification	84
4.3	Deriving core innovation concepts	87
4.4	Classification of risk factors into main phases of innovation process	87
4.5	Classification of innovation concepts	88
4.5.1	Validation of consistency of risk factor classification	89
4.6	Root causes associated with technological innovation risk factors	89
4.7	Innovator type of the organization	93
4.8	Assesing priorities of risk factors related to different innovator types	96
4.9	Assesing priorities of root causes related to each risk factor	100
4.10	Risk management model for technological innovations in Textile and Apparel industry	104
4.11	Validation of the risk management model	104
4.11.1	Feedback of the industry validation process	104

4.11.2 Validation of the risk management model with System Usability Scale	105
4.12 Discussion	107
5. Conclusion and future research	112
5.1 Conclusion	112
5.2 Limitations and future research	114
Reference List	115
Appendix A: Questionnaire (QE1) to validate the consistency of the Classification	144
Appendix B: Summary of Normality tests on feedback of QE1	
Summary of Hypothesis test on feedback of QE1	148
Appendix C: Questionnaire (QE2) assesses the industry's willingness to share information on core innovation concepts	158
Appendix D: Questionnaire (QE3) – To validate the consistency of risk factor classification	160
Appendix E: Questionnaire (QE4) – To gather reasons behind the occurrence of risk factors of technological innovations	162
Appendix F: Questionnaire (QE5) – To obtain input data to the FFNN in assessing the innovator type of the organization	164
Appendix G: Data Visualization	181
Appendix H: Neural network architectures	194
Appendix I: Risk factor interdependencies	199
Appendix J: Abbreviations of Figure 3.10 Questionnaire (QE6), to obtain for pairwise comparisons	200
Appendix K: User Guide	203
Appendix L: System Usability Scale	240

LIST OF FIGURES

Figure	Description	Page
Figure 3.1	Consent to share information on risk factors of core innovation concepts in questionnaire (QE2)	39
Figure 3.2	Causes for product not being accepted due to over Value-addition	43
Figure 3.3	Fewer orders and order quantities	44
Figure 3.4	Higher lead times	44
Figure 3.5	Difficulty in convincing operators on changes	45
Figure 3.6	Not achieving the expected profit	45
Figure 3.7	Finding out the customer market share	46
Figure 3.8	Structure of the FFNN used in classification	56
Figure 3.9	Risk breakdown structure to evaluate priorities	58
Figure 3.10	Breakdown structure of the technological innovation risk factors and root causes	61
Figure 3.11	Main phases of the risk management model	64
Figure 3.12	The game board	65
Figure 3.13	Symbols of the key mechanisms	66
Figure 3.14	Unit cell of the Game board	67
Figure 3.15	Game pieces	68
Figure 3.16	Checklist of the pitch-making meeting	70
Figure 3.17	Breakdown of main processes related to each phase of the risk management model	71
Figure 3.18	Assessing risk level with risk matrix	74
Figure 3.19	Four risk levels and their boundaries	75
Figure 3.20	Risk matrix with different risk levels	75
Figure 3.21	Risk Prioritization matrix	76
Figure 3.22	Risk prioritization and management	76

Figure 3.23	How to define risk levels	78
Figure 4.1	Inter-connections of innovation concepts	82
Figure 4.2	Classification of innovation concepts using the Grounded theory	83
Figure 4.3	Summary of responses for the classification on P1-Structuring the organization for a sustainable innovation	83
Figure 4.4	Summary of responses for the classification on P2 - information, outside the organization for a sustainable innovation	84
Figure 4.5	Summary of responses for the classification on P3 - implementing a sustainable innovation	84
Figure 4.6	Summary of hypotheses regarding boxplot ranges in business model innovation	85
Figure 4.7	Classification of risk factors into main phases of the innovation process	89
Figure 4.8	Validation loss over 5 epochs	96
Figure 4.9	Priorities of 14 technological innovation risk factors related to 6 innovator types	99
Figure 4.10	Priorities of main phases of innovation process related to 6 innovator types	99
Figure 4.11	Priorities of root causes related to C1	100
Figure 4.12	Priorities of root causes related to C2	100
Figure 4.13	Priorities of root causes related to C3	101
Figure 4.14	Priorities of root causes related to C4	101
Figure 4.15	Priorities of root causes related to C6	101
Figure 4.16	Priorities of root causes related to C7	101
Figure 4.17	Priorities of root causes related to C8	102
Figure 4.18	Priorities of root causes related to C8	102
Figure 4.19	Priorities of root causes related to C9	102

Figure 4.20	Priorities of root causes related to C10	102
Figure 4.21	Priorities of root causes related to C11	103
Figure 4.22	Priorities of root causes related to C12	103
Figure 4.23	Priorities of root causes related to C13	103
Figure 4.24	Priorities of root causes related to C14	103
Figure 4.25	Risk management model	106

LIST OF TABLES

Table	Description	Page
Table 2.1	Summarized interpretations of innovation concepts	9
Table 2.2	Summarized characteristics of different innovator types	13
Table 3.1	Percentage distribution of feedback on questionnaire (QE1)	34
Table 3.2	Technological innovation risk factors in the literature	39
Table 3.3	Technological innovation risk factors identified from the industry	41
Table 3.4	Risk factors and corresponding root causes of technological innovations	49
Table 4.1	Inter-connections of innovation concepts	81
Table 4.2	Hypothesis test summary related to business model innovation concept	85
Table 4.3	Hypothesis test summary of Kruskal-Wallis test results	86
Table 4.4	Core innovation concepts related to main phases of innovation process	87
Table 4.5	Refined list of risk factors related to technological innovations	87
Table 4.6	Risk factors and corresponding root causes of technological innovations	89
Table 4.7	Summary of the neural network configurations used to determine innovator type of the organization	94
Table 4.8	Summary of the network parameters	95
Table 4.9	Priorities of risk factors related to different innovator types using ANP	97
Table 4.10	Alternative suggestions to form teams for the Pitch-making meeting	105

LIST OF ABBREVIATIONS

Abbreviation	Description
A	Alternatives
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
ANP	Analytic Network Process
ANN	Artificial Neural Network
ASQ	After Scenario Questionnaire
BGT	Behavioural Game Theory
C	Clusters
CATPCA	Categorical Principle Component Analysis
CGT	Co-operative Game Theory
CI	Consistency Index
CR	Consistency Ratio
ELM	Extreme Learning Machine
FFNN	Feed Forward Neural Network
FMEA	Failure Mode and Effect Analysis
HR	Human Resources
HCI	Human-Computer Interaction
HRM	Human Resource Management
IP	Intellectual Property
IS	Information Systems
KNN	K- Nearest Neighbour
MCDM	Multi-Criteria Decision Making
N	Nodes
NDA	Non-Disclosure Agreement
NCGT	Non-Corporative Game Theory
NLPCA	Non Linear Principle Component Analysis

PCA	Principle Component Analysis
PSSUQ	Post-Study System Usability Questionnaire
RBM	Random Boltzmann Machine
RBN	Radial Basis Network
RCA	Root Cause Analysis
RCASE	Root Cause Analysis Solver Engine
R&D	Research and Development
RCI	Random Consistency Index
SDS	Super Decision Software
SVM	Support Vector Machine
SUS	System Usability Scale
TAM	Technology Acceptance Model
UMUX	Usability Metric for User experience
Wrt	With respect to

LIST OF APPENDICES

Appendix	Description	Page
Appendix - A	Questionnaire (QE1) to validate the consistency of the classification	144
Appendix - B	Summary of Normality tests on feedback of QE1 Summary of Hypothesis test on feedback of QE1	148
Appendix - C	Questionnaire (QE2) assesses the industry's willingness to share information on core innovation concepts	158
Appendix - D	Questionnaire (QE3) – To validate the consistency of risk factor classification	160
Appendix - E	Questionnaire (QE4) – To gather reasons behind the occurrence of risk factors of technological innovations	162
Appendix - F	Questionnaire (QE5) – To obtain input data to the FFNN in assessing the innovator type of the organization	164
Appendix - G	Data Visualization	181
Appendix - H	Neural network architectures Risk factor interdependencies	194
Appendix - I		199
Appendix - J	Abbreviations of Figure 3.10 Questionnaire (QE6), To obtain feedback for pairwise comparisons	200
Appendix - K	User Guide	203
Appendix - L	System Usability Scale	240

CHAPTER 1

INTRODUCTION

1.1 Sri Lankan textile and apparel industry

Constituting \$4.5 billion in exports for 2023, Sri Lanka's textile and apparel industry has exhibited remarkable performance and sustained growth over the past four decades, with a slight fluctuation observed in 2023 [1]. As the leading contributor to the country's foreign exchange, it accounted for 41.8% of total exports [1]. Additionally, the sector has directly employed over 300,000 individuals and indirectly created job opportunities for 600,000 people [2]. Apparel sector contributes around 7% to the country's GDP, according to the statistics in 2023 [3]. To leverage the strategic contribution to the economy, the Sri Lankan government has the vision of elevating the country to an \$ 8 billion global apparel hub by 2025 [3]. However, based on statistics from the Central Bank of Sri Lanka and provisional data from the Joint Apparel Association Forum (JAAF), the Sri Lankan apparel industry is currently on a downward trajectory, on a year-on-year basis since the final quarter of 2022 [4]. While the global textile and apparel industry embraces customized, sophisticated and sustainable products, steering away from traditional large-scale orders, the Sri Lankan apparel sector faces compounded challenges [5],[6]. The industry must prioritize customized products to effectively respond to evolving market demands. Additionally, comparisons reveal that Sri Lankan apparel prices and lead times significantly surpass those of competitors, eroding its global competitive edge and curtailing economic benefits [7]. Consequently, the primary challenges for the Sri Lankan textile and apparel industry lie in offering customized, sophisticated, and sustainable products at competitive prices within minimal lead times, essential for maintaining competitiveness and reaping economic gains in global trade [7].

Elevating innovative capabilities has become the key solution in achieving the similar challenges faced by other contemporary industries [1], since, regardless of the product or service produced; innovation has emerged as a critical determinant of any organization's ability to "Stay Relevant" [7], [8]. Apple's dynamic technologies, like the iPhone, can revolutionize lives, enabling experiences previously unimaginable [9]. AIG, a multinational insurance giant operating in 80+ countries, leverages cutting-edge tech and embraces continuous improvement for sustained dominance [10]. Game-changing technological strides, from self-driving cars to crypto-currencies and personalized medicine, underscore the global impact of innovation [11]. In addition to wearable smart textiles, interactive fabrics, and high-performance apparel, the integration of automated processes signifies the cutting-edge innovations driving the textile and apparel industry forward. These observations underscore the necessity for an innovative approach to ensure survival and growth in the global market, a common

imperative shared by all manufacturing and service industries, including textile and apparel [12].

The apparel business transforms from labor-intensive to capital-intensive production, driven by advanced manufacturing technologies. This shift brings advantages in efficient and effective production, more sustainable procedures, and shorter lead times [13], [14].

1.1.1 Innovations in the Sri Lankan textile and apparel industry

To maintain its global market share, Sri Lanka's textile and apparel industry too, has implemented innovation in a variety of areas including sophisticated manufacturing infrastructures to ensure higher product quality as well as process efficiency and effectiveness. Furthermore, this improves the security and safety of both workers and machines, while lowering the cost involved [2]. Modern technologies have been endorsed across the entire supply chain to ensure the smooth flow of the entire process [15], [16], [17].

Yet, innovation carries significant risks, jeopardizing the economic gains of innovators [18]. Notably, Zara, global clothing giant, faced scrutiny for high levels of toxic chemicals in its products, leading to environmental and customer pressure [19]. In response, Zara committed to zero hazardous chemical discharge throughout its supply chain by 2020, successfully regaining market share. Other major brands, including Calvin Klein, Benetton, Giorgio Armani, and the Gap, faced similar challenges but pledged to go Toxic-Free for global business survival proving that surviving in the global market necessitates adopting a sustainable innovative approach. Most brands developing wearable fashion technology have failed due to issues in merging fashion with cutting-edge technology. This combination often leads to innovative product failures. [20].

This elucidates the intricate nature of innovation, which entails numerous risks. Consequently, the identification and proficient management of these risks have emerged as pivotal priorities [21]. Thus, early in the innovation process, understanding the interdependence in complex systems can lead to the creation of better, original, and copy-proof product architectures as well as intelligent risk management [21]. This permits and promotes effective and efficient innovation, whereas failing to do so would fail. Working with complicated systems, if well handled, can give a firm plenty of options that might otherwise be unavailable [22]. Moreover, evidence implies that the current extremely high level of volatility in the textile and apparel sector will worsen in the years and decades to come.

In addition, the relationship of sustainability to the firm competitiveness too is significant to leverage the business strategies related to innovations. As per the study carried out by Fanny et.al, putting the sustainability approach on product, process, and managerial aspects will enhance the competitive advantages in terms of increased

value creation, reduced costs and non-financial assets [22]. Further, the sustainability approach reduces the risk involved in innovation [23].

Innovation is about continually reaching better performances. Thus, incorporating risk management into the innovation processes unleashes significant opportunities for the organizations. This facilitates the implementation of new solutions for the long-term sustainability of resources, organizations, and the global environment [24].

1.2 Research gap

To excel in the dynamic global market, Sri Lanka must adeptly produce customized, sophisticated, and sustainable products at competitive prices while also meeting short lead time requirements to effectively navigate competitive challenges. The industry identifies three primary concerns impacting its trajectory. Bridging the gap between the current and desired future state hinges largely on technological innovation, which stands as the foremost contributor among various innovation concepts. Efficient and effective risk management is crucial due to the inherent risks associated with innovations. Therefore, comprehensive research on risk management in the context of technological innovations is essential for the survival and growth of any organization.

This research analyzes various innovation concepts applicable across all industries, including textile and apparel. Furthermore, it classifies these concepts, offering valuable insights for selecting the most suitable innovation approach throughout the entire innovation process. This addresses a crucial gap in existing literature. Effectively managing risks associated with innovations requires a thorough grasp of the pertinent risk factors (variables linked to increased risk) and root causes (fundamental reasons behind these risk factors). This enhanced understanding significantly improves decision-making. However, existing literature lacks a consolidated list of risk factors and root causes related to technological innovation, as they are dispersed across various research papers. Furthermore, there is a notable absence of quantitative analysis of risk factors and root causes specific to technological innovations in the textile and apparel industries. Complicating matters, risks vary in impact, with some being tolerable while others are either intolerable or must be minimized to an acceptable degree. Consequently, establishing a risk criterion for assessing acceptable levels is crucial in the decision-making process. Understanding diverse risks associated with innovation, along with their individual contributions, is vital for analyzing their impact on the final product. Additionally, optimal resource allocation is paramount to achieving favorable outcomes in product quality, lead time, and costs. Hence, these insights enable firms to comprehend and focus on the most effective and pragmatic risk management strategy tailored to their innovative approach.

As the impact of risks and available resources varies across products and organizations, crafting a unique risk management strategy tailored to both the product

and the organization proves challenging. Moreover, a company must adeptly utilize this strategy while safeguarding confidential information from third parties. Early identification of the optimal innovation approach, aligned with the organization's resources, not only secures market share but also guides effective actions throughout the entire innovation process. This model not only offers insights into risk management across various innovation concepts but also introduces a novel approach to risk management strategies in the textile and apparel industry. Consequently, this innovative risk management model bridges existing gaps, highlighting the research's significance.

1.3 Research problem

The global competitiveness of the Sri Lankan textile and apparel industry is hindered by challenges in producing customized, sophisticated, and sustainable products at competitive prices, within short lead times. While technological innovation stands out as the primary solution among other innovation concepts for these issues, the industry struggles with a notable rate of innovation failures and unsuccessful attempts. This underscores the critical need for effective and efficient risk management strategies within the technological innovation processes to enhance the industry's overall performance while achieving sustainable goals.

1.3.1 Aim of the research

The aim of the research is to develop a risk management model associated with technological innovations in the textile and apparel industry, and thereby minimize/manage the risks involved in the technological innovation process.

1.3.2 Research Objectives

1. Identify innovation concepts
2. Evaluate the contribution of risk factors and root causes involved in technological innovations related to the textile and apparel industry
3. Develop a risk management model in technological innovations
4. Validate the risk management model

1.3.3 Scope of the research

The study's goal is to identify the factors influencing the success of technological innovations in the textile and apparel industry in Sri Lanka, as well as to create a model to manage the risk involved in the technological innovation process. The Grounded theory, Analytic Network Process, Neural Networks, core concepts of Cooperative Game Theory, Behavioral Game Theory, Collaborative approach, psychological effects in decision-making, and board game concept have become the foundation for developing the risk management framework.

1.3.4 Research design

This research is analytical mixed research that incorporates both quantitative and qualitative approaches. The risk variables involved in technological innovations are risk factors and root causes. These data were collected through a review of the literature, as well as structured and semi-structured interviews with industry experts during factory visits, over-the-phone interviews, and questionnaires with Likert-scales. This include, employees in positions of Executives, Senior Executives, Managers, Senior Managers, and General Managers across various departments, (Human Resource, finance, marketing, merchandising, sourcing and supply chain, Product development, raw material inspection, cutting, stores, Industrial engineering, production, quality, finishing departments) well as staff members from the production department all of whom provided insights based on their job-specific expertise.

Since the research is based on developing a risk management strategy in innovations related to the textile and apparel industries, key exporters of the apparel industry and the main textile manufacturers of Sri Lanka were considered for the research. The "Industry Capability Report" published by the Export Development Board of Sri Lanka in 2017 [25] was used to identify key apparel exporters. This consists of 135 apparel manufacturers related to 13 main groups. Together with 10 main textile manufacturers in Sri Lanka, 145 factories were considered as the population of the research. All 145 factories have adopted innovations in their manufacturing process. They pursued both incremental and breakthrough innovations [26]. The sample was selected according to simple random sampling and the sample size was calculated based on the following formula [27].

$$n = N / \{1 + N(e)^2\} \quad (1)$$

Where n is the sample size, "N" is the population size 145, and e is the level of precision, which is considered to be 0.05 in this research. Accordingly, at a 95% confidence level, the calculated sample size was 106. This sample was used in structured interviews and obtaining questionnaire feedback during the research.

1.4 Outline of the thesis

The thesis is structured to provide a clear and logical progression of the research. Chapter 1 introduces the research problem and reviews the existing literature relevant to the study. Chapter 2 expands on this by offering a comprehensive overview of the literature, establishing the theoretical foundation for the research. Chapter 3 outlines the chosen research methodology, detailing the approaches and techniques employed. Chapter 4 presents the results, validates the developed risk management model, and discusses key findings. Finally, Chapter 5 concludes the research by summarizing the study, addressing its limitations, and suggesting potential future research directions

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The comprehensive literature review conducted during the research is presented in this chapter. The main points covered in this chapter are summarized below.

- Challenges in the textile and apparel industry
- An overview of different innovation concepts
- Different approaches to the innovation process
- Role of technological innovations in textile and apparel industry
- Risk in innovation process
- Risk management in the technological innovation process
- Risk factors related to the technological innovation process
- Root causes related to risk factors of technological innovation
- Interconnections between different factors
- Classification techniques
- Artificial neural networks for data classification
- Consistency of the data classification
- Dealing with large data sets
- Root cause analysis methods
- Prioritization techniques of root causes
- Methods used in risk management models
- Visual representation in problem-solving
- Validation

2.2 Challenges in the textile and apparel industry

Textile and apparel manufacturing industries have emerged as highly sought-after industries worldwide, serving as vital sources of income and economic incentives for millions of individuals [28]. This has intensified the competitiveness of both sectors on a global scale. Moreover, the textile and apparel industries significantly contribute to income generation in the Sri Lankan economy, simultaneously offering a substantial number of employment opportunities for the local population [2]. However, statistics underscore the imperative for the Sri Lankan textile and apparel industry to prioritize the production of customized, sophisticated, and sustainable products at competitive prices, all while minimizing lead times. This strategic focus is crucial for bolstering

competitiveness in the global market [29]. Ongoing research has conclusively identified that embracing technological innovation, among other innovation concepts, is pivotal in achieving this objective, aligning seamlessly with the overarching theme of sustainability [30]. Existing literature highlights the industry's multifaceted efforts to achieve its goals through diverse measures. Advanced technologies, such as smart working, smart manufacturing, smart products, and intelligent supply chains, play pivotal roles in aligning with contemporary business trends, particularly those focused on sustainability. The textile and apparel sector, for instance, has significantly shifted from labor-intensive practices to automation, incorporating robotics, Computer-Aided Design (CAD), and Computer-Aided Manufacturing (CAM). This strategic shift not only contributes to cost efficiencies but also leads to shorter lead times [31].

In tandem with process innovation, the industry has embraced new product development and innovative approaches to bolster its competitive edge, infusing novelty into its product offerings [32]. Beyond mere technological advancements, this holistic approach has not only streamlined processes but also elevated efficiency levels, resulting in the production of high-quality goods within remarkably short time frames [32].

Furthermore, the literature highlights the significant efforts directed toward enhancing the supplier chain to attain competitive advantages in the textile and apparel industry [33]. Additionally, backward integration has been integrated into the system, aiming to streamline processes, reduce both time and costs and provides a greater control over the production of raw materials locally within Sri Lanka [33]. While considerable efforts are dedicated to enhancing technological innovations across different stages of the innovation process, the industry still struggles to compete effectively in the global market. This challenge persists due to various factors contributing to failures. According to Rasika et al. [12], internal quality failures have emerged as a significant concern. The findings underscore issues in quality control and assurance methods, operator skill levels, awareness of quality standards, and absenteeism as root causes of this problem. Human resource challenges further exacerbate productivity and cost minimization issues, with a scarcity of skilled workers due to high turnover, absenteeism, and diverse workforce attitudes and behaviors. Management skill levels also play a crucial role in exacerbating these challenges [2]. Moreover, a decline in demand from key market segments like the US and UK emphasizes the necessity to explore new markets [3]. Reduced and canceled orders escalate the risk of failure [18], while market volatility, environmental regulations, and safety hazards add additional risk factors to the industry landscape [34]. Research indicates that the absence of process automation or access to the latest technology poses a significant risk to achieving competitive advantages through lower costs, increased production efficiency, and reduced lead times [21]. Additionally, inefficiencies in resource utilization, poor information flow, and non-productive activities have been identified as hindrances to the productivity of the Sri Lankan apparel industry [22]. Addressing

these multifaceted challenges requires a comprehensive approach encompassing technological upgrades, quality assurance enhancements, human resource management improvements, and strategic market diversification efforts. Scholars have extensively explored the front-end decision-making processes, particularly in the identification of optimal innovation approaches. Their research delves into streamlining the entire innovation process, spanning from conceptualization to implementation. The overarching goal is to enhance the overall performance of the innovation process, shorten product development cycle times, maximize profitability, and elevate the quality of design solutions enhancing the sustainability of the product as well as the whole process [35]. In the textile and apparel industry, focus on sustainability has emerged as a crucial focal point for both customers and manufacturers. It represents a delicate balance between economic prosperity and environmental impact, making it a pivotal consideration in decision-making processes [23].

Despite significant advancements, a comprehensive approach to risk management in various industries is still lacking, with only a few models addressing industry-specific risk factors [36]. Research conducted by Suborna et al. highlights the inadequacy of current risk management strategies in the apparel manufacturing sector of developing countries like Sri Lanka, where the adoption of limited strategies or the inefficacy of those in place has been observed [37]. Additionally, a critical aspect identified in risk management is the irregular assessment of risk consequences and likelihood, coupled with a lack of dedicated resources for such evaluations [37].

Moreover, the literature suggests that the textile and apparel industry sees higher returns from technological investments compared to investments in other industrial equipment [38]. Furthermore, Industry 4.0, representing the forefront of the new industrial revolution, is emerging as a decisive force driving sustainability and competitive advantage throughout the entire textile and apparel supply chain [39]. This paradigm shift is characterized by a multitude of features including automation, digitization, optimized resource allocation, production enhancement, adaptability, and enhanced human-machine interaction [40]. Furthermore, the integration of Industry 4.0 technologies into textile and apparel businesses, coupled with Business Intelligence Systems (BIS), empowers companies to derive broader benefits through informed decision-making based on relevant data and insightful reports. Therefore, integrating advanced technologies into management, manufacturing, and operational processes becomes crucial to addressing industry challenges and promoting technological innovations [39], alongside the development of a robust risk management model to bridge existing gaps in the current literature.

In par with these technological advancements, the textile and apparel industry witnesses a surge in innovative concepts and approaches aimed at further enhancing competitiveness. The literature presents various innovation concepts tailored to specific applications, offering a spectrum of options for organizations to explore [41].

Effective decision-making hinges upon a comprehensive grasp of diverse innovation concepts, their interconnectedness, and systematic classification. This depth of understanding enhances the capacity to adeptly apply pertinent innovation principles and enhance resource allocation. Moreover, classifying these concepts serves to mitigate confusion arising from similarities among differing terms, which have often been named haphazardly. This addition emphasizes the importance of structured classification in addressing confusion stemming from inconsistent naming practices.

2.3 An overview of different innovation concepts

An extensive exploration of the literature reveals the identification of 21 unique innovation concepts spanning across 31 manufacturing and 19 service industries worldwide. These concepts encompass a wide spectrum of sectors, including electronic commerce, telecommunications (both fixed and mobile), high-tech industries, logistics, textiles, electrical wiring, biotechnology, medical services, information technology and computing, the Internet of Things, real estate, pharmaceuticals, software services, apparel, pulp and paper, metallic products, machinery and equipment manufacturing, and photo-electronic industries. Notably, these industries are distributed across diverse regions, with representation from countries such as China, Canada, Switzerland, and India. Summarized interpretations corresponding to these 21 innovation concepts are collated in Table 2.1 for comprehensive understanding and reference.

TABLE 2.1: SUMMARIZED INTERPRETATIONS OF INNOVATION CONCEPTS

Innovation Concept	Summarized Interpretations
Process innovation	Process innovation uses different concepts to improve the firm's performance and increase the return on investment by incorporating the concepts such as Business Process Re-Engineering (BPR), Just In Time (JIT), Total Quality Management (TQM), and Lean manufacturing Process innovation is a methodology that leverages various concepts to enhance a firm's performance and maximize its return on investment [50], [51],[52],[53],[54],[55],[56],[57].

Technological innovation	<p>Technological innovation fosters the survival and sustained growth of organizations by generating Intellectual Property (IP) rights, as well as economic and social benefits. This is closely connected with Research & Development, product, process, management, culture, and structure innovations. To optimize resource utilization, organizations leverage technological innovations [34],[38],[39],[40],[42],[43],[44],[45],[46],[47],[48],[49],[52],[56],[57],[62],[63],[64],[65],[66],[67],[68],[69],[70],[71],[72],[73].</p>
Enterprise innovation	<p>To achieve strategic objectives, businesses need to improve their operational efficiency and effectiveness, which can be done by shortening processes. This leads to Business Model Innovation. Management control is an effective tool that can help achieve organizational strategic goals by providing complete oversight over funds, materials, equipment, technology, personnel, and marketing, all of which can promote business innovation [74].</p>
Human Resource Management innovation (HRM)	<p>Innovation in Human Resource Management (HRM) is crucial for the success of a company. It improves talent recruitment and development and is closely linked to innovation performance and capability. By adopting innovative HRM practices, organizations can unlock the potential of their employees and drive innovation across all operations [40],[47],[65],[75],[76].</p>
Service innovation	<p>Service innovation is crucial for the success of any organization. By continuously developing and improving services, companies can meet the ever-changing needs of their customers, leading to higher satisfaction and greater success [34],[38],[42],[43],[54],[58],[77],[78].</p>
Resource innovation	<p>Resource innovation is the process of optimizing an organization's internal and external resources to maximize the utilization of all funds. This can include finances, inventory, personal skills, production materials, equipment, or information technology [79],[80].</p>
System innovation	<p>System innovation is crucial for creating an environment that fosters enterprise innovation. Adopting new systems and processes can streamline operations, reduce costs, and create more opportunities for technological innovation [65].</p>
Regional indigenous innovation	<p>Regional Indigenous Innovation helps enhance regional competitiveness, market share, and sustainable development by addressing key technical issues faced by a region [62],[64].</p>

Green innovation	Green innovation encompasses energy-saving technologies, waste recycling, pollution prevention, and the development of eco-friendly products and processes that enhance a company's environmental performance and competitive edge [81].
Ecological innovation	Ecological innovation develops sustainable and eco-friendly products and processes, focusing on renewable resources, reducing waste, and pollution. It aims to minimize the negative impact of human activities on the environment [61].
Marketing innovation	Marketing innovation is a vital aspect of a company's survival, growth, and economic success. It involves understanding the needs and wants of customers to stay up-to-date with current trends and demands. By doing so, the company can develop effective management concepts and techniques for product and process innovation [42],[43],[44],[49],[40],[47],[51],[52],[59],[68],[72],[75].
User innovation	User innovation primarily concentrates on enhancing customer satisfaction, which is a fundamental component of marketing innovation [82], [83].
Strategy innovation	Strategy innovation involves various concepts like technological, marketing, organizational, management, and cultural innovations. It helps to create new business opportunities and improves the quality and performance of the firm [42], [44], [47].
Management innovation	Management innovation involves linking the organization's vision for innovation with research and development. This includes strategic business models, organizational structure, and HRM innovation, with a significant impact on the organization's overall performance. [40],[43],[44],[84].
Institution Innovation	Institutional innovation pertains to an organization's human resource practices that aim to foster a culture of innovation among employees. This includes incentive mechanisms, reward systems, and performance management strategies that encourage innovative thinking and actions [40],[43],[44],[51].
Organizational innovation	Organizational innovation helps optimize the structure of an organization to ensure its survival and growth. This involves incorporating technology, HRM innovations, and the management vision of the organization [40],[43],[44],[47], [52], [60], [63], [75].
Culture innovation	Culture innovation, when combined with strategy, management, institutional, market, technology, and HRM innovation, leads to sustainable growth and helps solve bottleneck problems in technological innovation. It creates a learning culture that

Cooperative innovation	<p>encourages innovative thinking, which in turn improves employee performance, educational qualifications, motivation, intelligence, teamwork, recognition, and remuneration - all of which are crucial factors that determine a firm's success [40],[43],[44],[49],[57],[63],[64],69],[75],[85].</p> <p>Cooperative innovation involves collaborating with others to co-finance R&D initiatives. This fosters innovative collaboration and interactive cooperation, leading to higher profits and a stronger competitive advantage. It also helps reduce uncertainty, share resources, save costs, and ensure long-term survival and development [44], [49], [86].</p>
Business Model innovation	<p>Business Model Innovation focuses on building strong relationships with customers, enhancing customer processes, and supporting the product life cycle. It also emphasizes continuous learning and innovation to solve complex market problems [38], [46], [54], [58], [60], [65], [87].</p>
Life Cycle innovation	<p>Life Cycle Innovation involves working closely with customers to deeply understand their values, which is key to producing innovative solutions that meet their requirements. This helps businesses re-engineer their processes and improve their overall performance [46],[47],[58].</p>

Industries adopt different innovation concepts throughout their entire supply chain, according to the applications. Among the various innovative concepts introduced in the literature, technological innovation has emerged as a hot topic, as it revolutionizes living standards by taking them to the next level [88], [89]. Since it pushes the limits of manufacturing, production, marketing, and the entire supply chain, technological innovation has become a governing factor in creating a sustainable economy in every manufacturing field, including the textile and apparel industry [90]. Thus, it's worthwhile to pay more emphasis on technological innovations. The literature demonstrates how technological advancements, in addition to benefiting other industries, have also significantly impacted the textile and apparel industry.

Moreover, the literature offers a diverse array of strategies for organizations to foster innovation within their operations. Selecting the most fitting approach holds paramount importance in optimizing innovation endeavours, highlighting its pivotal role as a critical subject for deliberation [91].

2.4 Different approaches to the innovation process

A thorough analysis of the literature reveals the presence of diverse innovator types categorized based on the method of innovation or the approach employed to introduce products or services to the market. Manly et al. in their report from the Boston Consulting Group [92], have delineated six distinct innovator types, encapsulating the

entire spectrum of innovation initiation. These categories include creators, solution builders, leveragers, expanders, defenders, and fast followers. Literature elaborates characteristics of 6 innovator types, introduced in the Boston Consulting Group report, January 2017 [96]. Literature summarizes the main traits of these 6 innovator types as illustrated in Table 2.2.

TABLE 2.2: SUMMARIZED CHARACTERISTICS OF DIFFERENT INNOVATOR TYPES

Innovator Type	Characteristics
Creators	Entrepreneurial thinking, actively seeking out gaps in the market to drive innovation. To succeed in creative and innovative fields, individuals need a blend of key skills and attributes. These include being open to new ideas, fostering creativity, and engaging in analytical and strategic thinking. Strong communication and leadership abilities, coupled with the capacity for collaborative teamwork, are essential. Adaptability, motivation, and the ability to make decisions and take risks are also crucial. Industry experience and a global mind-set further enhance effectiveness. Creation, however, comes with significant risks and demands considerable effort, time, resources, mental energy, risk tolerance, discipline, and persistence [92], [93],[94],[95],[96],[97].
Solution Builders	Strive to delight customers by deeply understanding their needs and preferences. Key factors for success include analyzing competitors' products and behavior, understanding available market products and patents, and addressing customer pain points with shorter product life cycles, fair pricing, and better quality. Timing market positioning is crucial, as understands customer needs to avoid overpricing. Building strong customer relationships and staying informed about new trends are also essential [92],[93],[94],[95],[96],[97].
Leveragers	Innovate by optimizing their core capabilities to create superior business models. To stay competitive, businesses must conduct ongoing market research on trends and competitor behavior, continuously innovate their existing models, and expand their market through new features and marketing strategies. Offering improved products with added benefits through resource, process, and energy innovations is key, along with building stronger customer trust [92], [93],[94],[95],[96],[97].

Defenders	Continuously refine product ideas and concepts to maintain their dominant position in the market. To maintain a competitive edge, companies should focus on their advantages, especially in mature or slow-changing sectors. Continuous improvement of current offerings and vigilant monitoring of potential disruptions are essential. Mergers, acquisitions, and partnerships can help keep pace with industry changes, while a skilled team and ongoing training is critical for sustained success [92],[93],[94],[95],[96],[97].
Expenders	Mandate for growth. To succeed, companies should focus on one or two key strengths, maintain consistent market experimentation, and foster an open, empowering innovation culture. A highly skilled team, continuously trained in relevant technologies, is essential. Strategies to reduce product life cycle and costs while staying competitive with fast-moving rivals are critical. Delivering high quality, fair prices, durability, and performance helps build brand recognition and customer loyalty, which can support the success of future innovations under the same brand [92],[93],[94],[95],[96],[97].
Fast Followers	Possess the agility and skills to swiftly respond to competitors' actions and develop improved solutions. Success in innovation requires focusing on sensing and reacting quickly to competitive changes, which reduces risk. Rapid decision-making, continuous market experimentation and competitor awareness are key. A highly skilled team with advanced technological knowledge, ample resources and investment, and a strong innovative culture are essential. Additionally, companies must find ways to shape innovations into superior offerings for customers [92],[93],[94],[95],[96],[97].

2.4.1 Different innovator types in the textile and apparel industry

Examining various innovation approaches in literature alongside real-world business examples reveals distinct strategies of leading companies. Adidas pioneers new materials and technologies, like recycled ocean plastics, embodying the role of a creator [98]. Nike maintains market dominance with innovative sports apparel, showcasing a solution builder approach. Zara's agile and market-responsive business model epitomizes a leverager [99]. Lululemon diversifies into new market niches and establishes global tech hubs, illustrating the approach of an expander [99]. H&M secures its market segment through incremental product enhancements, adopting the characteristics of a defender [100]. Conversely, Forever 21 swiftly reacts to competitors' actions as a fast follower to maintain its relevance [101]. However, not every innovative organization achieves its full potential, as the choice of innovation approach significantly influences its success within the competitive landscape [102].

2.5 Role of technological innovations in textile and apparel industry

The textile and apparel industry is a pivotal component of growing economies worldwide, responding to fast-changing customer behaviors through innovation [95]. Innovative technologies offer customizable, sophisticated, and sustainable products at competitive prices, driving competitiveness in global trade. Manufacturers leverage innovation to adapt to evolving customer needs and a competitive market [103], streamlining operations and modernizing processes effectively. Technological innovation plays a crucial role in developing novel fabrics with innovative features, including smart clothing and health-conscious garments, sustaining the apparel industry [104]. Improved internet connectivity enhances communication, while Artificial Intelligence (AI) revolutionizes customer shopping experiences, real-time data tracking, inventory management, and supply chain optimization [105]. Big data aids in trend forecasting and analyzing customer behavior, informing business strategies to maintain brand relevance [105]. Block-chain technology enhances supply chain transparency, addressing inventory issues effectively [106]. Technological innovation is crucial in transitioning to a sustainable economy, facilitating sustainable manufacturing processes and recycling solutions [107]. However, research indicates that innovation attempts often fail due to inherent risks [21].

2.6 Risk in innovation process

The industry provides evidence of failures in innovation within the apparel and textile sectors [108]. Among the pressing concerns, failures in innovation, which lead to dissatisfaction among the customer, may result in a loss of the market share. Besides, this increases the excessive use of resources, time, and money. In addition, loss of customer reputation may hinder the future orders as well [20].

Highlighting the consequences, a single failure of a sportsman's shoe caused a significant setback for the sportswear giant Nike, resulting in a staggering \$1.1 billion reduction in market capitalization. H & M has stopped orders due to not meeting the environmental sustainability requirements [19]. Inadequate risk management has impeded progress which underscores the critical importance of effective risk management in the innovation process, as even a single oversight can potentially lead to disastrous outcomes for an organization [114],[115]. Since, technological innovation makes the most significant contribution to the innovation outcome, effective and efficient risk management in the technological innovation process is imperative to reap the full potential of the innovation efforts [110],[114].

The literature provides invaluable theories and methodologies for scrutinizing innovation-related risks and quantifying them effectively [79],[176],[177]. A comprehensive understanding of these theories and methods can lead to the implementation of more effective risk management solutions.

2.7 Risk management in the technological innovation process

Researchers stress the importance of risk management in ensuring the success of innovation processes [112]. The realm of contemporary literature on risk management models encompasses a diverse range of theories, methodologies, and mathematical tools designed to identify, analyze, categorize, and assess risks across different processes and contexts [115]. These resources offer valuable insights for pinpointing existing gaps in the risk management process. In contemporary literature, a critical focal point of the risk management models is the intricate interplay between diverse risk factors, which elevate the overall risk level, and the challenges encountered during the technological innovation process within the manufacturing and service organizations, including the textile and apparel industry.

2.7.1 Risk factors related to the technological innovation process

An exhaustive review of the literature underscores a crucial aspect: failure to assess the innovation concept considering the organization's financial, structural, marketing, and technological capacities represents a substantial risk factor linked to technological innovations [111],[116]. This oversight profoundly influences the success of outcomes, determining whether the organization possesses adequate capabilities for successful implementation [111],[116]. Budgeting accuracy poses risks across industries, where inadequate financial and structural capacity may hinder innovation implementation [117], and insufficient financial resources can lead to research fund shortages or cost overruns, obstructing project success and potentially leading to cancellation. Immature or inadequate technological leadership and mismanagement are critical risk factors, as effective leadership is pivotal for organizational success [118] and lack of clear vision and goals can hinder progress, emphasizing the importance of inspiring and engaging leadership. The absence of a team with the necessary technological capabilities poses a significant risk, rendering innovation efforts futile [119]. At the same time, strong marketing skills are essential to secure innovation and market share [119]. Successful innovation must align with the company's long-term goals and competitive advantage, as competitors may exploit unprotected ideas or skills [116],[120]. Sharing ideas with investors, subcontractors, or partners exposes innovation, making it susceptible to intellectual theft and undermining market share efforts [120], and strength shortages are critical, with the lack of skilled personnel posing a significant risk to organizations [120],[121], as strengths, including human resources, financial capabilities, and leadership skills, are vital resources for achieving objectives and sustaining operations [120],[121]. Human Resources (HR) play a crucial role in organizational success, requiring strategic management to maintain high morale and performance [122],[123]. HR risks, such as team member accountability issues and technological incompatibility, can hinder organizational goals and lead to employee turnover [124]. Failing to manage talent retention risks may result in higher employee turnover rates, impeding goal achievement and requiring additional time and effort for talent acquisition [125].

Positive employee relationships and strategic retention approaches are essential for mitigating this risk [124],[125], and brand recognition risks can lead to customer dissatisfaction and loss of market share, affecting long-term success [120],[121], while ensuring a skilled supplier base is crucial for meeting innovation goals, with raw material availability and quality being significant considerations [116].

Commercialization methods and information resource risks, such as inadequate market research and creativity, can harm business outcomes [126]. Effective marketing strategies are essential for innovation sustainability and market penetration. Proper product positioning and understanding market trends are critical for successful product launches and market share retention [127]. Failing to identify threats and opportunities may lead to market share loss and business failure, as seen with BlackBerry smartphones [18]. Alignment of innovation process stages and life cycle management are also essential for successful innovation outcomes [119],[128]. Failure to address organizational and marketing innovation concepts can hinder technological innovation progress [129], and clear goal-setting, documentation, and project boundaries are critical for innovation project success [130],[131], while miscommunication and missed opportunities due to lack of collaboration can lead to project failure [132].

Learning from innovations and effective risk management are vital for project consistency and success [133], [134]. Supervision and control throughout the process are essential for mitigating risks and ensuring project success [134]. Failure to manage risks in technological innovation can lead to fines and legal consequences, highlighting the need for formal risk management processes [126]. Lack of technical capacity and R&D process issues can also impede innovation success [121],[135]. Moreover, identifying the root causes is essential for ensuring that innovation efforts target genuine problems within a specific context. Many innovation initiatives falter because they address the wrong problems, often targeting the wrong audience. Therefore, researchers in the literature have highlighted the importance of identifying potential root causes of risk factors that can lead to innovation failures. [136].

2.7.2 Root causes related to risk factors of technological innovation

Various causes, including both direct contributing factors and root causes, exist. Identifying the root causes is essential for effectively addressing the issue. It's imperative to systematically tackle underlying root causes to effectively manage risk factors, thereby safeguarding innovation endeavors from potential wastage.

- Failing to assess the innovation concept related to financial, structural, marketing, and technological capabilities. [67],[116].

This risk factor emphasizes the importance of evaluating the innovation concept thoroughly in terms of financial, structural, marketing, and technological capabilities. Insufficient investment availability, lack of external funding opportunities, and

inaccurate budgeting can hinder the implementation of innovative ideas. Additionally, the absence of prior expertise in evaluating innovation concepts and leadership's lack of experience in guiding the innovation process contribute to the failure to assess innovation concepts effectively.

- Not aligning the company's long-term goals with its innovation strategy [126].

Misalignment with long-term organizational goals can lead to ineffective innovation strategies. Not considering the company's long-term objectives during the innovation process and lacking the necessary organizational strengths to develop ideas that align with these goals are significant root causes. This emphasizes the importance of ensuring that innovation initiatives are aligned with the broader strategic objectives of the organization.

- Violating intellectual property rights or stealing intellectual property from others [120].

Violating intellectual property rights or failing to protect intellectual property assets can pose significant risks to technological innovations. Root causes include neglecting to conduct thorough checks on intellectual properties related to the innovation, not securing patents or other appropriate protections, and failing to establish Non-Disclosure Agreements (NDAs) with relevant stakeholders. Protecting intellectual property is essential for safeguarding innovative ideas and preventing unauthorized use or replication by competitors.

- Lack of organizational strength (including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base) [120],[121].

Organizational strength deficiencies encompass various factors such as human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base. Root causes include skill shortages within the organization, inadequate training initiatives to develop necessary skills, and a lack of a learning culture that fosters continuous improvement. Additionally, ineffective supplier selection processes and relationship issues between team members can further exacerbate organizational strength deficiencies.

- Not implementing better commercialization methods and inaccurate market positioning [126].

Ineffective commercialization strategies and inaccurate market positioning can undermine the success of technological innovations. Root causes include inadequate customer education about products or services, lack of consultation with experienced third-party experts in the commercialization process, and insufficient market research to inform proper market positioning. Developing robust commercialization strategies and accurately positioning products in the market are essential for maximizing the success of innovation initiatives.

- Redundancy and unprecedented risks [67].

Redundancy and unprecedented risks highlight the need to identify and mitigate potential risks that may arise during the innovation process. Root causes include failure to analyze redundancy risks, insufficient market research to anticipate market trends, and unawareness of competitive advantages that could differentiate products or services from competitors. Understanding market dynamics and competitive landscapes is crucial for effectively managing redundancy and unprecedented risks in innovation projects.

- Incorrect or distorted information [120].

Misinformation, such as inaccurate market analysis or failure to identify customer requirements, can lead to flawed innovation strategies. Root causes include inadequate market analysis, failure to identify customer needs accurately, and inaccuracies in feasibility studies that inform the innovation process. Addressing misinformation and ensuring that innovation initiatives are based on accurate market insights and customer feedback is essential for achieving successful outcomes.

- Failure to generate technological ideas through customer feedback, basic research, and creativity [67],[126].

Customer feedback is invaluable for refining and improving technological innovations. Root causes include overlooking customer feedback, failure to meet customer expectations, and inability to keep up with evolving technological trends. Incorporating customer feedback into the development process and ensuring that innovations address customer needs effectively are critical for enhancing product relevance and competitiveness.

- Risk involved in material resources [116].

Material resource risks highlight challenges related to raw material quality, supply chain disruptions, and inadequate procedures for handling material rejections. Root causes include issues with raw material quality, supply chain disruptions that affect material availability during production, and inadequate protocols for managing rejected materials. Ensuring a stable and reliable supply of materials is essential for mitigating material resource risks in innovation projects.

- Advancements and the emergence of new technologies [120].

Technological advancements can present both opportunities and challenges for innovation projects. Root causes include insufficient market research to identify emerging technologies or technological trends, lack of resources to adopt new technologies, and failure to leverage technological advancements to enhance innovation outcomes. Staying abreast of technological developments and strategically integrating new technologies into innovation initiatives are essential for maintaining competitiveness in rapidly evolving markets.

- Not aligning the development, implementation, and output of the entire process due to incomplete project information and communication issues [120].

Incomplete alignment across the development, implementation, and output phases of innovation projects can lead to inefficiencies and suboptimal outcomes. Root causes include inaccurate process definition, ineffective stakeholder engagement, and communication issues that hinder collaboration and coordination among project teams. Addressing these root causes and ensuring seamless alignment across all phases of the innovation process is crucial for maximizing project success and achieving desired outcomes.

- Unavailability of a robust risk management strategy [126].

Inadequate risk management practices can expose organizations to various risks that may derail innovation projects. Root causes include a lack of robust evaluation mechanisms, failure to assign responsibilities for risk assessment and mitigation, and ineffective monitoring of risk exposure throughout the innovation process. Implementing effective risk management strategies and ensuring comprehensive risk assessment and mitigation efforts are essential for safeguarding innovation initiatives and minimizing potential disruptions.

- Inadequate technical capability [126].

Technical capacity deficiencies, such as inadequacies in machinery, equipment, or skilled workforce, can impede innovation projects. Root causes include resource inadequacy, inability to address capacity gaps, and failure to plan for workforce skill requirements. Addressing these root causes and ensuring sufficient technical capacity are essential for overcoming technical challenges and facilitating successful innovation outcomes.

- Issues in the research and development process [135].

Researchers have identified the corresponding root causes for the risks involved in the research and development phase as not defining the development process in achieving the right product/service, impossible to overcome challenges in the development process, not performing a development trial, unable to apply the same methods/development process for bulk production and Any alternative methods increasing the requirements of costs/ lead time/ special skills and other [137],[138],[139],[140].

Moreover, the literature emphasizes the importance of discerning the interconnections among various factors pivotal to the development of a robust risk management model.

2.8 Interconnections between different factors

Developing effective risk management models requires a deep understanding of the interconnections between various factors, as the outcomes are influenced by the complexity of these interconnections [141]. Researchers employ diverse methods, including correlation and regression analysis, clustering algorithms, association rule

mining, time series analysis, Bayesian methods, and graph neural networks, to discern relationships between factors [141]. However, each method presents unique strengths and limitations. Correlation analysis, for instance, requires measurable variables and only captures linear relationships [142], while regression analysis is unsuitable for qualitative phenomena [143]. Additionally, association rule mining is not universally applicable and is more effective with larger datasets. Graph neural networks excel at capturing relationships but are computationally demanding for larger datasets. Moreover, simplifying the interconnections among various factors is crucial for facilitating well-informed decision-making.

2.9 Classification techniques

Data classification is crucial for converting raw data into actionable insights, facilitating comprehensive decision-making, and maximizing the value of data assets within organizations. Additionally, feature selection is crucial, particularly in datasets with numerous variables, as it enhances classification accuracy and performance [144]. Various methods exist for qualitative and quantitative data classification. Qualitative analysis often involves "coding," where codes represent themes or ideas. However, software tools like NVivo or Atlas.ti may not fully interpret the context of words or phrases, potentially leading to misinterpretation [145]. When exploring quantitative methods for data classification, K-Nearest Neighbor (KNN) emerges as a straightforward supervised machine learning algorithm applicable to both classification and regression tasks, especially suited for multi-class problems [146]. However, its accuracy is contingent upon data quality and performs optimally with a limited number of inputs. Additionally, KNN is slower, sensitive to outliers, and requires the selection of an optimal number of neighbors when classifying new data [146]. Decision Trees represent another data classification approach. However, even minor alterations in data can alter the tree structure, potentially yielding unexpected results [147]. Support Vector Machines (SVM) excels in scenarios with clear margins between classes. Nevertheless, they are restricted to binary outputs and struggle with larger datasets or overlapping target classes [148]. Naïve Bayes, while assuming feature independence, is recognized as a suboptimal estimator [146]. Random Forest, an extension of decision trees, accommodates a substantial number of variables but introduces complexity, rendering it less efficient for real-time predictions. Gradient Boosting Classifier builds robust models by aggregating weaker ones, yet its application is limited to binary targets [149],[150]. Lastly, Logistic Regression is suitable for linear data and binary predictions [146]. While each method has its strengths and weaknesses, underscoring the significance of choosing the most suitable technique according to specific data characteristics and desired outcomes, it's important to note that these methods also exhibit common limitations, including the need for binary target requirements, applicability solely to independent data, incapacity to classify overlapping data, and constraints in prediction efficiency and effectiveness [151].

In addition, a comprehensive exploration of various classification methods sheds light on the versatility of Artificial Neural Networks (ANN) across diverse applications, encompassing clustering, classification, pattern recognition, text classification, information extraction, regression, risk detection, and more, with the list expanding continuously [152].

2.9.1 Artificial neural networks for data classification

Neural networks offer numerous advantages [152],[153]. They excel in pattern recognition across various data types, including images, text, time series, and sound. Additionally, their self-learning capability enables the identification of hidden trends with minimal human error. Moreover, neural networks can process a vast number of parameters, yielding consistent outcomes. Notably, they are adept at learning and modeling complex decision-making processes, especially in uncertain data environments. Furthermore, once trained, neural networks provide swift predictions. Crucially, they serve as effective tools for analyzing and quantifying risks associated with innovations, making them invaluable for predicting and forecasting specific events based on historical data [152],[153].

The literature introduces various neural network architectures suitable for data classification, each with its advantages and limitations. Radial Basis Network (RBN) [154] offers a faster learning rate, while Random Boltzmann Machine (RBM) [155] is versatile for both supervised and unsupervised data, boasting simplicity and speed during training, along with powerful generative capabilities. Extreme Learning Machine (ELM) [156] demonstrates excellent generalization performance and rapid learning, outperforming Support Vector Machines (SVM) but introduces randomness leading to uncertainty and potential generalization degradation with inappropriate activation functions. Kohonen's network [157], a self-organizing map, effectively categorizes data in both supervised and unsupervised settings, organizing complex datasets with easily interpretable data mapping. However, determining input weights and ensuring nearby points behave similarly pose challenges. Support Vector Machine (SVM) [158] excels in binary classifications, particularly in text classifications. Feed Forward Neural Network [159],[160],[161], the basic type of network processing information in one direction offers simplified architecture advantageous for classification, characterized by resilience to noise, strong learning ability, simplicity, and speed. Bayesian Neural Networks (BNNs), an extended version of Feed Forward Neural Networks (FFNNs), are better suited for smaller datasets but with higher computational demands and increased complexity [141].

Neural networks have several drawbacks. They are often considered "black boxes," as their structure reveals little about the function being approximated [162]. Additionally, neural networks may require more data and computational complexity compared to traditional algorithms [162], [163]. Determining the optimal network structure can be challenging, often relying on trial and error [162], [163]. Other drawbacks include

hardware dependence, longer training times, over-fitting, under-fitting, and reduced prediction accuracy [162], [163], [164].

2.10 Consistency of the data classification

Most validation methods for the consistency of qualitative data classifications rely on independent evaluations by at least two experts, ensuring cross-validation of findings [165]. Additionally, coding consistency across all categories can be assessed using Cohen's kappa (interpretative reliability coefficient, k), with values above 0.8 generally indicating consistent categorization [165]. Furthermore, the Kruskal-Wallis test can be employed to statistically verify the consistency of categorizations. This test identifies significant differences between groups but does not indicate which groups are distinct [166].

Furthermore, researchers highlight that larger data sets can sometimes mislead the decisions produced by various analyses.

2.11 Dealing with large data sets

Variables or data with similar trends or information may produce more related results. Hence, instead of using all [167], the same result can be obtained with a smaller data set. Thus, dimensionality reduction methods play an important role in addressing the various issues that arise when dealing with large data sets. Correspondence Analysis (CA), Multiple Correspondence Analysis (MCA), and Principle Component Analysis (PCA) methods are widely used dimensionality reduction methods to reduce variables as much as possible while retaining as much information as possible, as well as to investigate relationships between dependent variables [168].

These methods work with various data types. PCA is primarily used for numerical data, whereas CA (correspondence analysis) and MCA (multiple correspondence analysis) are used for nominal categorical data [169]. Furthermore, MCA is an excellent tool for gaining a general understanding of how categorical variables are related. The correspondence analysis technique is used to summarize relativities in tables. Because tables are so common in data analysis, this is a technique that can be used in a variety of situations [168]. Both CA and MCA have limitations when it comes to interpreting relationships between more than six variables. Because plotting every level of all categorical variables in the same map makes the resulting maps extremely difficult to use. [169]. Moreover, checking conclusions with raw data is extremely difficult [169].

Besides, in machine learning applications, Principal Component Analysis (PCA) is a popular dimension reduction method [170]. It displays properties that vary widely across the data set. Furthermore, by transforming correlated variables into linearly uncorrelated principle Components (PC's), PCA highlights variations and highlights strong patterns in the data set [171]. Aside from that, PCA accomplishes a variety of

tasks, including outlier detection, prediction, data visualization, variable selection, and classification [172]. The PCA report displays several outputs in various plots including Scree plot, profile plot, pattern plot, and loading plot [173]. PCA, on the other hand, cannot be used in the analysis of categorical data which contains non-linearly related variables measured using the Likert scale (ordinal). As a result, Non-Linear Principal Component Analysis (NLPCA) or the Categorical Principle Component Analysis (CATPCA) the nonlinear equivalent of PCA, can be used for nominal (qualitative) and ordinal data types [174],[175].

Furthermore, various causes, including both direct contributing factors and root causes, exist. Identifying the root causes is essential for effectively addressing the issue.

2.12 Root cause analysis methods

In the process of developing a risk management model, analysing root causes is crucial for effective problem-solving and prevention of recurring issues [176]. Root Cause Analysis (RCA) aims to systematically identify and resolve underlying issues, offering a structured approach to problem-solving [176], [177]. Various methods are employed for root cause analysis, including Pareto charts, which highlight the significance of different problems based on frequency or cost [178]. The 5 Whys method drills down into successive layers of a problem through a series of questions, offering a simple yet effective approach to identify- causes [178]. Fishbone diagrams categorize possible causes into branches stemming from the original problem, providing a deeper understanding of contributing factors [178]. Scatter plots help uncover relationships between variables, aiding in cause identification [178]. Failure Mode and Effects Analysis (FMEA) explores potential defects or failures during product or process design [178]. Factor analysis and Fault Tree Analysis delve into systematic interdependence among variables to identify latent factors and system failures [179],[180]. Events and Casual factor Analysis establishes event timelines leading to incidents, while Kepner Tregoe offers problem-solving and decision-making methods [179],[181]. Barrier Analysis assesses system controls to pinpoint potential failures, and Problem Tree Analysis creates diagrams of potential causes for observable problems [179]. Issue Trees narrow down root causes and solutions, providing a quantitative problem-solving approach [182]. Additionally, RCASE automates root cause analysis, and P-M analysis addresses chronic losses resulting from complex combinations of causes [180],[183]. These diverse methods provide comprehensive approaches to root cause analysis in risk management, enhancing decision-making and problem-solving processes.

Apart from this, the importance of understanding the contribution of root causes in developing robust risk management models cannot be overstated, as decisions heavily rely on assessing the associated risk levels [184],[185].

2.13 Prioritization techniques of root causes

Evaluating risk factors involves prioritization, effectively tackled by Multi-Criteria Decision Making (MCDM) methodologies, which offer various tools such as AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), SAW (Simple Additive Weighting), and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) [186]. AHP and TOPSIS, frequently used for evaluating alternative priorities or rankings, stand out in decision-making within the MADM (Multiple Attribute Decision Making) model [187],[188]. AHP, especially, is widely recognized for its ability to facilitate decision-making across various disciplines, providing support to decision-makers in diverse fields [189]. However, complex interactions between decision elements may render hierarchical structuring infeasible, necessitating the use of the Analytic Network Process (ANP) to address such scenarios [190], [191]. ANP, a generalization of AHP, excels in handling problems with interdependencies, offering insights into complex issues [192]. While manual implementation of ANP is laborious, Super Decision Software streamlines the process by allowing the creation of tailored network structures [193]. This user-friendly tool accepts various input formats and provides comprehensive results, including consistent assessments of priorities, thereby aiding decision-makers in effectively analyzing complex problems [193]. Through ANP and Super Decision Software, researchers can delve into intricate problem spaces, uncovering influential elements and gaining deeper insights into multifaceted issues [190].

Moreover, in-depth analysis of risk management models in the literature typically addresses specific issues related to risk factors and utilizes previously described methods. However, there is a growing demand for comprehensive risk management models that provide a holistic view of organizations as well as the innovation process.

2.14 Methods used in risk management models

When analyzing the problem-solving processes in non-apparel and textile industries, Game theory serves as a valuable framework for risk management, offering insights into complex interactions and facilitating improved decision-making among stakeholders in various scenarios. By analyzing economic competition, labor negotiations, conflicts, and resource allocation, Game theory enhances outcomes by optimizing payoffs and reducing costs [194],[195]. However, the reliance on assumptions of rationality and self-interest can lead to unreliable results in real-world situations [196],[197]. Behavioral Game Theory (BGT) addresses these limitations by integrating psychology and philosophy, providing a more nuanced understanding of decision-making processes and individual biases [188]. Moreover, group discussions in risk management, incorporating diverse perspectives and expertise, enhance decision-making by providing a broader scope of information and promoting cooperation among team members [199],[200]. While game theory offers valuable

insights, challenges remain in its application, including the complexity of solving games involving mixed strategies and limitations in economic modeling [194], [201]. Overall, while game theory offers valuable tools and insights for risk management, addressing its limitations and complexities is crucial for maximizing its effectiveness in real-world scenarios. Hence remodeling coalitions in the CGT with the collaborative approach both within the team (intra-team collaboration) and between teams (inter-team collaboration) will offer richer explanations on managing the risk involved, leading towards achieving a common goal of the organization [201].

Besides, research have shown that visualization relocates cognitive tasks to a physical space where the entire problem becomes clearer, enabling organizations to approach them more methodically and collaboratively, thereby enhancing their ability to achieve business objectives [202]. This approach can be particularly valuable when developing risk management models.

2.14.1 Visual representation in problem-solving

Research indicates that 90% of information transmitted to the brain is visual, and the brain processes visual information differently than auditory or other perceptual data [202], [203]. Another benefit is company's return on investment can be significantly improved through improved analytical skills and involving every employee in the analysis process [202]. Using data-driven insights to formulate actionable strategies enhances the professional growth and development of any organization. Most importantly, visualization of problems provides a quick, intuitive, and simpler way of conveying critical concepts, making the analysis process more dynamic and understandable even by a non-technical audience [204]. In data visualization, it is critical to present the data most effectively for the specific project, audience, and purpose. It should also be clearer, more comprehensible, and more organized so that the team can quickly identify the most important points [202]. This will enable the entire team to collaborate on the analysis process [202],[203]. Thus, visualizing a problem is a better way to get a project to the desired state.

The literature emphasizes that the validation process is crucial in proving the effectiveness of efforts made to develop a risk management model. This validation is essential for demonstrating the intended utility of risk management models [205].

2.14.2 Validation

Validation of a system is essential to ensure its capability to perform its intended function under specific operational conditions, and to demonstrate its ability to produce accurate results within its designated parameters [206],[207]. Both qualitative and quantitative research can benefit from validation efforts, with qualitative data providing depth and detail to comprehend implications, and quantitative data supporting broader research points [208]. Validation in qualitative research assesses the appropriateness of tools, processes, and data, while quantitative validation

compares model predictions with experimental observations [209]. Criteria such as internal validity, external validity, reliability, and objectivity are used to evaluate quantitative research, while qualitative validation focuses on credibility, transferability, dependability, and conformability [210].

Validated questionnaires are commonly used in the validation process, and it's crucial to ensure they remain unaltered as even minor modifications can invalidate their accuracy [211]. These questionnaires should only be used with the population for which they were created and validated. Additional techniques for validating qualitative research include triangulation, respondent validation, and actively seeking alternative explanations. Commonly used questionnaires for measuring application usability include the Usability Metric for User Experience (UMUX), the Post-Study System Usability Questionnaire (PSSUQ), and the After Scenario Questionnaire (ASQ) [212]. Rubin's research indicates that usability is now considered a business phenomenon [213]. Besides, TAM (Technology Acceptance Model) finds out, user's behavioural intention. Another method to determine validity is through the System Usability Scale (SUS), a ten-item questionnaire answered using a 5-point Likert Scale ranging from "Strongly Disagree" to "Strongly Agree". Although initially designed for testing website usability, studies suggest the SUS is suitable for testing the usability of various products and can detect changes with just two participants [214].

Moreover, literature on risk management models tailored specifically for technological innovations in the textile and apparel industry is scarce, with existing models often being generalized and not industry-specific. Given the varying resources and competencies across organizations, there is a need for customized risk management models tailored to the unique challenges of technological innovations in the textile and apparel industry. Developing such tailored models would fill a significant gap in the literature and better address the specific needs and complexities of this industry.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter introduces the procedure for developing a risk management model for technological innovations within the textiles and apparel industry. The model is meticulously developed through a comprehensive synthesis of findings from literature reviews, insights obtained from questionnaires, and perspectives shared during interviews. Furthermore, the validation of this model by industry experts provides substantial validation of its effectiveness and relevance within the field.

The main points covered in this chapter are summarized below:

- Interconnections of innovation concepts
- Classification of innovation concepts
- Validation of the consistency of the classification
- Core innovation concepts
- Base for the risk management model
- Risk factors associated with technological innovations
- Refined list of risk factors associated with technological innovations
- Classification of risk factors into main phases of innovation process
- Validation of the consistency of risk factor classification
- Root causes associated with technological innovations
- Innovator type of the organization
- Structuring the Neural Network
- Priorities of risk factors related to different innovator types
- Priorities of root causes on risk factors
- Limitations in developing a customized risk management model
- The rationale for the risk management model
- Methodology for forming the game
- The risk management model and validation

3.2 Inter-connections of innovation concepts

As per the definitions made by different researchers, the literature contains various types of innovation concepts as illustrated in Table 2.1, representing both common as well as diverse characteristics to one another. For effective risk management and streamlined decision-making in the supply chain, a thorough evaluation of diverse innovation concepts and their interconnections is essential.

3.2.1 Detailed analysis of the interpretation of innovation concepts

Product innovation involves enhancing or introducing new functions to meet customer needs, necessitating a strategic plan for technological advancements through research and development activities [6],[262],[263],[264],[265]. Similarly, service innovation entails introducing new or significantly improved service concepts, relying on technology or systematic methods for implementation [9],[13],[42],[263],[265], [266]. Both types of innovation require a knowledgeable team, skilled human resources, and an organizational learning culture. Recruiting capable employees and providing training and incentives are essential for product innovation success [2], [6],[16],[43], [267]. Introducing new ideas, workflows, and technologies to enhance organizational efficiency is crucial for both product and service innovations, aligning with core business objectives. Product innovation involves close collaboration with customers to understand their values deeply, fostering independent and creative thinking among team members [3],[6],[34]. Both product and process innovations contribute to market sustainability, driven by awareness of technological changes and effective resource utilization. Implementing new marketing strategies is vital for innovation success, involving significant changes in product design, packaging, placement, promotion, or pricing. Additionally, product and service innovations intersect with key concepts like strategy, culture, human resources, business model, management, and marketing. Process innovation plays a critical role in enhancing the effectiveness of both product and service innovations, strengthening their relationships with various innovation concepts [2],[3],[6],[9],[21],[34],[43],[94],[266],[268],[269],[270].

Further, technological innovation, as defined in the literature, encompasses processes aimed at improving existing products or developing new ones, closely related to 21 other innovation concepts across different levels [6],[22],[24],[262],[263],[265]. These concepts include product, process, service, regional indigenous, user, business model, life cycle, enterprise, system, green, ecological, marketing, strategy, management, institution, organizational, culture, cooperative, and human resource innovations.

Besides, successful innovation requires structuring organizational activities to support development and production processes [6], [262], [263]. Enterprise innovation focuses on improving operational efficiency and effectiveness in achieving innovation goals, directly linked with system, marketing, cooperative, technological, and human resource innovations. System innovation, on the other hand, is intrinsically linked with technological innovation, as technological advancements often necessitate corresponding system adaptations [22].

Apart from this, regional indigenous innovation addresses key technical issues, utilizing indigenous knowledge to promote regional development, and is related to technological innovations [22],[265]. Furthermore, strategy innovation involves planning for improvements by encouraging advancements in technology or services

through research and development activities, directly linking with technological, human resource, and strategy innovations [6], [24],[262],[263],[265]. Moreover, green and ecological innovation involves the development of products and processes contributing to long-term development, directly related to technological, product, process, and service innovations [2],[3],[6],[9],[21],[34],[43],[94],[266],[268],[269],[270]. They significantly impact a company's environmental performance and competitive advantages, connecting with marketing, strategy, and management innovation concepts to enhance revenue generation. Marketing innovation provides vital external information for informed decision-making on innovation strategies, enhancing customer relationships and identifying technological trends, patents, and competitors [2],[3],[6],[9],[21],[34],[43],[94],[266],[268],[269],[270]. It benefits product, technological, service, enterprise, user, strategy, business model, human resource, and life cycle innovations, linking with all previously mentioned concepts. In addition, user innovation focuses on customer satisfaction within the broader context of marketing, product, and service innovations. Moreover, strategy innovation involves organizational planning to encourage technological or service advancements through research and development investments [6],[39],[262],[263],[271], connecting with marketing, management, institutional, organizational, cultural, cooperative, and human resource innovations for effective long-term planning.

Apart from this, management innovation [2], [42],[266],[268] focuses on achieving innovation goals by defining what to produce, how to produce, and the technology to use, closely related to product, process, service, and technological innovations. It encompasses organizational structuring, establishing a supportive culture, skill development, and operational efficiency improvements, connecting with various innovation concepts. On top of that, innovation [6],[42],[90],[272] promotes innovative performance through human resource mechanisms, aligning with technological, marketing, organizational, cultural, cooperative, and human resource innovations. Moreover, organizational innovation [2], [6], [21], [43],[44], [52],[266],[267], [268], [273] involves managing work processes to improve or change products, processes, or services, connecting with technological, marketing, institutional, cultural, human resource, business model, life cycle, cooperative, product, process, and service innovations. Further, culture innovation [2], [16],[22],[25],[43],[45],[263], [266],[268],[273],[274] fosters creative thinking and value extraction from knowledge, intersecting with technological, marketing, strategy, management, institutional, cooperative, and human resource innovations. Additionally, cooperative innovation focuses on increasing innovation efficiency, linking with technological, strategy, management, human resources, and enterprise innovations.

Similarly, human resource innovation serves as the foundation for all other innovation concepts, as various human resource activities drive the entire supply chain. Also, business model innovation [3],[13],[24],[42],[44],[266],[267] introduces new ideas, workflows, methodologies, services, or products, connected with product, process,

service, technological, marketing, and strategy innovations. Besides, Life cycle innovation [3],[6],[42] involves understanding customer needs closely, intersecting with marketing, product, service, and user innovation concepts.

Chapter 4(Results), subsection 4.1 summarizes the interconnections among the 21 innovation concepts identified through the analysis. Further, visualisation of these interconnections provides a more comprehensive understanding of interconnections.

3.2.1.1 Visualization of interconnections of innovation concepts

Given the qualitative nature of the data aimed at understanding interconnections among innovation concepts, graph visualization is preferred over numeric data-centric techniques to identify relationships between different elements (different innovation concepts) in different contexts.

Apart from this, Graph theory emerges as the optimal approach due to its broad applicability across domains [141]. Graph theory illustrates the interconnections of different factors using nodes and edges. In this study, 21 innovation concepts identified in the literature, as described in Table 2.1, were considered as nodes. Edges represented the connections between these innovation concepts. Additionally, the mapping of nodes and edges were based on interpretations and underlying meanings summarized in Table 2.1.

Graphviz was chosen for its graph drawing capabilities, simplifying the process by requiring only node, edge, and label specifications. With Graphviz, users can easily create visualizations without needing advanced programming skills, streamlining the learning process. Additionally, its automatic layout features efficiently positions nodes and edges, eliminating the need for manual adjustments and reducing extra effort. Besides, this provides customization options to improve the appearance of the graph. Due to the absence of quantifiable information, the graph serves solely to visualize relationships without quantification.

Chapter 4 (Results), subsection 4.1.1, Figure 4.1 illustrates the visual representations of the interconnections among the 21 innovation concepts.

Moreover, inter-connections derived using Graph theory illustrates that; all the innovation concepts have connections with at least 3 or more other innovation concepts, which confirms that they are sharing similar characteristics. Further, researchers sometimes assign different names to identical innovation concepts based on their applications, which can complicate the decision-making process. Therefore, there is a need to minimize redundant innovation concepts with similar meanings and systematically classify them based on insights shared in the literature.

3.3 Classification of innovation concepts

Qualitative data classification can be achieved through methods such as thematic analysis, Content analysis, Grounded theory, Mind mapping, Constant comparative analysis, and using software like MaxQDA or NVivo. These methods all have in common, is a constant comparative process, in which data processing involves, sorting and organizing raw data into groups (codes and themes) according to their attributes [215],[216]. Among them, Grounded theory has emerged as widely preferred for qualitative data classification due to its robustness, practicality, and relevance. Its multiple stages of coding facilitate the refinement of data, leading to the development of clear and robust concepts and ultimately enhancing the research conclusions [217]. Therefore, the Grounded theory was chosen as the preferred method for classifying innovation concepts in this study [218]. Open coding, axial coding, and selective coding have been employed to derive codes and categories relevant to innovation concepts [219].

During the classification process of innovation concepts according to Grounded Theory, the 21 innovation concepts identified in the literature were considered codes. Summarized definitions and underlying meanings of these concepts were utilized to compare and contrast similar data. Further analysis, utilizing axial coding from Grounded Theory, deduces the linking patterns among these codes, which are classified as categories. Together, the codes and categories collaborate to complete the classification which becomes the core category.

3.3.1 Classification of innovation concepts using Grounded Theory

Analysis of similar codes through axial coding reveals their association with distinct phases of the innovation process. The initial phase encompasses all preliminary work required to initiate an innovation. The subsequent set of codes pertains to acquiring external information. Finally, a third set of similar codes indicates a phase corresponding to the development, bulk production, and market introduction of the innovation. Consequently, three main phases, which were classified according to the Grounded theory, have been identified and defined as, Intra-Organizational Innovation Phase (P1), which involves organizing the organization for sustainable innovation; Peripheral Innovation Phase (P2), which entails gathering external information for sustainable innovation; and Sustainable Innovation Phase (P3), which involves implementing sustainable innovation.

P1 - Intra-Organizational innovation phase: This involves aligning the organization's vision, strategic planning, organizational culture, human resource development, reward systems, and investment capabilities to improve efficiency and drive future growth. These elements are crucial for fostering sustainable innovation and maintaining a competitive edge in the global market. Achieving this can be done through organizational management, structural enhancements, cultural development,

cooperative strategies, human resource optimization, institutional adjustments, and enterprise innovations [40], [42], [43], [44], [47], [49], [51], [52], [57], [60], [63], [64], [65], [69], [74], [75], [76], [85], [86].

P2 - Peripheral innovation phase: The primary goal of innovation is to develop products or services that meet customer needs while maintaining market share. This requires a deep understanding of customer requirements, market trends, and competitors to identify potential threats and opportunities. Failure to accurately assess these factors can lead to an innovation's failure. As summarized in Table 2.1, this understanding is essential for staying competitive and ensuring continual growth. Mastery of marketing, business models, life cycles, and user innovation is crucial for achieving sustainable innovation and economic success [40], [42],[43],[44],[46], [47], [51], [52], [54], [58], [59], [60], [65], [68], [72], [75],[82], [83], [87].

P3 - Sustainable innovation phase: A firm's dynamic capabilities lie in its ability to create products or services that establish market dominance, ensuring the organization's success and longevity. Effective implementation of any innovation encompasses technological, product, process, service, system, regional indigenous, resource, green, and ecological innovation concepts. These are complemented by innovation concepts associated with the initial and subsequent innovation phases, driving the organization toward sustainable innovation [34],[38], [39], [40], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [77], [78], [79], [80].

Chapter 4 (Results), subsection 4.2, Figure 4.2, presents the classification of the 21 innovation concepts into the main phases of the innovation process

Since the classification was based on qualitative analysis, which heavily relies on the analytical and integrative abilities of the person who performed the analysis, as well as the personal knowledge of the social context in which the data was collected, the derived theory can manifest in various forms [220]. Therefore, it is crucial to ensure the consistency of classification [207].

3.3.2 Validation of the consistency of the classification

Since the innovation concepts were identified in the literature related to different industries, a questionnaire (QE1), was developed and distributed among 350 textile and apparel industry experts, to see if the industry agreed with the given innovation concepts and their classification.

The questionnaire (QE1), included in Appendix A, encompasses the innovation concepts classified using Grounded theory within the main phases, P1, P2 and P3 of the innovation process, which have been identified as “Categories” during the classification process. To enhance understanding of the innovation concepts,

summarized meanings of the 21 innovation concepts were provided. Subsequently, respondents were asked to indicate their level of agreement with the classification of innovation concepts based on a Likert-type scale: 1-Strongly Disagree, 2-Disagree, 3-Undecided, 4-Agree, and 5-Strongly Agree.

Questionnaires (QE1) was distributed among 350 persons, and 321 completed feedback were received. The percentages of the feedback received for each response option - strongly disagree, disagree, undecided, agree, and strongly agree on each phase, illustrated in Table 3.1. This has been graphed to validate the consistency of the classification and presented in Chapter 4 (Results), subsection 4.2.1, Figures 4.3, 4.4, and 4.5.

TABLE 3.1: PERCENTAGE DISTRIBUTION OF FEEDBACK ON QUESTIONNAIRE (QE1)

Phase of the innovation process	Percentage (%) distribution of responses				
	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
P1	0.1	3.0	7.7	36.8	52.4
P2	0.2	4.8	5.7	31.5	57.8
P3	0.1	0.4	10.3	43.5	45.7

Since the graphical representation of the feedback received from the questionnaire was based solely on the number of responses, without any further analysis, statistical validation was conducted separately to assess the accuracy and consistency of the results.

3.3.2.1 Statistically proving the consistency of the classification

The statistical validation of the consistency of the classification confirms the reliability of the process, and Kruskal-Wallis test has been used for the task. Since this is a non-parametric test, the data from questionnaire (QE1), were tested for normality using the Kolmogorov-Smirnov test, which is appropriate for datasets larger than 50. The test was performed in SPSS, were illustrated in Table B.1 through Table B.21 in Appendix B. The significant values of the Kolmogorov-Smirnov test for all 21 innovation concepts were 0.000 ($p < 0.05$), indicating that the dataset was not normally distributed. In addition, the feedback from questionnaire (QE1) was measured on an ordinal scale; the use of the Kruskal-Wallis test was justified and aligned with the rationale outlined in previous research [88].

In further justifying the use of the Kruskal-Wallis test, the feedback was based on three independent variables: P1 - Intra-organizational innovation, P2 - Peripheral innovation, and P3 - Sustainable innovation, representing key phases of the innovation process. These independent variables, which influenced innovation concepts, were considered observably independent (P1, P2, and P3). The dependent variables, innovation concepts, were measured on an ordinal scale using a Likert scale (ranging from 1 to 5). Therefore, the Kruskal-Wallis test was applied to examine the following hypotheses.

Null hypothesis – The distribution of responses (medians) are same across all categories

Alternative Hypothesis – At least one median is different

The analysis involved two statistical tests: the Independent Samples Median Test and the Kruskal-Wallis Test, both applied to evaluate the feedback from the Questionnaire (QE1). These tests, conducted using SPSS software on all 21 innovation concepts, were instrumental in validating the consistency and reliability of the classification process.

Chapter 4 (Results), subsection 4.2.2, Table 4.3, illustrates the hypothesis test summary that demonstrates the consistency of the classification.

Since innovation concepts classified under each main phase share similar characteristics, this can be further streamlined by analyzing the underlying meanings of innovation concepts under each phase, which reduces the complexity of the decision-making process by limiting the analysis of similar data. Besides, this classification enhances the effectiveness in addressing issues.

3.4 Core innovation concepts

Grounded theory was used to refine the classification. The underlying meanings of each innovation concept listed under each main phase were further analyzed to determine if they shared more similar characteristics in order to simplify the classification even further.

This procedure was replicated across all three main phases P1, P2 and P3, to deduce core innovation concepts from each main phase, which represents the characteristics of the other innovation concepts listed under the same phase.

3.4.1 Deriving core innovation concepts from three main phases using Grounded Theory

P1 – Intra organizational innovation phase– Structuring the organization for a sustainable innovation

In Chapter4 (Results), subsection 4.2, Figure 4.2, innovation concepts are classified across key phases of the innovation process, emphasizing factors crucial for sustainable innovation. Concepts such as management, strategy, culture, human resources, cooperation, organizational, and institutional innovation align closely with the intra-organizational phase. This phase includes strategic planning, organizational culture, human resource management, training, rewards systems, investment capabilities, risk management, and vision alignment, essential for achieving innovation goals [52], [174], [193], [229].

Management innovation, central to the organization's vision, plays a pivotal role in driving innovation across areas like research and development [52], [174], [193], [229]. Strategy innovation, as per Xu [16], guides integrated innovation across technology, organization, marketing, management, culture, and institutions, enhancing competitive advantage [16], [169], [175], [193].

Culture innovation, integrating strategy, management, institutional, marketing, technology, and HR management concepts, nurtures a learning culture conducive to innovation [22],[40],[42],[53],[59],[64], [68],[72], [267],[277],[276]. Human resource (HR) innovation, vital for the success of technological and product innovations, focuses on recruiting capable team members and motivating them through training and incentives [42], [54], [64], [270],[277]. Institutional innovation enhances innovative performance through incentive mechanisms aligned with HR and intra-organizational concepts [269], [270], [276],[278].

Organizational innovation promotes competitive advantages by fostering new ways of organizing work processes, managing relationships, and cultivating an innovative culture [22], [44], [52], [54], [64], [70], [270], [276], [277]. Together, these concepts form the foundation for structuring organizations for sustainable innovation within the intra-organizational phase, where management innovation stands out as the core concept.

P2 - Peripheral innovation phase - Information outside the organization for a sustainable innovation

The ultimate goal of innovation is to create products or services that solve customer pain points and profitably introduce them to the global market. This requires a deep understanding of customer needs, market trends, and competitor identification, which are essential for innovation success.

Marketing innovation, as noted in the literature, involves working closely with customers to meet market demands and directly influences technological, product, and process innovations, enriching business strategies with external insights [279], [280], [273]. User innovation, focused on customer satisfaction, aligns with marketing innovation in the peripheral innovation phase.

Business model innovation prioritizes continuous customer relationships, process improvements, and problem-solving to enhance competitive advantage and long-term growth. Though connected to product and process innovations, its primary impact is on marketing innovation by seeking external information [22], [39], [47], [49], [267], [282], [283].

Life cycle innovation, which works closely with customers to understand their values, leverages product innovation during emergence and process innovation during growth and maturity. It is closely tied to marketing and business model innovation, with a focus on effective customer satisfaction [47], [270], [283].

In summary, marketing innovation encompasses business model, life cycle, and user innovation, making it the key concept in the peripheral innovation phase.

P3 - Sustainable innovation phase - Implementing a sustainable innovation

A firm's dynamic capabilities rest on its ability to create market-leading products or services, ensuring success and longevity. The sustainable innovation phase, shown in Figure 4.2, includes technological, product, process, service, green, ecological, resource, system, and regional indigenous innovations. These components converge to bring innovations to market. Process innovation is crucial in turning ideas into tangible products, while service innovation focuses on implementing new or improved service concepts [22], [39], [47], [267], [273], [282].

Technological innovations drive market disruption and enhance competitiveness by improving quality, reducing prices, and shortening lead times [336], [20]. While service innovation often transcends technological domains, technological concepts are key to achieving service innovation goals [40], [70], [267], [276], [283].

System innovation, defined by Jing [267], involves technology and information exchange and is fundamental to technological innovation [67]. Resource innovation, according to Meissner et al. [267], emphasizes the effective use of resources, a critical part of technological innovation [40], [42], [267], [276]. Regional indigenous innovation addresses technical challenges in regional development, using local knowledge for progress and fitting within technological innovation [40].

Ecological and green innovations focus on sustainability. Ecological innovation advances sustainable development with eco-friendly technologies, while green

innovation aims at creating greener products, processes, and performance [47]. Both are driven by technological innovation.

The successful implementation of any innovation involves technological, product, process, service, system, regional indigenous, resource, green, and ecological innovations. These efforts are enhanced by leveraging intra-organizational and peripheral phases. Since all these concepts rely on technological innovation, it serves as the core driver of sustainable innovation.

The analysis identified core innovation concepts: management innovation from P1, marketing innovation from P2, and technological innovation from P3. Chapter 4 (Results), subsection 4.3, Table 4.4 summarizes these findings.

Further, innovations often fail to meet expectations [20] due to the inherent risks in the innovation process. To manage these risks effectively, it is crucial to identify the factors that increase risk during innovation. Managing risk factors for individual components is simpler and more efficient than addressing the entire process at once. The core innovation concepts, management, marketing, and technological innovations are derived from the main phases P1, P2, and P3, respectively, using Grounded Theory. This approach identifies the core concept that represents key ideas of other innovation concepts within the same phase. Therefore, managing risks related to these core concepts helps mitigate overall risk effectively.

3.5 Base for the risk management model

Effective management of overall innovation risk requires addressing risks within core innovation concepts. This necessitates a thorough understanding of the associated risk factors and access to relevant industry information. To gather these insights, Questionnaire QE2 (included in Appendix C) was developed. Its primary objective was to assess the industry's willingness to share crucial information for evaluating risks in core innovation concepts. The questionnaire incorporates key risk factors (labelled A through S) identified from the literature. [79],[176],[177],[179].

QE2 was distributed among textile and apparel industry experts in Sri Lanka, resulting in 73 completed responses. The analysis of these responses aimed to evaluate the industry's readiness to share essential information for developing a comprehensive risk management model across the three core innovation concepts. Figure 3.1 presents the responses from various organizations, highlighting their consent to share information on the primary risk factors (A through U) outlined in the questionnaire (QE2) in Appendix C.

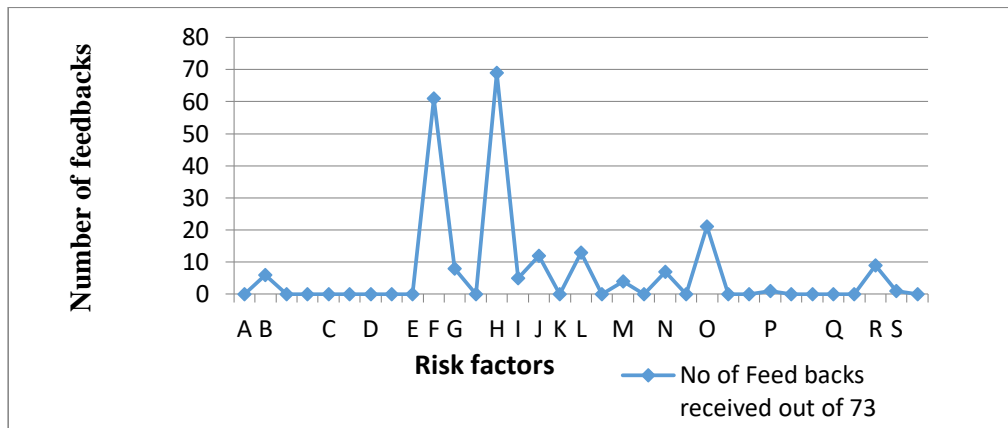


Fig. 3.1: Consent to share information on risk factors of core innovation concepts

Based on the feedback received, the industry did not confirm its willingness to share confidential data related to management and marketing innovations with a third party. Thus, assessing risk in management and marketing innovation proved challenging since organizations were hesitant to disclose confidential information regarding innovation strategies, organizational strategies, budgets, and human resource plans, making it difficult to evaluate the associated risks. They were willing to share information related to technological innovations, but not on all risk factors associated with technological innovations, as indicated in the feedback.

Given this constraint, the focus shifted to technological innovations. Further, technological innovation emerged as the dominant factor driving organizational survival and growth [69],[70], thus establishing itself as the base for developing a risk management model. Hence, an in-depth analysis of risk factors associated with technological innovations has become essential.

3.6 Risk factors associated with technological innovations

An extensive analysis of literature was done to find out risk factors introduced, related to technological innovations. This includes manufacturing and service organizations, including the textile and apparel industry, worldwide. Table 3.2 illustrates the summarized risk factors of technological innovations found in the literature.

TABLE 3.2: TECHNOLOGICAL INNOVATION RISK FACTORS IN THE LITERATURE

Risk Factor	Technological innovation risk factors in the literature
1	Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities [67], [116].

2	The company's long-term goals are not aligned with its innovation strategy [126].
3	Violating intellectual property rights or stealing intellectual property from others [120].
4	Lack of organizational strength (including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base) [120], [121].
5	Failure to adopt better methods of commercialization, and inaccurate market positioning [126].
6	Redundancy (a profitable innovation today may become obsolete shortly) and Unprecedented risks - (risks beyond the organization's control, fluctuations in customer demand, social and economic environment, and national industrial policies) [67].
7	Information resource risk, including distorted market information [120].
8	Failure to generate technological ideas through customer feedback, basic research, and creativity resulted in Innovation failure to address customer pain points [67], [126].
9	Material resource risks, which affects timely delivery of goods [116].
10	Technological advancements and the emergence of new technologies [120].
11	Failure to properly align the development, implementation, and output of the entire process (incomplete project information and communication issues) [120].
12	Lack of a better risk-control mechanism, which risk management, must be combined with the enterprise's development plan, strategies, manpower, and financial investments, including a lack of risk supervision and control activity throughout the process and failure to adopt the "learning-through-experiment" process [126].
13	Inadequate Technical Capacity [126].
14	Issues with the R&D process, sample-to-batch challenges, Inbound and outbound communication issues, as well as inconsistency in project organization and management [135].

Moreover, an expert review was conducted through structured and semi-structured interviews to confirm that the identified risk factors were common to both the textile and apparel sectors. These interviews also aimed to uncover any additional risk factors encountered in each sector throughout the innovation process across the entire supply chain. The interviews continued until information saturation was reached.

Table 3.3 presents a compilation of technological innovation risk factors derived from structured and semi-structured interviews conducted with industry experts, where

information was gathered separately from the textile and apparel sectors, and the identified risk factors were common to both.

TABLE 3.3: TECHNOLOGICAL INNOVATION RISK FACTORS IDENTIFIED FROM THE INDUSTRY

Risk Factor	Technological innovation risk factors identified from the industry
1	Redundancy (The possibility of a profitable innovation today may be redundant shortly) and Unprecedented risks - Risks outside the control of the organization, fluctuations in the customer demand, social and economic environment, national industrial policies
2	Innovation is not aligned with the company's long-term goals
3	Not adopting better ways of commercialization, Inaccurate market positioning
4	Not generating the technological innovation idea through customer feedback, basic research, and creativity/ Product is not solving the pain point of the customer, and inadequate market research
5	Not assessing the innovation idea in terms of finance, structural, marketing, and technology
6	Human resource risks including team members not being held accountable, technological incompatibility, technical skill incompatibility, and attitude.
7	Not properly aligning development, implementation, and output of the whole process (project information incompleteness)
8	Shortages in the strength of the organization (including skilled team, Financial, Leadership, contracts, Brand recognition, and skilled supplier base)
9	Not having a better risk controlling mechanism, which risk management needs to be combined with the enterprise's development plan, strategies, investments of manpower and funds, including lack of risk supervision and control activity throughout the process and not adopting the process of "learning through experiment"
10	Material resource risks, which affects timely delivery of goods
11	Risk of information resource, including distorted market information and project information incompleteness

12	Not focusing well on information transmission and utilization during the project, Problems in inbound and outbound communication
13	Risk of technological advancement in the market and Emergence of new technologies
14	Limited technical capacity
15	Theft of intellectual property, including patents, copyrights, trademarks, or trade secrets.
16	Issues related to the supplier base which hinders the development and production plans
17	Issues in R & D process, sample to bulk challenges, inconsistency of project organization and management
18	Over-value addition to the product will not be accepted by the customer
19	Fewer orders and order quantities
20	A lead time of the innovation may be higher than expected and cannot achieve the required time lines, this will lose orders
21	Difficulty in convincing operators about process changes
22	Not achieving the expected time savings/ profit
23	Unable to find out customer market share

3.6.1 Refined list of risk factors associated with technological innovations

The analysis reveals discrepancies between technological innovation risk factors identified in industry interviews and those documented in the literature. The literature highlights 14 risk factors associated with technological innovations, while feedback from the industry observed 23. Consequently, a comprehensive analysis was warranted to compare all these factors and consolidate the definitive list. The industry's list of risk factors overlaps with 14 identified in the literature, yet it introduces 9 additional ones. Hence, there emerged the need of a thorough investigation of industry-specific risk factors that were not covered in the existing literature. Among the methods discussed in subsection 2.12, Fishbone diagrams were chosen due to their ability to categorize potential causes into branches stemming from the core problem, facilitating a deeper comprehension of contributing factors [178]. Given the straightforward nature of the issue's context, Fishbone diagrams were deemed suitable as they provide a structured framework for analysis without unnecessary complexity. Figures 3.2 through 3.7 present root causes analysis done

using Fishbone diagrams, for the industry-specific risk factors, labeled from 18 to 23 in Table 3.3, while factors up to 18 were common to both literature and industry.

Figure 3.2 delves into the reasons behind customer reluctance to accept excessive product enhancements. Industry experts highlight that customers resist additional costs for unrequested innovations unless explicitly authorized. Consequently, this poses a significant risk of customer rejection. The fishbone diagram encapsulates related causes, echoing risk factors of Table 3.2, as distorted market information (Seventh risk factor) and failure to solicit customer feedback or generate innovative ideas addressing customer needs (Eighth risk factor).

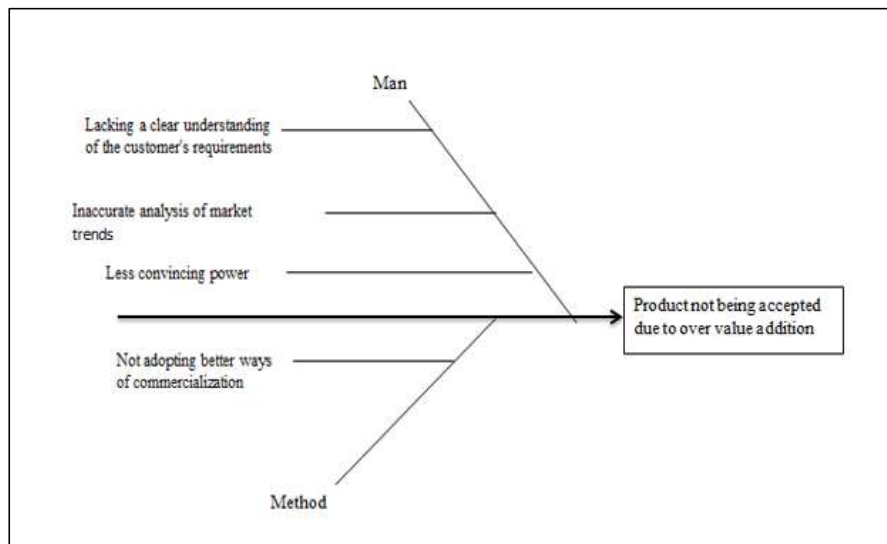


Fig. 3.2: Causes for product not being accepted due to over value addition

Fewer orders and quantities can jeopardize innovation success, leading to lower revenue and delaying breakeven points, as emphasized in industry discussions. This risk, highlighted by experts, stems from factors detailed in Figure 3.3, aligning with literature on failure to assess innovation concepts based on financial, structural, marketing, and technological capabilities (Risk Factor 1) and unforeseen risks (Risk Factor 6) in Table 3.2.

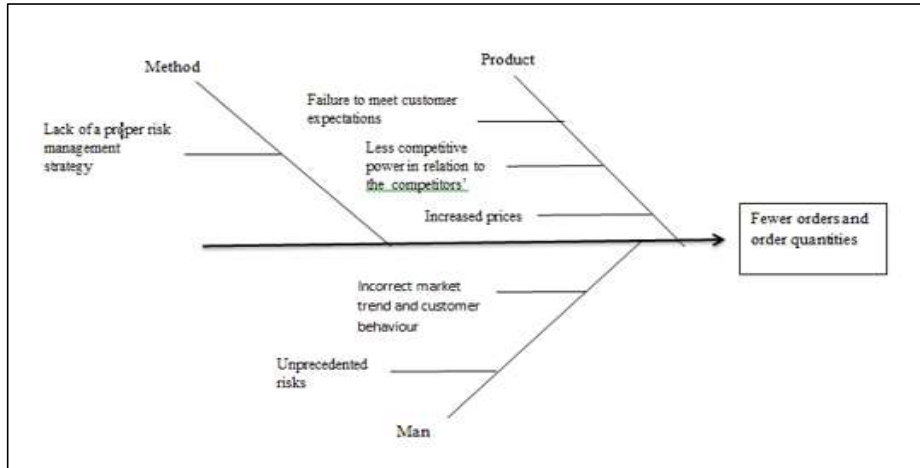


Fig. 3.3: Fewer orders and order quantities

Figure 3.4 shows the causes of longer lead times, a major risk in the textile and apparel industry due to rapidly changing customer demands. Managing the entire supply chain is the key to reducing lead times. The factors in Figure 3.4 align with risk factors for technological innovations listed in Table 3.2, such as lack of organizational strength, material resource risks, and misalignment in process development, inadequate technical capability, and R&D issues, lack of a proper risk management strategy consistent with risks identified in the literature.

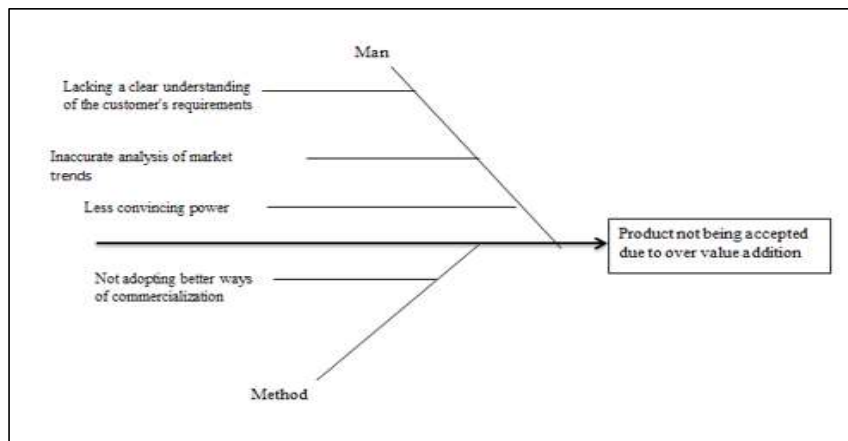


Fig. 3.4: Higher lead times

Industry experts highlighted the challenge of introducing new processes and convincing operators to adopt changes. Operator and team resistance underscores the need for strong persuasion skills. Figure 3.5 outlines potential causes, aligning with the risk factor of lack of organizational strengths noted in Table 3.2 and supported by the literature.

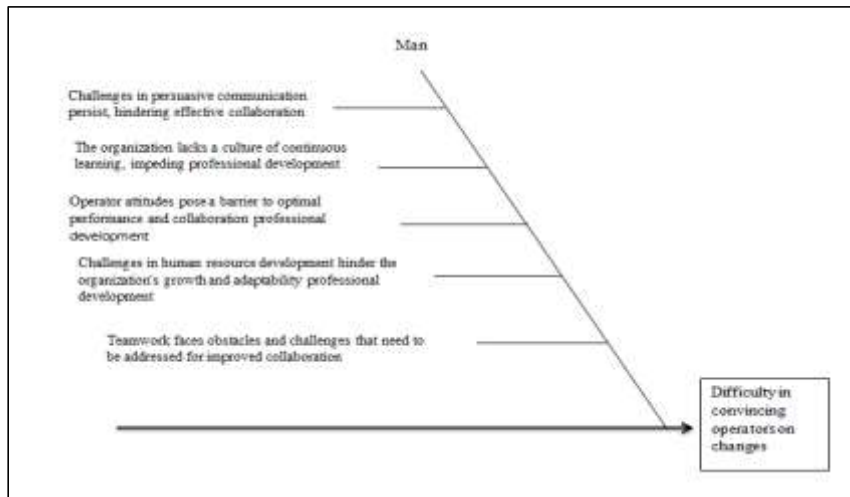


Fig. 3.5: Difficulty in convincing operators on changes

The overall profit of the innovation process is crucial, yet deviations from planned costs have been observed in industries, heightening the associated risks and impacting the outcome. Figure 3.6 illustrates the reasons for not achieving the expected profit margins, covering all the risk factors in Table 3.2, identified in the literature.

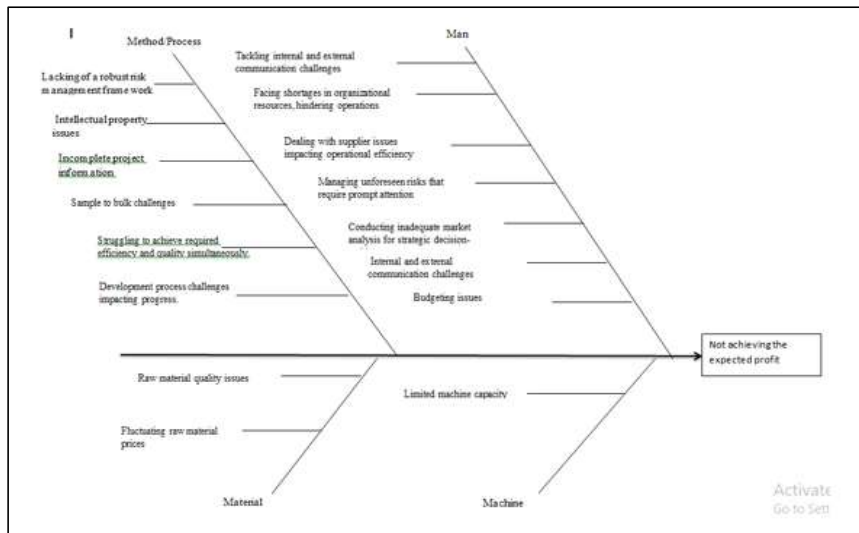


Fig. 3.6: Not achieving the expected profit

Another significant challenge faced by the industry was identifying the right customer market for their innovation. Failure to pinpoint the appropriate market niche can undermine all innovation efforts. The literature has already addressed possible causes for this challenge illustrated in Figure 3.7, as evidenced in Table 3.2.

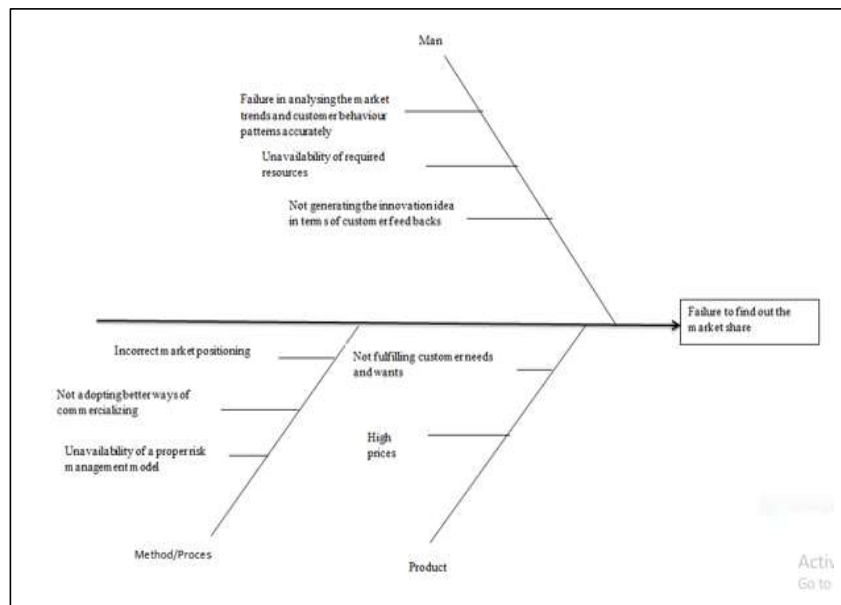


Fig. 3.7: Finding out the customer market share

Root cause analysis reveals that the risk factors identified within the industry align with those documented in the literature. However, a discrepancy arises as the industry has designated these risks using distinct terminology. Experts endorsed that the risk factors associated with technological innovations were consistent across the literature and the industry with no exception to both textile and apparel sectors.

The refined list of 14 risk factors related to technological innovations has presented in Table 4.5, subsection 4.4 in Chapter 4 (Results).

A thorough understanding of when risk factors emerge during the innovation process greatly enhances the effectiveness of the risk management model [221], [222]. This promotes the early detection of risks and allows for targeted analysis of specific phases, rather than applying a uniform approach to all phases. In addition, the effective use of organizational resources will be enhanced, contributing to managing the risk involved [223]. Thus, the next step was to classify risk factors according to the 3 main phases, P1, P2 and P3 of the innovation process.

3.7 Classification of risk factors into main phases of the innovation process

Consistent with existing research, Grounded Theory was used to classify risk factors based on the main phases of the innovation process, P1, P2 and P3, representing a novel contribution to the literature. The coding process integrated insights from a literature review on various risk factors associated with technological innovations, along with industry experts' perspectives on these risks and their occurrence during different phases of the innovation process, gathered through structured and semi-structured

interviews. Grounded theory has been used in the classification elaborate in the subsections of 3.7.1, 3.7.2, 3.7.3.

3.7.1 Intra-organizational innovation phase (P1)

From an organizational perspective, four risk factors—failure to evaluate the innovation concept against financial, structural, marketing, and technological capabilities, C1 misalignment of long-term goals with innovation strategy, C2 intellectual property infringement, C3 and lack of organizational strength (including human resources, financial resources, leadership, contracts, brand recognition, and skilled supplier base), C4 are classified under the intra-organizational innovation phase. Since, risk factors C1, C2, C3, and C4 lay the groundwork for structuring the organization for long-term innovation, representing the codes of the intra-organizational innovation phase according to Grounded Theory. Further, this phase assesses the organization's capacity to undertake innovation by comparing required resources to available resources.

3.7.2 Peripheral innovation phase (P2)

The peripheral innovation phase focuses on external information and interactions beyond the organization's boundaries. Risk factors of product commercialization, C5 redundancy, and unprecedented risks, C6 and the accuracy of external information, C7 are beyond the organization's control but require precise identification and appropriate actions to manage the associated risks.

3.7.3 Sustainable innovation phase (P3)

Sustainable innovation phase encompasses both product and process innovation phases.

Product innovation phase: This phase primarily addresses product-related risk factors critical to innovation success. The organization's focus is on efficiently addressing customer pain points, C8 to ensure market survival. Raw materials, C9 play a vital role in achieving innovation goals, impacting quality. Market technological advancements and emerging technologies, C10 can have a significant impact on product quality, novelty, cost, and time. These factors, C8, C9, and C10, are key components of the product innovation phase.

Process innovation phase: Ensuring the accuracy of defining the entire innovation process is crucial for achieving desired goals. Proper alignment of development, implementation, and output, C11 streamlines the process flow. Implementing an effective risk control mechanism, C12 is essential to avoid potential disasters. Adequate technical capacity, C13 is crucial for both development and bulk production processes. Additionally, research and development, C14 are pivotal in determining innovation success. These factors, C11, C12, C13, and C14, contribute significantly

to the process innovation phase. Classification of the risk factors into main phases was depicted in Chapter 4 (Results), subsection 4.5, Figure 4.7.

Since this involves qualitative data and solely depends on the person who performed the analysis, the validation process was needed to ensure the consistency of the classification.

3.8 Validation of the consistency of risk factor classification

To validate the consistency, a method involving the collection of feedback through a structured questionnaire was employed [224]. Questionnaire (QE3) was developed to cross-validate the consistency, which presented the risk factors and 3 main phases of the innovation process, requesting respondents to indicate to which phase the risk factors can be classified into, to measure their level of agreement with the classification. The questionnaire (QE3) is outlined in Appendix D. This involved seeking validation from ten industry experts, consisting of eight individuals from the apparel industry and two from the textile industry, all of whom were part of the sample selected for the study.

The consistency was assessed by analyzing the feedback received on (QE3), from the 10 industry experts.

Based on feedback from 10 experts, nine agreed with the classification shown in Figure 4.7, while one agreed only on classifying 13 risk factors. This was finalized in Chapter 4 (Results), subsection 4.5.1.

Furthermore, understanding the fundamental root causes behind risk factors is essential for effectively addressing issues and preventing their recurrence. This strategic approach prioritizes tackling the root cause rather than merely alleviating symptoms, thereby guaranteeing lasting solutions.

3.9 Root causes associated with technological innovations

A comprehensive review of the literature identifies 65 root causes tied to 14 specific risk factors related to technological innovations, finalised in Table 4.5, subsection 4.4 in Chapter 4 (Results). Risk factors were labelled as "C" and root causes as "A." For example, the root causes for risk factor C1 related to the failure to evaluate innovation concepts based on financial, structural, marketing, and technological capabilities were listed as A1.1 through A1.5. The number of root causes differs for each risk factor.

TABLE 3.4: RISK FACTORS AND CORRESPONDING ROOT CAUSES OF TECHNOLOGICAL INNOVATIONS

Risk Factor	Root causes
C1 Failure to evaluate the innovation concept based on the company's financial, structural, marketing, and technological capabilities	A1.1 Insufficient investment available for the project [286].
	A1.2 Limited opportunities to secure external funding (loan, joint venture, mortgage, other) in the absence of internal investment [287].
	A1.3 Failure to review the innovation idea by experts to assess necessary implementation steps and potential risks [288].
	A1.4 Leadership lacks prior knowledge and experience to effectively guide the innovation process [289].
	A1.5 Inaccuracy of the budgeting process [117].
C2 The company's long-term goals are not aligned with its innovation strategy	A2.1 Failure to consider the company's long-term goals during the innovation process [290].
	A2.2 Lack or unavailability of necessary resources and capabilities to develop the innovation in line with long-term goals [290].
C3 Violation of intellectual property rights or theft of intellectual property from others	A3.1 Failure to verify existing intellectual property related to the product, such as patents [119].
	A3.2 Not securing the innovation with a patent or other appropriate methods [291].
	A3.3 Lack of Non-Disclosure Agreements (NDAs) with relevant personnel [291].
C4 Lack of organizational strength, including human resources, financial resources,	A4.1 Lack of long-term critical skill holders within the organization [292].
	A4.2 Insufficient skills and knowledge among team members [292].

	leadership, contracts, brand recognition, and a skilled supplier base	A4.3	Failure to provide adequate training to improve skills and knowledge (internal, on-the-job, external, or other appropriate training) [293].
		A4.4	Absence of a learning culture within the organization [130], [294].
		A4.5	Poor relationships among team members [295].
		A4.6	Difficulty convincing operators to adopt process changes [296].
		A4.7	Lack of time and resources for "learning through experimentation" [134].
		A4.8	Poor decision-making when selecting suppliers (price, lead time, material quality, cost benefits, credit terms, accreditations) [297].
		A4.9	Disagreements with suppliers reduce negotiation opportunities [298].
C5	Failure to adopt improved methods of commercialization and inaccurate market positioning	A5.1	Absence of a mechanism to inform customers about new products or services [299].
		A5.2	Failure to consult experienced third-party teams during the commercialization process [300].
		A5.3	Failure to consult experienced third-party teams during the commercialization process [300].
C6	Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic environment changes, and shifts in national industrial policies)	A6.1	Analysis of the information on redundancy or unprecedented risks which can impact the organization [17].
		A6.2	Being the first entrant into the market [302].
		A6.3	Presence of significant competitors [302].
		A6.4	Lack of competitive advantages over rivals (price, quality, user-

	can impact the organization		friendliness, market segment, brand recognition, durability, lead time) [17].
		A6.5	Lack of understanding of customer demand patterns related to the innovation [303].
		A6.6	Innovation does not comply with legislation or national industry policies [304].
C7	Risk of incomplete and inaccurate information, including distorted market data	A7.1	Failure to conduct a proper target market analysis [17].
		A7.2	Inability to identify the actual needs of the customer [118].
		A7.3	Problems arising from the feasibility study [305].
C8	Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points	A8.1	Failure to incorporate customer or market research feedback into the innovation process [306].
		A8.2	Innovation does not meet customer expectations [287].
		A8.3	Innovation fails to compete with current technological trends [287].
C9	Material resource risk affects timely delivery of goods	A9.1	Raw material quality does not meet customer requirements or predetermined standards [307].
		A9.2	Unavailability of raw materials during bulk production [307].
		A9.3	Lack of proper procedures for handling rejections and replacements of raw materials [308].
C10	Risk posed by the emergence of new technologies and technological advancements	A10.1	Insufficient market research on innovation trends and competitors [17].
		A10.2	Lack of consideration for upcoming technological advancements in product or service innovation [309].
		A10.3	Negative impacts on the innovation due to lack of

			resources for implementing new technology [310]
C11	Failure to properly align the development, implementation, and output of the entire process, including incomplete project information and communication issues	A11.1	Inaccuracies in defining the overall innovation process [130].
		A11.2	Failure to clearly define each phase of the process with specific instructions [131].
		A11.3	Inadequate determination of the information to be shared at each phase with appropriate personnel [131].
		A11.4	Process issues that hinder meeting required timelines [131].
		A11.5	Process issues that affect achieving the desired innovation quality [303].
		A11.6	Process inefficiencies that prevent achieving cost savings [306].
		A11.7	Failure to identify all relevant stakeholders in the process [132].
		A11.8	Lack of effective communication channels [308].
		A11.9	Failure to share required information and provide access to stakeholders [132].
C12	Lack of a robust risk-control mechanism integrated with the company's development plans, strategies, manpower, and financial investments, including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach	A12.1	Lack of an appropriate evaluation mechanism with necessary control parameters [294].
		A12.2	Ineffective review methods (internal, third-party, or both) [311].
		A12.3	Failure to control the process according to the plan [17].
		A12.4	Inadequate frequency of analyzing control parameters [294].
		A12.5	Failure to identify risks involved in the innovation process [294].
		A12.6	Low success rate of past innovations [309].
C13	Inadequate technical capacity to support innovation	A13.1	Insufficient capacity of machinery and equipment for bulk production [137].

	A13.2	Lack of contingency plans to meet capacity needs (joint venture, subcontracting, collaboration, purchasing, hiring) [312].
	A13.3	Inadequate workforce availability for bulk production [292].
	A13.4	Inaccurate definition of the skills required to complete the innovation [292].
	A13.5	Lack of plans to acquire necessary technical skills [313].
C14	A14.1	Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management
	A14.2	Failure to define the development process for achieving the best product or service [138], [112].
	A14.3	Inability to overcome challenges during development [137], [310].
	A14.4	Failure to conduct development trials [314].
	A14.5	Inability to scale the development process for mass production [113].
		Alternative methods increase costs, lead times, or require special skills and resources [177].

In addition, Questionnaire (QE4), presented in Appendix E, was developed to address the 14 risk factors that increase the likelihood of risks in technological innovations. The questionnaire aims to identify the root causes behind the occurrence of these 14 risk factors as recognized by the textile and apparel industry in Sri Lanka. Questionnaire (QE4) was distributed to industry experts in diverse roles across all departments involved in the innovation process. This broad representation allowed for a comprehensive understanding of the root causes across various levels and areas of expertise within the industry. In addition, structured and semi-structured interviews were conducted with these experts, using Questionnaire (QE4), until the sample outlined in subsection 1.3.4 in Chapter 1(Introduction), was fully covered.

The literature review confirmed the existence of root causes related to these risk factors, further validated by industry experts. Consequently, 65 root causes associated with the 14 risk factors were finalized and summarized in Chapter 4 (Results), subsection 4.6, Table 4.6.

Apart from the risk factors and root causes, there is a notable correlation between the method chosen for innovation and the level of risk inherent in the innovation process. Various approaches, often referred to as innovator types, have been delineated in the literature, encompassing the full spectrum of methods for implementing innovation.

3.10 Different innovator types

Among the different innovator types introduced, the report from Boston Consulting Group introduces, 6 innovator types covering possible approaches to innovations [92]. These approaches include creators, solution builders, leveragers, expanders, defenders, and fast followers have been considered in this study.

Each type of innovator, as outlined in Table 2.2 of Chapter 2 in the Literature, exhibits distinct characteristics and requires a unique set of organizational resources to succeed. Therefore, it is essential to identify the most suitable innovator type for an organization that aligns with its core competencies. This ensures the optimal use of resources and maximizes profits.

Furthermore, this comprehensive understanding aid in formulating a risk prioritization strategy tailored to the organization's chosen innovator type. Additionally, focusing exclusively on a specific innovator type rather than considering a diverse range can lead to more effective innovations with significant growth potential. Moreover, organizations can leverage this insight to identify the next most suitable innovator type, and thereby facilitating business expansion while minimizing risk exposure.

3.10.1 Innovator type of the organization

In determining the innovator type, an organization's proficiency in managing the root causes of technological innovations can serve as a basis that aligns best with its competencies, which need a classification process.

For this task, regression models including decision trees, K Nearest Neighbours (KNN), and ensemble methods such as Random Forests or Gradient Boosting Models were considered, based on the data's nature and interpretability requirements [230],[231]. However, the mentioned methods may fall short in achieving high accuracy when analyzing a broad range of input data. Further, this limitation is significant as inaccuracies stemming from data type mismatches and input/output issues can lead to imprecise predictions, jeopardizing organizational decisions.

In contrast, neural networks, often deemed superior to regression models, excel in handling complex and nonlinear data relationships [232], [233], [234]. Neural Networks can autonomously learn relevant features from data, eliminating the need for manual feature engineering. Additionally, neural networks can adapt to diverse data types and problem domains. Furthermore, Machine Learning (ML) and Deep Learning (DL) are subsets of artificial intelligence (AI) distinguished by their methods, architectures, and applications. DL, a specialized and advanced subset of

ML, relies on neural networks with multiple layers. ML finds applications across various scenarios, including spam filtering, recommendation systems, regression analysis, and classification tasks [235].

Deep learning, particularly deep neural networks, often requires significant computational resources, including specialized hardware [235], making the training process highly intensive. While Bayesian neural networks can yield comparable results as the FFNN. However, their complexity is considerably higher.

Given the smaller dataset and the relatively simpler nature of the classification task, a machine learning approach—specifically, a Feed Forward Neural Network (ML-FFNN)—was chosen. This decision was driven by the industry's preference for a more simplified and less complex model.

The Feed Forward Neural Networks (FFNN) proves useful for estimating data that cannot be separated linearly [236]. Moreover, their characteristics, such as being less affected by noise, possessing good learning ability, exhibiting less complexity, featuring simplified architecture, operating at faster speeds, and being widely used in classification tasks [236], [237], [238], supported the decision. This choice avoids unnecessary complexity and higher computational resource usage, which would be wasteful for the task.

3.10.1.1 Structuring the Neural Network

In this context, 65 root causes associated with 14 technological innovation risk factors were utilized as input for the Neural Network. Furthermore, since the existence of all these root causes was highlighted both in the literature and from the industry, the whole set of root causes has become an optimal number of root causes, to be used as inputs to the Neural Network. Even a minor root cause can lead to substantial failures if the likelihood of the associated risk is significant. The output or targets of the neural network were defined as the six distinct innovator types.

To achieve the desired output, the structure of a Feed Forward Neural Network (FFNN) is developed on the Matlab platform. Questionnaire (QE5), (Appendix F), comprising 65 root causes, was sought to gauge responses aimed at addressing specific innovation-related root causes, which have already been identified. Feedback was collected using a Likert-type scale, and additionally, respondents were asked to specify their innovator type for the already done innovations. Feedback of Questionnaire (QE5) was taken as input data for the Feed Forward Neural Network (FFNN). Table G.1 and Figure G1.1 through Figure G.65 in Appendix G present histograms visualizing the input data obtained from feedback of (QE5).

In terms of data preparation, out of the 89 feedbacks received, 6 had missing values. To resolve this issue, the missing values were replaced with the response "3," representing a moderate response; according to constant imputation. This approach

was chosen to minimize any potential bias towards extremes. While there is no universal rule for data splitting, literature suggests different ratios based on the data size and neural network model. A common ratio of 70/30 for training/testing is often optimal [240]. For datasets ranging from 100 to 1000 samples, a 60/10/30 split for training, validation, and testing, respectively, is recommended [240]. In this study, the dataset (n=89) was divided into 60% for training, 10% for validation, and 30% for testing to ensure an unbiased evaluation of model performance [239].

3.10.1.2 Hidden layers and the nodes

The number of hidden layers, nodes within each hidden layer, and the activation function were adjusted in an iterative process to determine the optimal structure. Through careful evaluation of the accuracy of each option, the neural network architecture yielding the highest accuracy was selected.

3.10.1.3 Output of the Neural Network

An organization's classification into a specific innovator type can be represented using a range from 0.00 to 1.00 across all six innovator types by enabling the model to select six answers. This can be achieved by employing an activation function that produces probabilistic outputs [241]. Figure 3.8 depicts the basic structure of the FFNN, with adjustments made to parameters such as the number of layers, nodes in the hidden layers, and the activation function to maximize accuracy in identifying the organization's innovator type. In the diagram, A1 through A65 represent the inputs to the neural network, which correspond to the 65 root causes related to technological innovations, while A0 represents the bias node. The parameters H1 through Hn denote the hidden nodes, and the six output nodes are designated for the six innovator types.

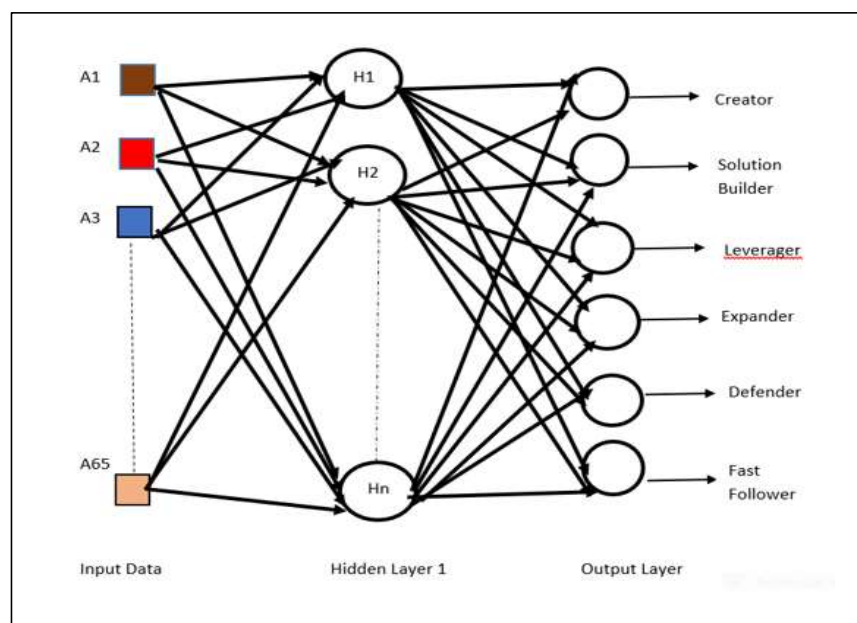


Fig. 3.8: Structure of the FFNN used in classification

Chapter 4 (Results), subsection 4.7 , Tables 4.7 and 4.8 present the summary of different NN architectures tested to select the most appropriate NN configurations and the parameters of the selected model, model 9 to find out the innovator type of the organization respectively. Besides, Table H.1 in Appendix H presents the detailed information on the different NN architectures tried out in achieving this task.

Refining the prioritization of risk factors and root causes has become an important aspect in identifying the urgency of risk mitigation efforts and also identifying which root causes and risk factors to prioritize.

3.11 Priorities of root causes and risk factors

Further, this describes effective and efficient ways of resource utilization, enhancing the full potential of the innovation process. This can be achieved by assessing the priorities of both risk factors according to the innovator type of the organization and the root causes related to each risk factor.

Among the methods introduced in the literature for assessing the priorities of different alternatives, Multi-Criteria Decision Making (MCDM) is a problem-solving technique that helps select the most appropriate alternative by considering multiple criteria [225], [226], [227]. In evaluating MCDM tools, AHP and TOPSIS are commonly used. AHP employs weighted aggregation through pair-wise comparisons and decision-maker preferences, while TOPSIS relies on distance-based calculations. Research shows that both methods are valuable for decision-making in the MADM model, but AHP is often more suitable for cases involving qualitative data and multiple criteria [228].

The interdependencies of the risk factors, as illustrated in Table I.1 in Appendix I, were analyzed and mapped using Graph Theory. The resulting interconnections are presented in Figure I.1 in Appendix I.

Given the interdependencies among risk factors, and recognizing that AHP operates within a hierarchical structure without supporting such interdependencies, the Analytic Network Process (ANP), has been applied. ANP accounts for interactions among factors, leading to a more comprehensive understanding of the problem [167]. Therefore, this study utilizes ANP to evaluate the priorities of risk factors and root causes based on the available data and the specific context [187], [188].

The ANP methodology comprises several key steps [229], facilitated by the Super Decision Software (SDS) for its accuracy, simplicity, and time efficiency [193]. This software simplifies the task by allowing the risk breakdown structure to be entered systematically, one phase of the innovation process and its related risk factors at a time [193]. Furthermore, the consistency of the priorities was validated using the Consistency Ratio (CR) determined by the SDS [190].

3.11.1 Priorities of risk factors related to different innovator types

Deriving priorities involves three steps: First, the problem is structured for use in the Super Decision Software. Second, a weighted super-matrix is created. Third, the super-matrix is used to determine the priorities. Figure 3.9 presents the risk breakdown structure used in the Super Decision Software. C1 through C14 illustrate the risk factors of technological innovations presented in Table 4.5, subsection 4.4 in Chapter 4 (Results)).

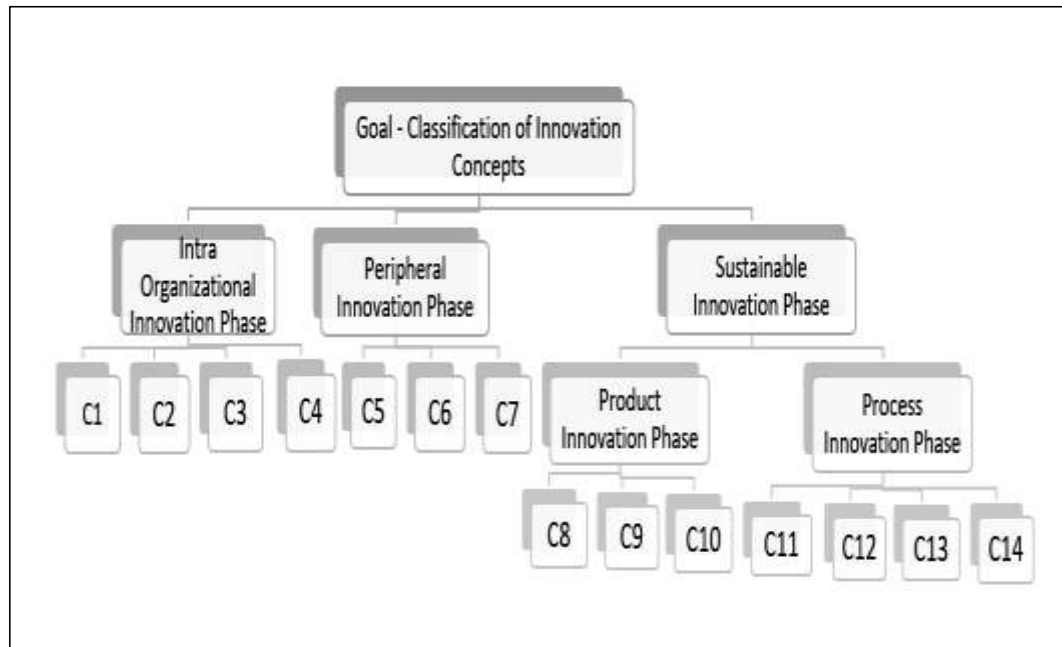


Fig. 3.9: Risk breakdown structure to evaluate priorities

Step 1:

- Decompose the problem into criteria and alternatives for pairwise comparisons and local priority vectors.
- Develop the risk breakdown structure based on classifying risk factors into the main phases of the innovation process (illustrated in Figure 3.2).
- Form clusters for criteria and alternatives, where the main phases of the innovation process (intra-organizational innovation phase through process innovation phase) serve as criteria and corresponding risk factors (C1 through C14, illustrated in Table) as alternatives.
- Organize risks into a network model within Super Decision Software, establishing connections.

Step 2:

- Form a weighted super-matrix from an un-weighted super-matrix through pairwise comparisons [193],[229].
- Determine the intensity of pairwise comparisons based on feedback from structured and semi-structured interviews with industry experts (Section 3.9) and previous research.
- Perform pairwise comparisons at cluster and node levels, comparing alternatives with criteria and vice versa [193].
- Calculate consistency of priorities within SDS.

Step 3:

- Perform super-matrix formation and transformation within SDS.
- Capture priorities from pairwise comparisons in an un-weighted super-matrix.
- Create a weighted super matrix by multiplying the un-weighted super-matrix by cluster weights.
- Use the limit super-matrix to determine priorities by increasing the weighted super-matrix to powers until convergence [193].
- Repeat the procedure for all six innovator types.

How the priorities of different risk factors changed according to the innovator type of the organization is illustrated in Chapter 4 (Results), subsection 4.8, Table 4.9.

In addition, understanding the priorities of root causes associated with each risk factor enhances comprehensive decision-making.

3.11.2 Priorities of root causes on risk factors

Following the same procedural steps outlined in the immediate section 3.10.1, the risk breakdown structure illustrated in Figure 3.10 was developed by reorganizing the risk factors and root causes as detailed in Chapter 4 (Results), subsection 4.6, Table 4.6. The sub-models, highlighted in red rectangles, were inputted into the Super Decisions software, comprising clusters, nodes, and alternatives necessary for analysis. In Figure 3.10, C1 through C14 denote distinct clusters within the risk breakdown structure, specifically technological innovation risk factors; N1.1 through N14.2 denote Nodes associated with each cluster, and A1.1 through A14.5 denote the alternatives, consisting of root causes. Table J.1 in Appendix J provides abbreviations for all elements in Figure 3.10, along with the risk factors and root causes illustrated in Table 4.6 (Chapter 4 – Results, Subsection 4.6).

Pairwise comparisons were conducted based on insights gathered from industry experts through structured and semi-structured interviews, referring to the Questionnaire (QE6) included in Appendix J, which covers the sample size.

Chapter 4 (Results), subsection 4.9, Figures 4.12 through 4.25 present the priorities of root causes related to 14 risk factors. In-addition, Table 3 in Appendix K presents the summary of priorities corresponding to root causes of 14 risk factors.

However, limitations were encountered with the methods used in developing a risk management model. This underscores the need to explore alternative approaches to the task.

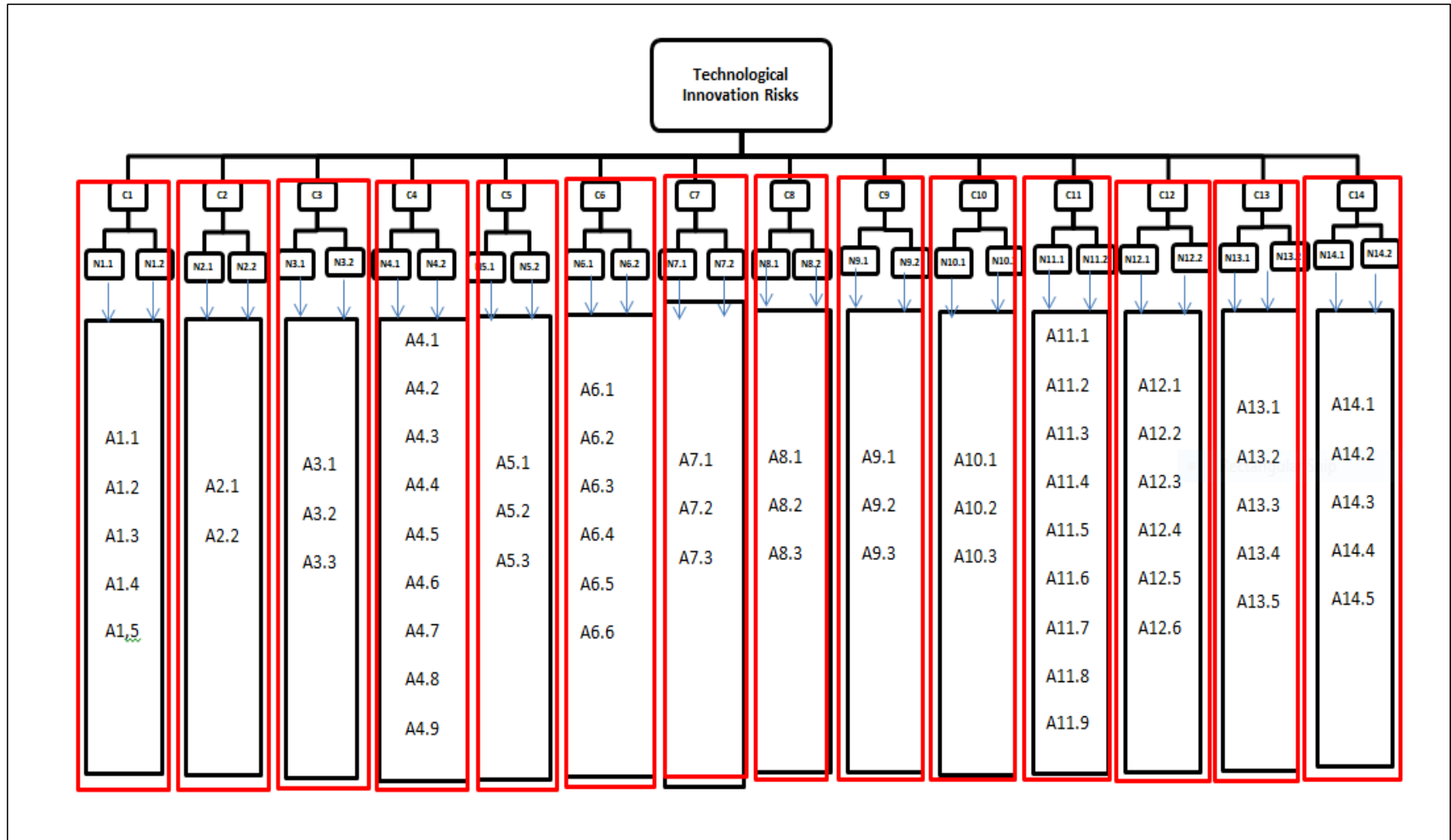


Fig.3.10: Breakdown structure of the technological innovation risk factors and root cause

3.12 Limitations in developing a customized risk management model

Recognizing the limitations of a one-size-fits-all risk management model, especially given the diverse resource availability and organizational competencies across entities, a decision was taken to develop a customized risk management model.

In the pursuit of designing a comprehensive risk management model covering the entire innovation process, various approaches were explored. Initially, efforts were directed towards managing risks associated with core innovation concepts, aiming to address overall risk. However, industry reluctance to disclose critical and confidential information on management and marketing innovations necessitated a shift towards focusing solely on technological innovations. Efforts to predict potential risks and their root causes accurately led to the exploration of inferential statistical methods. While regression models were commonly employed for such predictions, their practicality was hindered by data limitations. Despite efforts to locate a comprehensive training dataset tailored to the required information for model development within the industry's repository, none could be found. Consequently, the absence of an appropriate statistical method rendered this approach infeasible, prompting an exploration of alternative methodologies diverging from traditional statistical techniques.

Subsequently, neural networks were considered to identify the organization's innovator type and quantify associated risks. Although the first step, identifying innovator types, was completed, quantifying risk proved challenging due to a lack of historical data necessary to prepare a test dataset. The absence of consistent data derived from the same basis hindered this effort. Consequently, a generalized risk management strategy was deemed inadequate for effectively addressing the specific risks at hand, necessitating the derivation of an approach free from these constraints.

3.13 The rationale for the risk management model

Risk management strategies cannot be generalized because risks and their levels vary not just between organizations, but also across different products. The degree of risk is intricately linked to the objectives that drive an organization's existence. Factors such as human resources, financial strength, leadership proficiency, supplier expertise, contractual agreements, and brand reputation play significant roles in shaping an organization's risk appetite [242]. Furthermore, how organizations perceive, evaluate, and respond to risks varies widely, impacting their risk acceptance behavior [243]. Therefore, it is essential to develop customized risk management strategies that are tailored to both the unique characteristics of the product and the overarching goals of the organization. This tailored approach is critical for realizing the most favorable outcomes in the innovation process. Creating such strategies necessitates a thorough

understanding of the organization's innovation objectives and strategies, available investments, leadership competencies, marketing plans, human resource strategies, customer communication, supplier relationships, and specific research and development initiatives pertinent to the product. It is worth noting that these crucial factors are often treated as confidential, as organizations are generally reluctant to disclose sensitive information to third parties. Thus, there is a pressing need to develop an internal model that empowers teams to craft robust risk management strategies specific to the product while safeguarding the confidentiality of sensitive information, In response to the constraints outlined in section 3.12.1, the focus shifted towards leveraging Game Theory concepts. Game Theory elucidates decision-making in intricate settings, encompassing strategies to maximize payoffs, minimize costs, navigate group dynamics, and understand human behavior [194], [195], since these insights are essential in driving forward the organizational innovation process.

Following an extensive analysis of these principles, core concepts from Cooperative Game Theory, Behavioral Game Theory, a collaborative approach, psychological decision-making, and board game dynamics were integrated into the risk management model. This comprehensive model effectively addresses the identified requirements throughout the entire risk management process. Building on the applied concepts, this model follows the idea of coalition formation in cooperative game theory to achieve the best possible outcome, rather than insisting on a complete 100% coalition [197]. However, proving strict coalition formation mathematically is challenging because game theory models often require extensive mathematical validation. Additionally, the industry's reluctance to share information on financial payoffs makes such proof impractical. In addition, integrating elements of Behavioral Game Theory addresses the aspect of rationality within Game Theory by acknowledging the complexities of human behavior and decision-making processes. Further, cooperative behavior enhances team cohesiveness and decision-making ability.

Moreover, the size of the group has a significant impact on the effectiveness of the decisions made. Consequently, the game's methodology, which forms the base of the risk management model, has been designed to ensure game comprises smaller, tightly-knit units. This deliberate choice is rooted in the understanding that collective decisions tend to be more accurate than individual ones [249]. Moreover, the decision-making process becomes increasingly challenging in larger groups, with optimal effectiveness typically achieved in groups of up to 12 individuals [250]. Extensive research further supports the notion that small to intermediate-sized groups consistently outperform larger groups in terms of decision accuracy. By forming smaller groups, the game maximizes decision effectiveness and accuracy, thereby fortifying the risk management model and ensuring its robustness [251].

The risk management model has been developed as a board game, a hot topic in many scientific studies [244]. Visualizing problems through board games enhances the

robustness of decisions. Since then, researchers have found that the board gaming approach is interconnected with human psychology [245]. The board games reflect one's intelligence, skills, wisdom, and even tricky behavior in making strategic decisions [245], [246]. Further, board games are fairly simple as the core mechanisms are transparent, and even a layman can swiftly grab the way the game plays. Since the player will be given all the risk-related technical knowledge to find perspectives to formulate a highly effective solution.

In addition, players will be psychologically convincing that they would play a game, instead of striving to find a solution to a complex issue, they face. This brings out flexible and creative approaches which are crucial in effective decision-making [247]. In addition, considering the functions of the brain, each side of the brain has distinct functions where the right side of the brain is more visual, creative, and intuitive while the left brain is more verbal, orderly, and analytic. Visual representation with the use of a game board helps engage both the left and right hemispheres of the brain which is significant in creating a better risk management strategy. In addition, it is found that board games keep the brain sharper, which maximizes the accuracy of the decisions [248].

3.13.1 Methodology for forming the game

The game serves as a strategic tool for managing 14 risk factors associated with the technological innovation process, by managing the corresponding root causes of these 14 risk factors. The game comprises players, a game board, resources used to manage risks, and game pieces for the gameplay. The risk management model has been developed in the form of a game. It consists of 3 main phases including the pitch-making phase, the kick-start phase, and managing the unsolved risk factors, as illustrated in Figure 3.11.

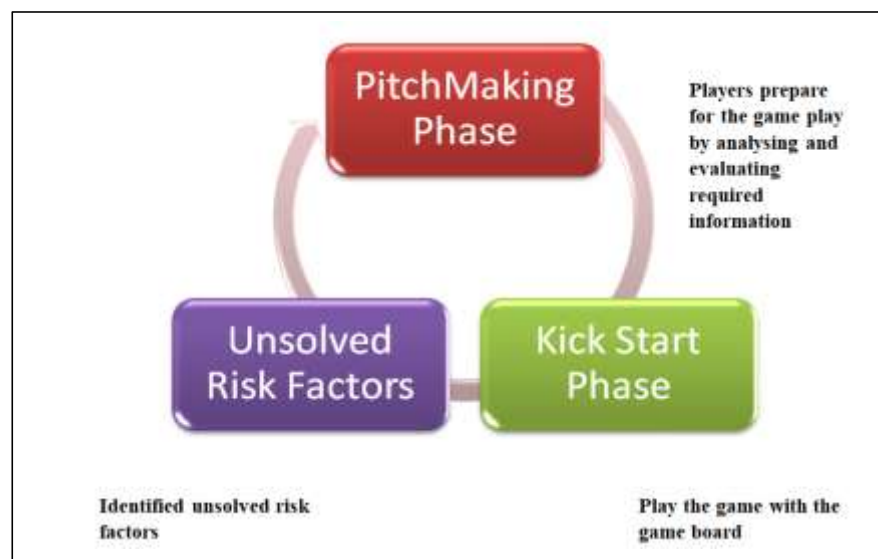


Fig. 3.11: Main phases of the risk management model

In this initiative, players comprising members from various departments actively engage in a game designed to tackle 14 distinct risk factors inherent in technological innovations, as outlined in Chapter 4 (Results), sub section 4.6, Table 4.6 in. Each risk factor is meticulously handled by a specialized team responsible of managing its root causes. To illustrate, consider the second risk factor from Table 4.6: “The Company’s long-term goals are not aligned with its innovation strategy.” This issue arises from two root causes: (1) Innovation planning that fails to consider the company’s long-term goals, and (2) A lack of necessary resources to develop innovation ideas that align with these long-term goals. As detailed in Table 3 in the guide book included in Appendix K, which provides a general idea of the departments responsible for solving root causes, the Senior Management team is responsible for managing the first root cause by integrating long-term goals into innovation planning. Meanwhile, departments such as Finance, R&D, HR, Merchandising, Marketing, Production, and Supply Chain are responsible for addressing the second root cause by ensuring the availability of strengths and resources needed to align innovation efforts with the company’s long-term objectives. However, the departments involved in managing risk factors may differ from one organization to another. Hence, teams can be formed based on individuals performing similar functions, irrespective of departmental labels. For instance, while one organization may have a dedicated merchandising department responsible for supplier orders, another organization may assign this responsibility to its supply chain management department. In both cases, despite the different departmental labels, the functional roles are similar.

Additionally, due to the varying number of root causes associated with each risk factor, the composition of teams may differ in terms of the number of participants. This flexibility ensures that the effectiveness of the gaming process remains unhindered by uniform team sizes. Players engage with the game board to solve the risk factors linked to the organization's technological innovation. Figure 3.12 depicts the game board, comprising 14 unit cells, with each cell representing one of the 14 risk factors associated with technological innovations.

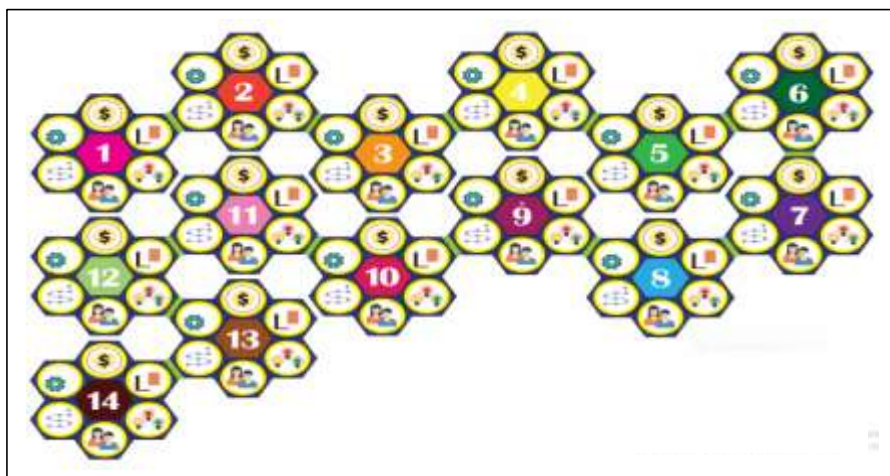


Fig. 3.12: The game board

Moreover, in the realm of operations management, priority was given to primary factors that may disrupt the manufacturing process [217]. Consequently, various combinations of the 7M's (Money, Man, Material, Method, Machine, Management, and Minutes) were evaluated [252]. Money, Man, Material, Method, and Machine were selected for inclusion on the game board as these mechanisms are vital for addressing the risks inherent in innovation and manufacturing processes. While Management and Minutes are also critical factors within the 7M's framework, Minutes were omitted under the assumption that they would inherently contribute to the innovation process. Risk management necessitates the most controlled approach, thereby automatically minimizing the significance of the Minutes factor.

Furthermore, despite Man and Management representing both indirect and direct labour, only one plot is assigned to them to simplify the game's complexity. This streamlined approach enables users to readily identify which factor to consider for each relevant risk factor based on the root causes. Money, Man, Material, Method, and Machine serve as common mechanisms for analyzing and managing root causes. Additionally, evaluating the risks associated with these factors in the context of innovation is crucial for refining the approach further. Figure 3.13 illustrates the key mechanisms of a unit cell: Money, Man, Material, Method, and Machine, which drive the game. Additionally, it includes an indicator representing the current risk level associated with these mechanisms. This risk level reflects the degree of risk based on the availability of key mechanisms and the effectiveness of managing related risks. Each mechanism has been assigned a unique symbol for easy identification, although these symbols are not standard.

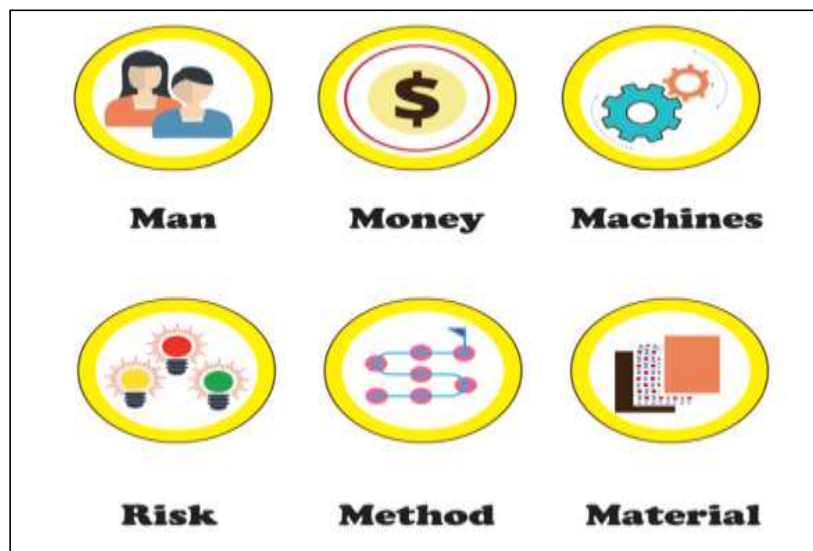


Fig. 3.13: Symbols of the key mechanisms

The unit cell of the game board, depicted in Figure 3.14 was designed including the key mechanisms of Man, Money, Machine, Method, Material and the Risk level

related to these mechanisms. Since these are the critical factors impacting the innovation process. Within each unit cell, strategic mechanisms are integrated to effectively address the root causes of potential risks. These decisions are informed by primary factors identified in operations management, ensuring resilience against disruptions in the manufacturing process [217]. Thus, the unit cell stands as a testament to proactive risk management and operational efficiency in the pursuit of successful innovation.



Fig. 3.14: Unit cell of the Game board

The game pieces, shown in Figure 3.15, are used to play the game on the game board. They represent the key mechanisms, including Man, Money, Machine, Material, Method, and Risk level. Players can place the game pieces in the relevant space on the unit cell. To quantify the results, these factors are assigned unit values based on the number of corresponding game pieces present on the game board. In addition, the game pieces are color-coded, with green indicating an excess of a particular resource and red signaling a deficiency. This color scheme aids teams in making informed decisions during gameplay by providing clear visual cues about the availability of resources.

Elaborating more on game pieces, Money required for innovation can be acquired through various methods represented by game pieces [253]. These methods include company investments, joint ventures, partnerships, loans, mortgages, and other funding sources, each of which can be indicated by flags fixed separately to the game pieces. The next resource Man, represents different levels of the organizational workforce involved in the innovation process.

However, the game pieces representing 'Machine,' 'Method and 'Material' are highly dependent on the specific innovation being undertaken. Since materials, methods and machine requirements vary according to the product. In accommodating this variability, customized game pieces can be utilized, with relevant information fixed to

each piece separately. This allows for greater adaptability and ensures that the game accurately reflects the unique requirements of each innovation scenario.



Fig. 3.15: Game pieces

The literature presents various risk levels associated with innovation processes [254], which can be estimated by taking the products of the severity and likelihood levels [255]. Mapping the risk to the corresponding risk level is a significant way to influence decision-making and can be used to determine the risk prioritization plan. Risk levels were classified into four different levels since having more risk levels is essential for obtaining sufficient resolution in the outcome [256].

Risk levels encompass Low, Moderate, High, and Extreme risks, each demanding varying degrees of attention and action. Low risks, though minimal in impact, remain significant and should be addressed post-mitigation of major risks. Moderate risks represent mid-level concerns crucial for maintaining project deliverable quality. High risks require prompt attention but are comparatively less severe than extreme risks, which are high-priority and demand immediate responses.

Apart from the elements in the game board, severity and likelihood levels of risks too need to be determined during the game to assess the risk levels. Severity, which is the highest level of damage possible due to an occurrence of a risk, needs an appropriate scale to assign ranks to identify the different levels. An ordinal scale has been used for ranking severity, as severity expresses a non-mathematical idea with a clear rank order but does not have an even distribution. Severity levels have been divided into five categories according to their severity levels. This includes 1 for Negligible, 2 for Minor, 3 for Moderate, and 4 for Major, and 5 for Catastrophic [255].

Differentiating between various levels of severity of risk events is needed in the game. A negligible risk event poses little to no impact on achieving organizational goals, resulting in minor repercussions for clients, the organization, and the workforce. Similarly, a minor risk event also entails minimal impact on organizational goals, with minor repercussions across stakeholders. Moving up the scale, a moderate risk event signifies a moderate impact on organizational goals, potentially leading to client losses, minor complaints, or penalties, in other words, not posing serious threats to the workforce. A major risk event significantly affects achieving organizational goals, potentially causing the loss of important clients, legal issues, and serious workforce challenges. At the top of the hierarchy, a catastrophic risk event carries severe consequences, including substantial financial losses, loss of major clients, and critical impacts on the workforce, making it imperative for organizations to address such risks with utmost urgency and attention.

Likelihood, which is the probability of a particular risk occurring [255] can be expressed as a probability value, rating, or frequency. Considering the simplicity, likelihood is determined as frequencies. Further, this approach uses an ordinal scale, facilitating easier interpretation compared to numerical values and providing support when explicit quantification is not feasible [256]. Likelihood levels have been classified into 5 groups, which include: 1- Rare (for the events unlikely to happen), 2 - Unlikely (for the events that may occur occasionally), 3 - Possible (for the events likely to occur sometimes), 4 - Likely (for the events more likely to occur several times), and 5 - Almost certain (for the events most certain to occur frequently).

The other important factor is determining the risk tolerance level, which an organization can accept for an individual risk [256] to take necessary actions on different risk levels. The risk tolerance level depends on the type of industry, objectives, financial strength, available resources, and the risk absorption level of the organization.

To ensure effective engagement in the game, a moderator will provide all team members with instructions on how to play. Additionally, each team must possess game pieces representing key mechanisms and risk levels. Teams will assign unit values to these game pieces, representing resources, to facilitate gameplay. Each team will receive a game card detailing the risk factors they need to address, along with related root causes and their priorities. This information is aided by pre-evaluated data.

Moreover, each of the 14 teams will be provided with a checklist titled "Pitch-making meeting checklist," as illustrated in Figure 3.16. This checklist is designed to guide the teams through the initial analysis of the innovation, resource requirements, and resource availability. It comprises 10 distinct points aimed at stimulating brainstorming and covering critical aspects related to the innovation being developed. These points include assessing risk levels based on severity and likelihood, conducting a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) to evaluate the

innovation's position, determining risk tolerance, exploring factors that could mitigate risks, and devising strategies to address them. Furthermore, the SWOT analysis serves as a powerful risk management tool, enabling teams to assess the organization's current position and identify potential blind spots before formulating a new strategy. Integrating SWOT analysis into the risk management strategy is crucial for achieving strategic objective [257],[258].

Pitch Making Meeting Check List
Risk factor:
1. What could go wrong?
2. How severe is the risk and the criteria to assess severity?
3. What is the worst-case scenario?
4. How likely is the risk to occur and criteria to assess the likelihood?
5. What is the risk tolerance?
6. Strengths and Weaknesses of the innovation
7. Efforts to combat
8. Threats and opportunities of the innovation
9. What could prevent this from happening?

Fig. 3.16: Checklist of the pitch-making meeting

3.14 The risk management model

The risk management model has been developed with three main phases, as illustrated in Figure 3.11. Each phase is further divided into multiple sub-phases, detailed in Figure 3.17.

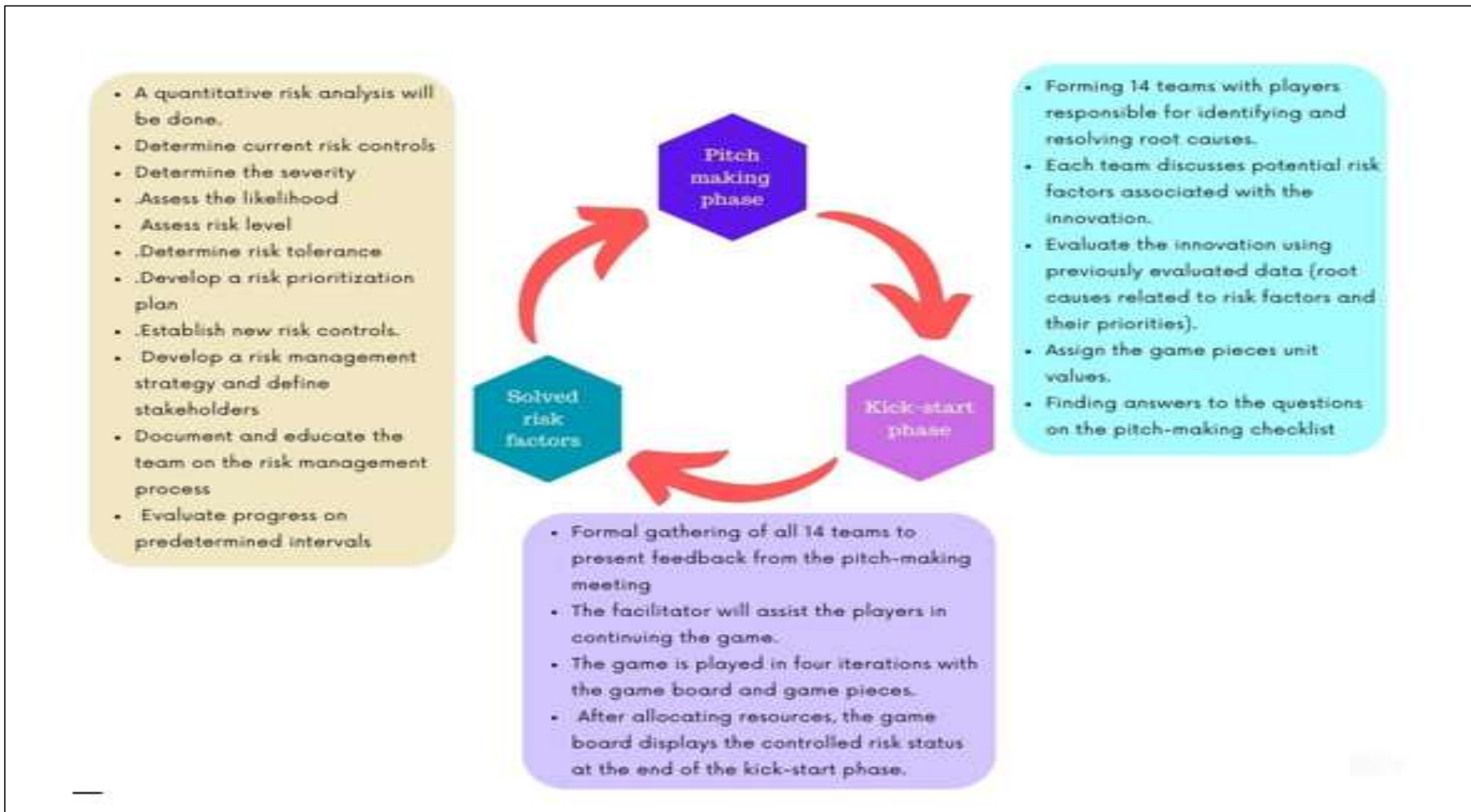


Fig. 3.17: Breakdown of main processes related to each phase of the risk management model

3.14.1 Pitch Making Phase

The Pitch-Making phase, illustrated in Figure 3.17, is dedicated to equipping players with essential game tools. A facilitator, proficient in the gaming process, is assigned to guide and ensure smooth progress throughout the game.

Fourteen teams, each comprised of members from different departments, need to be formed. Their main goal is to address the root causes associated with fourteen specific risk factors.

To aid in this task, each team receives a game card that details the specific risk factor to be addressed, the associated root causes, and their prioritization. Providing the root causes ensures that teams do not overlook any critical issues related to the risk factor, while prioritization helps teams understand the order of importance for addressing these root causes. This approach ensures a comprehensive understanding necessary for effective risk management. However, the specifics of the game card may vary between organizations based on their resource availability. The information (root causes and their priorities) related to game cards of 14 risk factors was illustrated in Table 3 in the guide book attached to Appendix K. Further, information included in each of the game card has been highlighted in the Table 1.

Additionally, a pitch-making meeting checklist is provided to facilitate a thorough analysis of the innovation. This tool assists the teams in conducting a detailed examination of the innovation, guiding them through the process step by step.

During discussions, players contribute ideas and expertise in identifying risk factors, root causes, and resource requirements aligned with organizational objectives and available resources. The aim is to pinpoint gaps in resources (money, manpower, methods, machines, and materials) required to progress with the innovation. Through negotiation, questioning, reasoning, and collaboration, players address checklist questions shown in Figure 3.16, facilitating better understanding and consideration of all potential outcomes, including risks and opportunities. Each team follows the same procedure independently.

3.14.2 Kick Start Phase

As illustrated in Figure 3.17, the game commences with a formal meeting where the results of the pitch-making session are presented to all 14 teams. This meeting serves to provide teams with a comprehensive understanding of the innovation, its consequences, and the impact of all 14 risk factors and root causes on innovation. Teams discuss strategies to improve weaknesses, leverage strengths, and allocate resources effectively.

The Kick Start Phase comprises of four steps, each introducing a group's resource allocation plan and associated risks. Following this, a session is held to share opinions on effective resource utilization and develop the best risk management plan for the

planned innovation. The game unfolds over four steps, allowing for thorough exploration and refinement of strategies.

Step 1: Each team strategically places game pieces on the corresponding slots of the game board, representing resource allocation and analysing the project's current status.

Step 2: Teams explain their decisions from the first step and introduce their interests and action plans. This process repeats sequentially for each team.

Step 3: Teams exchange views on each other's resource allocation plans. For example, teams 2 to 14 share thoughts about team 1's resource allocation plan. This allows for diverse perspectives and more effective resource allocations for the entire team and project.

Step 4: Resource allocation plans are adjusted based on agreed-upon actions from the third step, aiming for a better payoff for the organization as a whole. The game board now represents the controlled risk status after effective resource allocations.

Some risk factors may persist even after the kick-start phase. The third phase, Unresolved Risk Factors, is dedicated to managing these persistent risks.

3.14.3 Unsolved risk factors

Unsolved risk factors related to technological innovation are addressed in the third phase of the risk management model, as illustrated in Figure 3.17. This phase involves a quantitative analysis of the risks to determine the best-fitting risk management strategy for unsolved risk factors, thereby managing the total risk of technological innovations.

The main functions of this phase include identifying current risk controls, evaluating severity and likelihood to estimate risk level, determining risk tolerance, establishing the risk prioritization plan, defining new risk controls and the risk management strategy, and documenting the risk management process while educating the team.

The game uses a risk matrix to assess risk levels and establish a risk prioritization plan within the risk management process. An ordinal scale was chosen to represent consequences and likelihoods, facilitating interpretation even for people with less experience on this [260]. Since, interpreting results on an ordinal scale is simpler than dealing with numerical values, especially when explicit quantification is not feasible [260]. This approach enhances the usability and accessibility of the risk matrix across diverse stakeholders.

The risk levels of the remaining risk factors are assessed using the risk matrix. Figure 3.18 illustrates the criteria for assessing the risk level of a specific risk factor using the

risk matrix. In this illustration, the risk level of a risk factor, with Severity 3 and Likelihood 2, is 6. Numbers inside the matrix represent the risk levels.

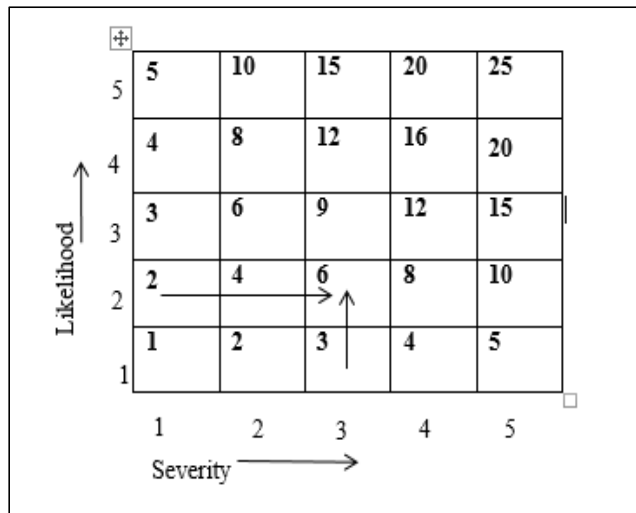


Fig. 3.18: Assessing risk level with risk matrix

To enhance resolution in risk prioritization, additional risk levels are deemed necessary. Industry experts and literature support the use of a 5x5 risk matrix, which serves as a screening tool in risk management activities. Discussions with industry experts led to the adoption of a 5x5 risk matrix with specific color patterns, as depicted in Figure 3.18, to aid intuitive risk prioritization decision-making [261].

Furthermore, different risk levels can be managed through Accepting, Avoiding, Mitigating, or Transferring. This involves defining boundaries for each level, which may vary depending on the resources of the organization. Figure 3.19 illustrates the necessity for organizations to establish these boundaries, marked with blue arrows. This defines the middle value of severity and likelihood scales, which an organization can tolerate for a particular risk level. This connects the different risk levels with actions of accepting, avoiding, mitigating, or transferring the risk.

Furthermore, this decision is solely depend on the risk tolerance levels of the organization. By doing so, organizations can tailor a risk management approach to the four specified risk levels with four different colors for easy identification.

Key to the color codes include,

- Low Risks
- High Risks
- Moderate Risks
- Extremely High Risks

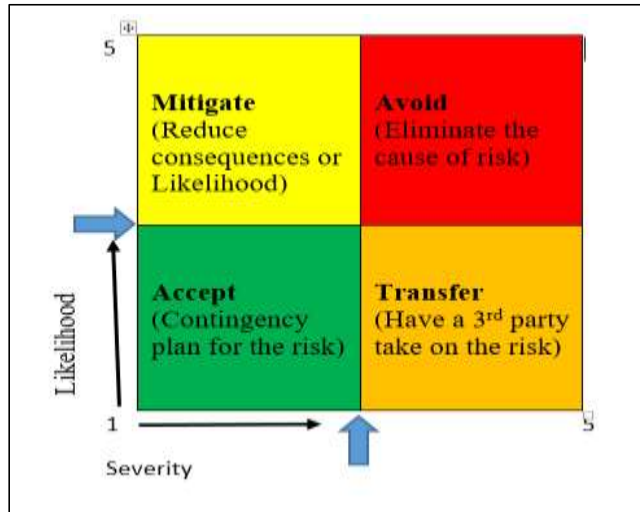


Fig. 3.19: Four risk levels and their boundaries

Hence, in developing the risk matrix with different risk levels, team can colour the risk matrix with different colors to visualize risk levels, and this is again subjective to vary according to the resource availability of the organization. Hence, organizations have to decide on the boundaries or the risk levels corresponding to 4 risk levels. Figure 3.20 illustrates different risk levels referring to the key to the color codes to identify risk levels.

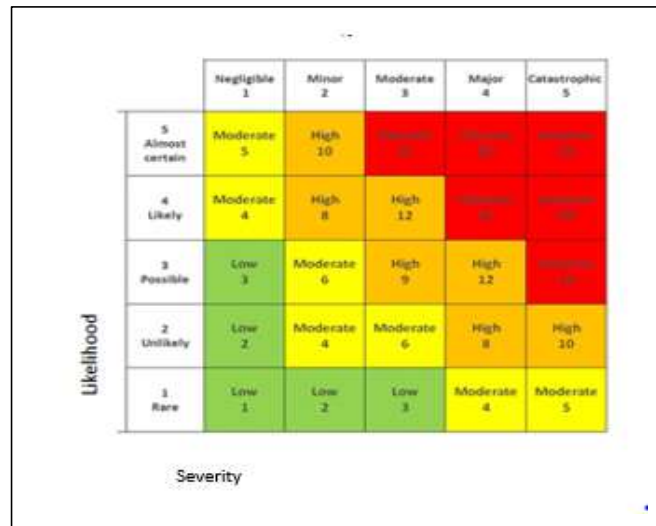


Fig. 3.20: Risk matrix with different risk levels

As the next step, developing the risk prioritization plan helps to decide which risks need prior attention. This can be done based on the risk matrix with different risk levels. Through risk prioritization, the team determines the basis for resource allocation and manages the realization of risk events with either high severity or high probability of occurrence.

A risk prioritization matrix can be set up to give extra weight to consequences than the likelihood. This is because, severity is more important than the likelihood of the risks with the same risk levels, as introduced in the literature [261]. Figure 3.22 illustrates a generalized risk prioritization matrix, where “P1” represents the most prioritized risk while “P25” represents the least.

In managing different risk priorities, a generalized risk prioritization plan incorporating priority numbers with the risk levels has been illustrated in Figure 3.21. However, the team needs to decide on the most effective and efficient risk prioritization plan to manage different risk levels. Which risks to be accepted, avoided, mitigated, or transferred may vary according to the risk management criteria selected by the organization. Colours of the risk prioritization matrix shown in Figure 3.22 can be incorporated with the risk management actions for each risk factor corresponding to each risk level.

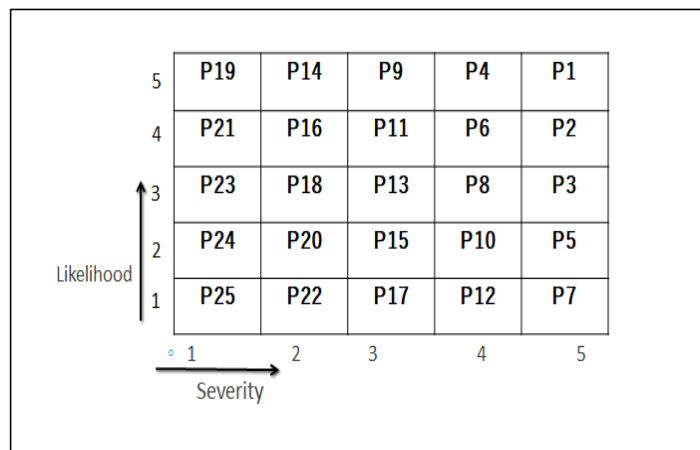


Fig. 3.21: Risk Prioritization matrix

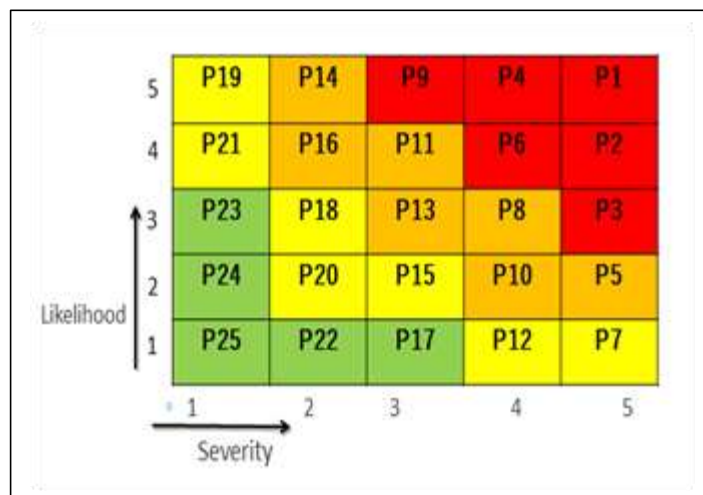


Fig. 3.22: Risk prioritization and management

Once the risk prioritization matrix has been crafted, the next step involves refining risk controls tailored to the identified risk factors. Before implementing new controls, it's imperative to assess the effectiveness of existing ones. Current risk controls are the activities already taken to detect, prevent or mitigate the risks involved. They can be categorized into 3 main groups: effective controls, ineffective controls and controls neither effective nor ineffective. This evaluation ensures that redundant or ineffective controls are identified and eliminated, optimizing the risk management process for efficiency and effectiveness.

Apart from this, the new controls, put in place to manage the available risks need to be tested for their effectiveness. Thus, it is required to create a corrective plan for the controls having deficiencies. Taking into account these considerations, the risk management strategy is formulated, encompassing,

- Clear introduction to the risks
- Action plans
- Stakeholders of the actions
- Clear instructions on the risk assessment method
- Time intervals to review and monitor the process
- Assumptions made during the process
- Limitations of the risk management strategy

The subsequent step entails documenting the risk management process and educating the team on the risk management strategy, along with delineating the actions to be taken. This is followed by monitoring and reviewing the process at predefined intervals. As risk management is an iterative process, the team must continuously monitor and review it to achieve continuous improvement in the risk management model. Additionally, to enhance the overall risk management strategy, maintaining a risk register, which is used to record all the risks occurred is crucial. This register aids in identifying both new and existing risks, suggesting changes to controls, assessing the effectiveness of risk evaluation methods, establishing timelines for monitoring and reviewing processes, and refining the risk management strategy as necessary.

Ultimately, when all 14 teams synergistically work towards the shared goal of organizational innovation, the game reaches its pinnacle. To reach this conclusive stage, it's imperative to allocate resources effectively and efficiently across the 14 teams and implement comprehensive action plans for managing the 14 risk factors associated with technological innovation.

As it's typically impossible to eliminate all risks in full, residual risks persist within the innovation process even after implementing control measures. These residual risks can be quantified by determining the variance between the "Risk level before applying control measures" and the "Risk level after applying control measures." These values are derived using the risk matrix, which assesses risk levels based on severity and likelihood values, as outlined in Figure 3.23.

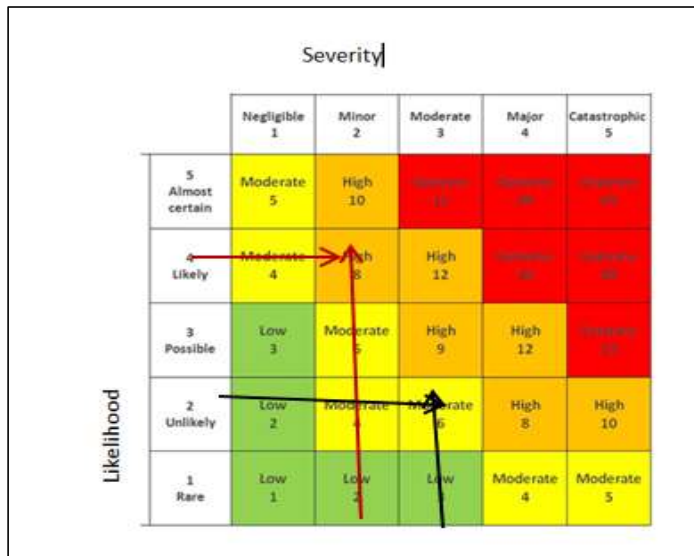


Fig. 3.23: How to define risk levels

Residual Risk Reduction = (Risk level before applying control measures – Risk level after applying control measures)

Risk level before applying control measures = $(2 \times 4) = 8$ →

Risk level after applying control measures = $(3 \times 2) = 6$ →

Residual Risk Reduction = $(8 - 6) = 2$

In this example, by following the implementation of control measures, there is typically a decrease in the overall risk level.

However, it's crucial to sustain the monitoring and reviewing process to identify further action plans aimed at minimizing any remaining risks. This entails establishing a new risk prioritization plan, devising additional risk controls, and refining the risk management strategies to effectively address evolving risks.

A comprehensive user guide titled "The Game Changer" will be supplied to aid in customizing and adopting the risk management model to align with the unique requirements of organizations. This guide, attached to Appendix K, aptly named after the game itself, will serve as a valuable resource, ensuring a thorough understanding of the process and facilitating its seamless integration into organizational frameworks.

3.15 Validation of the risk management model

The risk management model was presented to 5 industry experts, representing 3 key apparel manufacturers in the textile and apparel industry. Amendments done were presented in Chapter 4 (Results), subsection 4.11.1.

In addition, given that this methodology is entirely dependent on user interactions. Therefore, it is crucial to guarantee that this system's usability falls within the acceptable range for both design and human factor validations. From the available

methods to find out usability, System Usability Scale (SUS) has been selected for the research, since this is more of a process design methodology with a user-centered approach and the SUS is the most common and effective design validation technique used to confirm the usability of products and services [212]. The standard System Usability Scale (SUS) questionnaire was distributed to five industry experts for evaluation. Given that the minimum recommended sample size for validating SUS is two participants [214], the feedback from these experts is sufficient for a meaningful assessment.

The full questionnaire, (Table L.1 of Appendix L), interpretation of System Usability Score (Table L.2 in Appendix L), calculation steps, and individual System Usability Score (Table L.3 in Appendix L) were included in Appendix L. Further, the Average score and the interpretation of the result were presented in Chapter 4 (Results). , subsection 4.11.2

CHAPTER 4

RESULTS AND DISCUSSION

This chapter delineates the outcomes of the conducted research. Below, a concise summary of the primary findings is provided.

- Inter-connections of different innovation concepts
- Visualization of inter-connections of innovation concepts
- Classification of innovation concepts
- Validation of consistency of classification
- Statistical validation of consistency of classification
- Deriving core innovation concepts
- Classification of risk factors into main phases of innovation process
- Classification of innovation concepts
- Validation of consistency of risk factor classification
- Root causes associated with technological innovation risk factors
- Innovator type of the organization
- Assessing priorities of risk factors related to different innovator types
- Assessing priorities of root causes related to each risk factor
- Risk management model for technological innovations in textile and apparel industry
- Risk management model presents to organization
- Validation of the risk management model
- Feedback of the industry validation process
- Validation of the risk management model with System Usability Scale
- Discussion

4.1 Inter-connections of different innovation concepts

Table 4.1 summarizes 21 innovation concepts introduced in the literature and illustrates their inter-connections with other innovation concepts.

TABLE 4.1: INTER-CONNECTIONS OF INNOVATION CONCEPTS

Innovation Concept	Inter-connections of innovation concepts
Product innovation	Technology, strategy, culture, human resource, business model, enterprise, management, life cycle, organizational, cooperative, ecological, resource, green, marketing, process innovations
Process innovation	Technology, strategy, culture, human resource, business model, enterprise, management, life cycle, organizational, cooperative, ecological, resource, green, marketing, product innovations
Technological innovation	Product, process, service, regional indigenous, user, business model, life cycle, enterprise, system, green, ecological, marketing, strategy, management, institution, organizational, culture, cooperative, human resource, ecological, green innovations
Service innovation	Technology, strategy, culture, human resource, business model, enterprise, management, life cycle, organizational, cooperative, ecological, resource, green, marketing, process innovations
Enterprise innovation	System, marketing, cooperative, technology and human resource innovations
System innovation	Technological innovation
Regional indigenous innovation	Technology, human resource, and strategy innovations
Green innovation	Technology, product, process, service, marketing, strategy and management innovations
Ecological innovation	Technology, product, process, service, marketing, strategy and management innovations
Marketing innovation	Process, product, technology, service, enterprise, user, strategy, business model, human resource and life cycle innovations
User innovation	Marketing, product and service innovations
Strategy innovation	Marketing, management, institutional, organizational, cultural, cooperative, and human resource, business model, product, process, technological, service, regional indigenous innovations
Management innovation	Organizational, culture, enterprise, marketing, human resource, and institutional, strategy, technology, product, process, service innovations
Institution innovation	technology, marketing, organizational, cultural, cooperative, and human resource innovations
Organizational innovation	technology, marketing, institutional, cultural, human resource, business model, life cycle, cooperative, product, process, and service innovations

Culture innovation	Technological, marketing, strategy, management, institutional, cooperative, and human resource innovations
Cooperative innovation	Technology, strategy, management, human resource, and enterprise innovations
Human Resource Management innovation	Product, process, service, regional indigenous, user, business model, life cycle, enterprise, system, green, ecological, marketing, strategy, management, institution, organizational, culture, cooperative, Technology, ecological, green innovations
Business model innovation	Product, process, service, Technology, marketing, and strategy innovations
Life cycle innovation	Marketing, product, service, and user innovations
Resource innovation	Technology, product, process, service, green, ecological and human resource innovations

4.1.1 Visualization of inter-connections of innovation concepts

Figure 4.1 illustrates the inter-connections of 21 innovation concepts identified in the literature, as analyzed using Graph Theory.

Figure 4.1 demonstrates that each innovation concept is interconnected with at least three or more other innovation concepts. This underscores the interdependent nature of innovation concepts, highlighting that they cannot be viewed in isolation but are rather intricately linked to one another.

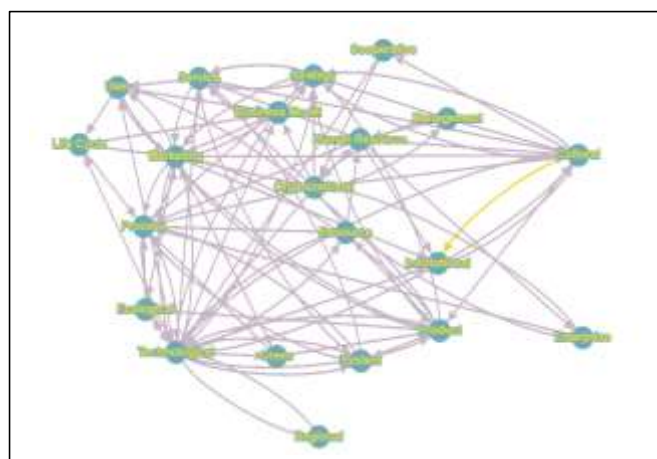


Fig. 4.1: Inter-connections of innovation concepts

4.2 Classification of innovation concepts

Figure 4.2 illustrates the summary of the classification of 21 innovation concepts into the main phases of the innovation process.

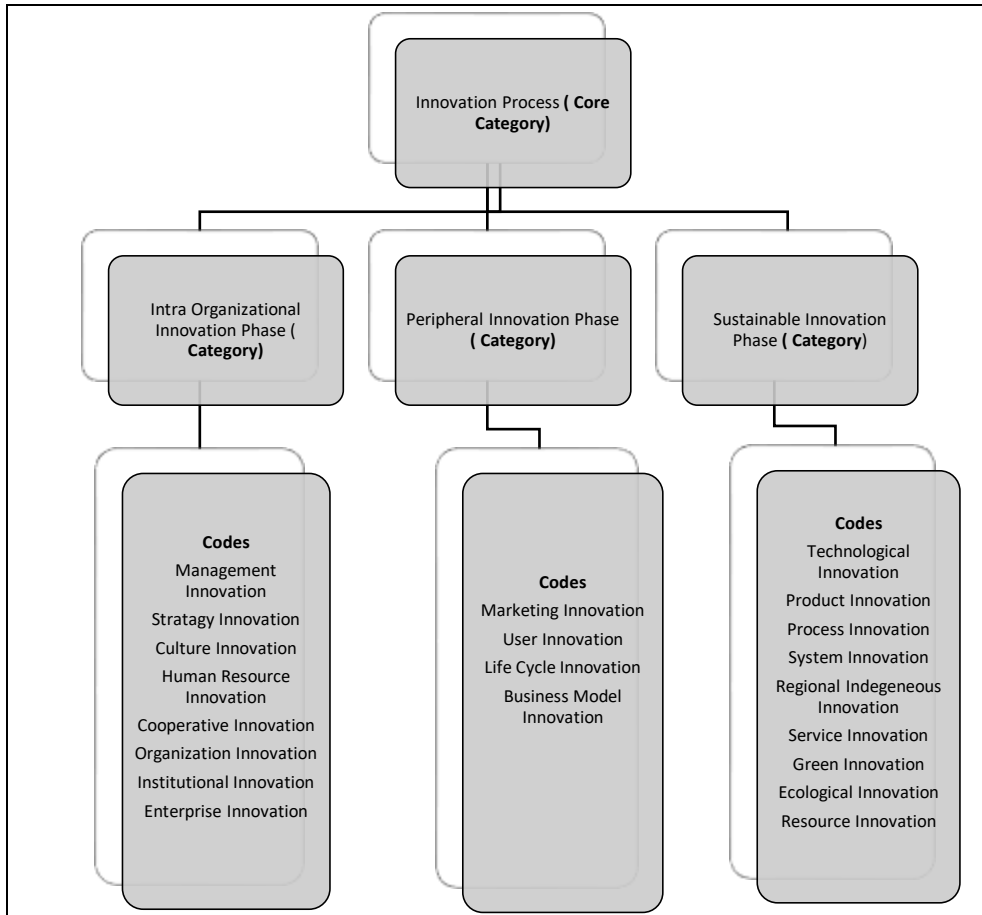


Fig. 4.2: Classification of innovation concepts using the Grounded theory

4.2.1 Validation of the consistency of the classification

Figures 4.3, 4.4, and 4.5, based on feedback from Questionnaire (QE1), illustrating the percentages of the responses on the classification of innovation concepts.

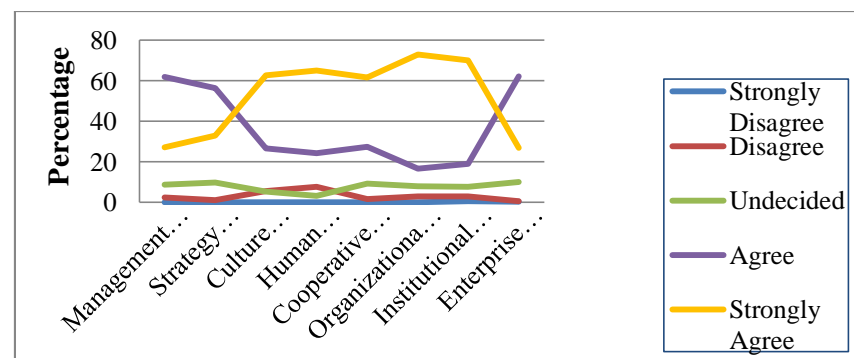


Fig. 4.3: Summary of responses for the classification on P1-Structuring the organization for a sustainable innovation

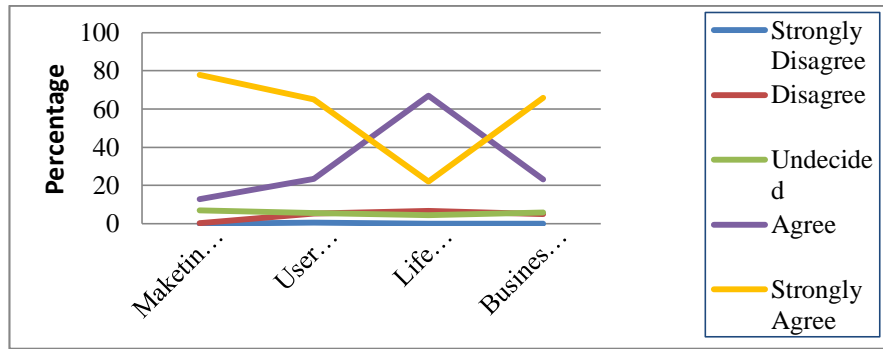


Fig.4.4: Summary of responses for the classification on P2 - information, outside the organization for a sustainable innovation

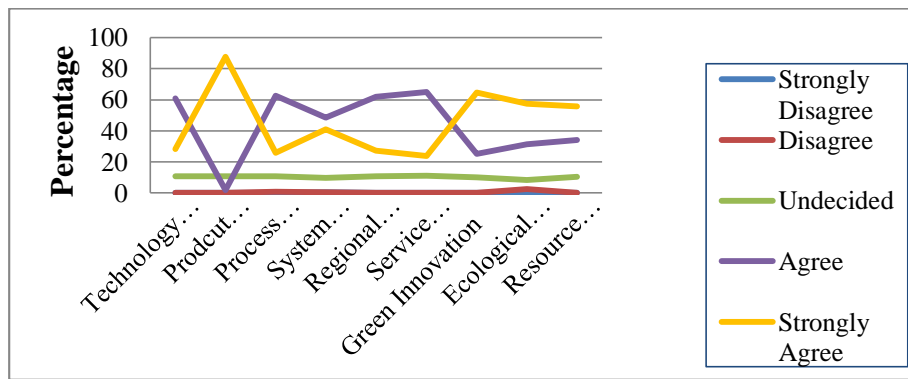


Fig.4.5: Summary of responses for the classification on P3 - implementing a sustainable innovation

The data shows that 89% of respondents selected "Agree" or "Strongly Agree," for classification related to each phase, indicating strong consensus compared to the remaining options ("Strongly Disagree," "Disagree," and "Undecided"), which covers only 11% of the total responses which demonstrate a high consistency in classification.

4.2.2 Statistical validation of the consistency of classification of innovation concepts.

Table 4.2 presents the hypothesis test summary of the Kruskal-Wallis test for the business model innovation concept. The "hypothesis test summary" box shows a p-value ("Sig.") of 0.000, which was less than 0.001, leading to the rejection of the null hypothesis. This proved that the distribution of responses was not the same across all categories.

TABLE 4.2: HYPOTHESIS TEST SUMMARY RELATED TO BUSINESS MODEL INNOVATION CONCEPT

Hypothesis Test Summary			
Null Hypothesis	Test	Sig.	Decision
The distribution of Responses is the same across categories of Category.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
Asymptotic significances are displayed. The significance level is .050.			

Further, there is very strong evidence to suggest the existence of differences between at least one pair of groups. In finding out which pairs, the box plot was used. The box plot compares the medians and the spread of the data by group. As illustrated in Figure 4.6 of the box plot of the business model innovation, a notable discrepancy was observed in one innovation phase, P2, while the other two (P1 and P3) remained consistent. Specifically, P2 exhibited a significant divergence from both P1 and P3 phases, with a notably higher median. This validates the classification of the business model innovation in to the phase P2, as depicted in Figure 4. 6.

Table 4.3 offers a concise summary of the hypothesis test results from the Kruskal-Wallis test conducted on all 21 innovation concepts.

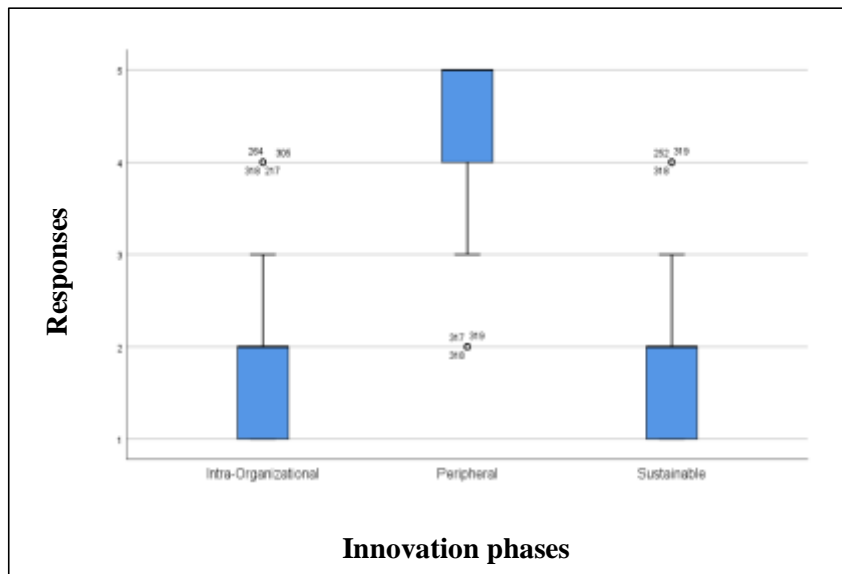


Fig. 4.6: Summary of hypotheses regarding boxplot ranges in business model innovation

TABLE 4.3: HYPOTHESIS TEST SUMMARY OF KRUSKAL-WALLIS TEST

Innovation Concept	Independent Samples - Kruskal- Wallis Test (Significance Level 0.5) – Box Plot range of the Majority of Responses		
	C1	C2	C3
Management Innovation	4-5	1-3	1-3
Strategy Innovation	4-5	1-2	1-3
Organizational Innovation	4-5	1-2	1-2
Institutional Innovation	4-5	1-2	1-2
Human Resource Innovation	4-5	1-2	1-2
Culture Innovation	4-5	1-2	1-2
Enterprise Innovation	4-5	1-3	1-2
Cooperative Innovation	4-5	1-3	1-3
Marketing Innovation	1-2	2-4	1-2
User Innovation	1-2	4-5	1-2
Life Cycle Innovation	1-3	2-5	1-3
Business Model Innovation	1-2	4-5	1-2
Technological Innovation	1-3	1-2	4-5
Product Innovation	1-2	1-2	3-4
Process Innovation	1-3	1-2	4-5
Service Innovation	1-3	1-3	3-5
Green Innovation	1-2	1-2	4-5
Resource Innovation	1-2	1-2	4-5
System Innovation	1-2	1-2	4-5
Regional Indigenous Innovation	1-2	1-3	4-5
Ecological Innovation	1-2	1-2	4-5

This clearly highlights the existence of three distinct sets of innovation concepts as highlighted in red squares, each set exhibiting varying results across the two remaining phases of the innovation process to which the concepts were classified. This proves the classification illustrated in Figure 4.2.

Furthermore, Table B.22 and the Figure B.1 through B.21 in Appendix B provides concise summaries of the hypotheses with boxplot images for all 21 innovation concepts.

4.3 Deriving core innovation concepts

Table 4.4 summarizes the core innovation concepts derived from each innovation phase using the Grounded theory.

TABLE 4.4: CORE INNOVATION CONCEPTS RELATED TO MAIN PHASES OF INNOVATION PROCESS

Main phase of the innovation process	Core innovation concept
P1 - Intra Organizational innovation phase	Management innovation
P2 -Peripheral innovation phase	Marketing innovation
P3 - Sustainable innovation phase	Technological innovation

4.4 Refined list of risk factors related to technological innovations

Table 4.5 illustrates the refined list of risk factors corresponding to technological innovations related to textile and apparel industry

TABLE 4.5: REFINED LIST OF RISK FACTORS RELATED TO TECHNOLOGICAL INNOVATIONS

No	Risk factors of technological innovations
C1	Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities
C2	The company's long-term goals are not aligned with its innovation strategy
C3	Violating intellectual property rights or stealing intellectual property from others
C4	Lack of organizational strength, including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base

C5	Failure to adopt improved methods of commercialization and inaccurate market positioning
C6	Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic environment changes, and shifts in national industrial policies) can impact the organization
C7	Risk of incomplete and inaccurate information, including distorted market data
C8	Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points
C9	Risks associated with material availability and quality
C10	Risk posed by the emergence of new technologies and technological advancements
C11	Failure to properly align the development, implementation, and output of the entire process, including incomplete project information and communication issues
C12	Lack of a robust risk-control mechanism integrated with the company's development plans, strategies, manpower, and financial investments, including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach
C13	Inadequate technical capacity to support innovation
C14	Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management

4.5 Classification of risk factors into main phases of innovation process

Figure 4.7 illustrates the classification of risk factors into the main phases of the innovation process, P1, P2 and P3, where P3 consists of sub phases of product and process innovations. Specifically, it represents sustainable innovation through product and process innovations. C1 through C14 illustrates the risk factors in Table 4.5.

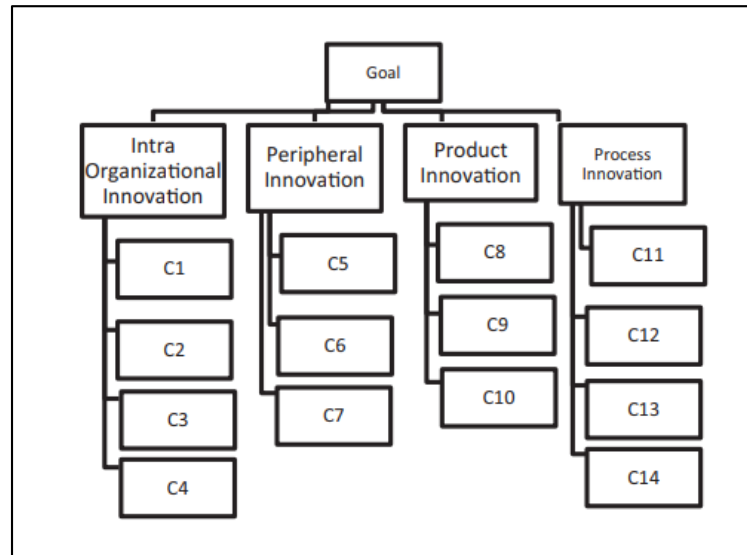


Fig. 4.7: Classification of risk factors into main phases of the innovation process

4.5.1 Validation of the consistency of risk factor classification

Feedback from 10 experts showed that nine agreed with the classification in Figure 4.7. However, one expert classified the risk factor “inadequate technical capacity” under the intra-organizational innovation phase. As a result, the classification in Figure 4.7 was finalized, with 90% of the experts in agreement.

4.6 Root causes associated with risk factors of technological innovations

Table 4.6 summarizes the 65 root causes related to 14 risk factors of technological innovations which has been introduced in the literature and further validated by industry experts. “C” Denotes the risk factors while “A” denotes the root causes in the Table 4.6.

TABLE 4.6: RISK FACTORS AND CORRESPONDING ROOT CAUSES OF TECHNOLOGICAL INNOVATIONS

Risk Factor	Root causes
C1 Failure to evaluate the innovation concept based on the company's financial, structural, marketing,	A1.1 Insufficient investment available for the project
	A1.2 Limited opportunities to secure external funding (loan, joint venture, mortgage, other) in the absence of internal investment

	and technological capabilities	A1.3	Failure to review the innovation idea by experts to assess necessary implementation steps and potential risks
		A1.4	Leadership lacks prior knowledge and experience to effectively guide the innovation process
		A1.5	Inaccuracy of the budgeting process
C2	The company's long-term goals are not aligned with its innovation strategy	A2.1	Failure to consider the company's long-term goals during the innovation process
		A2.2	Lack or unavailability of necessary resources and capabilities to develop the innovation in line with long-term goals
C3	Violation of intellectual property rights or theft of intellectual property from others	A3.1	Failure to verify existing intellectual property related to the product, such as patents
		A3.2	Not securing the innovation with a patent or other appropriate methods
		A3.3	Lack of Non-Disclosure Agreements (NDAs) with relevant personnel
C4	Lack of organizational strength, including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base	A4.1	Lack of long-term critical skill holders within the organization
		A4.2	Insufficient skills and knowledge among team members
		A4.3	Failure to provide adequate training to improve skills and knowledge (internal, on-the-job, external, or other appropriate training)
		A4.4	Absence of a learning culture within the organization
		A4.5	Poor relationships among team members
		A4.6	Difficulty convincing operators to adopt process changes
		A4.7	Lack of time and resources for "learning through experimentation"
		A4.8	Poor decision-making when selecting suppliers (price, lead time, material quality, cost benefits, credit terms, accreditations)

		A4.9	Disagreements with suppliers reduce negotiation opportunities
C5	Failure to adopt improved methods of commercialization and inaccurate market positioning	A5.1	Absence of a mechanism to inform customers about new products or services
		A5.2	Failure to consult experienced third-party teams during the commercialization process
		A5.3	Failure to consult experienced third-party teams during the commercialization process
C6	Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic environment changes, and shifts in national industrial policies) can impact the organization	A6.1	Analysis of the information on redundancy or unprecedented risks which can impact the organization
		A6.2	Being the first entrant into the market
		A6.3	Presence of significant competitors
		A6.4	Lack of competitive advantages over rivals (price, quality, user-friendliness, market segment, brand recognition, durability, lead time)
		A6.5	Lack of understanding of customer demand patterns related to the innovation
		A6.6	Innovation does not comply with legislation or national industry policies
C7	Risk of incomplete and inaccurate information, including distorted market data	A7.1	Failure to conduct a proper target market analysis
		A7.2	Inability to identify the actual needs of the customer
		A7.3	Problems arising from the feasibility study
C8	Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points	A8.1	Failure to incorporate customer or market research feedback into the innovation process
		A8.2	Innovation does not meet customer expectations
		A8.3	Innovation fails to compete with current technological trends

C9	Material resource risk affects timely delivery of goods	A9.1	Raw material quality does not meet customer requirements or predetermined standards
		A9.2	Unavailability of raw materials during bulk production
		A9.3	Lack of proper procedures for handling rejections and replacements of raw materials
C10	Risk posed by the emergence of new technologies and technological advancements	A10.1	Insufficient market research on innovation trends and competitors
		A10.2	Lack of consideration for upcoming technological advancements in product or service innovation
		A10.3	Negative impacts on the innovation due to lack of resources for implementing new technology
C11	Failure to properly align the development, implementation, and output of the entire process, including incomplete project information and communication issues	A11.1	Inaccuracies in defining the overall innovation process
		A11.2	Failure to clearly define each phase of the process with specific instructions
		A11.3	Inadequate determination of the information to be shared at each phase with appropriate personnel
		A11.4	Process issues that hinder meeting required timelines
		A11.5	Process issues that affect achieving the desired innovation quality
		A11.6	Process inefficiencies that prevent achieving cost savings
		A11.7	Failure to identify all relevant stakeholders in the process
		A11.8	Lack of effective communication channels
		A11.9	Failure to share required information and provide access to stakeholders
C12	Lack of a robust risk-control mechanism integrated with the company's development plans, strategies, manpower, and financial	A12.1	Lack of an appropriate evaluation mechanism with necessary control parameters
		A12.2	Ineffective review methods (internal, third-party, or both)
		A12.3	Failure to control the process according to the plan

	investments,	A12.4	Inadequate frequency of analyzing control parameters
	including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach	A12.5	Failure to identify risks involved in the innovation process
		A12.6	Low success rate of past innovations
C13	Inadequate technical capacity to support innovation	A13.1	Insufficient capacity of machinery and equipment for bulk production
		A13.2	Lack of contingency plans to meet capacity needs (joint venture, subcontracting, collaboration, purchasing, hiring)
		A13.3	Inadequate workforce availability for bulk production
		A13.4	Inaccurate definition of the skills required to complete the innovation
		A13.5	Lack of plans to acquire necessary technical skills
C14	Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management	A14.1	Failure to define the development process for achieving the best product or service
		A14.2	Inability to overcome challenges during development
		A14.3	Failure to conduct development trials
		A14.4	Inability to scale the development process for mass production
		A14.5	Alternative methods increase costs, lead times, or require special skills and resources

4.7 Innovator type of the organization

Different Neural Network architectures were tested using MATLAB, and the results were summarized in Table 4.7. A detailed analysis of these tests is included in Table H.1 in Appendix H.

TABLE 4.7: SUMMARY OF THE NEURAL NETWORK CONFIGURATIONS USED TO DETERMINE INNOVATOR TYPE OF THE ORGANIZATION

Model Type	Number of Layers	No of nodes in layers	Activation Function	Accuracy	Comments
1. Medium neural network	1	25	ReLu	46.1 %	
2. Medium neural network	1	25	ReLu	42.7%	Keeping only 35 components to explain 95% variance according to PCA
3. Optimizable neural network	1	50	Tanh	51.7%	
4. Medium KNN				38.2%	
5. Fine Tree				49.4%	Maximum number of splits according to Gini's diversity index - 100
6. Optimizable tree				50.6%	Maximum number of splits according to Gini's diversity index - 10
7. SVM Kernal				39.3%	
8. Bilayered Neural Network	2	1 st layer 10, 2 nd layer 10	ReLu	41.6%	
9. Wide neural network	1	100	ReLu	60.7%	

10. Trilayered neural network	3	1 st layer – 10, 2 nd layer – 10, 3 rd layer - 10	ReLU	37.1%	
11. Optimizable Neural Network	2	1 st layer – 96, 2 nd layer - 243	Sigmoid	52.8%	Optimizer: Bayesian optimization
12. Wide Neural Network	1	1 st layer -100	Tanh	52.8%	

Among the various configurations, Model 9 was selected to identify the organization's innovator type due to its highest accuracy of 60.7% among the 12 models tested. Table 4.8 illustrates the network parameters for the selected model, identified as model 9.

TABLE 4.8: SUMMARY OF THE NETWORK PARAMETERS

Training results	
Accuracy (Validation)	60.7%
Total cost (Validation)	Not applicable
Prediction speed	~5400 obs/sec
Training time	0.92314 sec
Model Type	
Preset	Wide Neural Network
Number of fully connected layers	1
First layer size	100
Activation Function	ReLU
Iteration limit	1000
Regularization strength (Lambda)	0
Standardize data	Yes
Optimizer options	Hyper parameter options disabled
hyper parameter options	Disabled
Feature selection	All features used in the model, before PCA
PCA	PCA disabled
Misclassification costs	Not supported

Regarding the model tuning, changing the number of hidden layers from 1 to 2 to 3 changed accuracy from 60.7% to 52.8% and 37.1%, respectively. Hence, one hidden layer with 100 nodes and the ReLu activation function gives the best accuracy of the options tried. However, the sigmoid and Tanh gave lower accuracies than the ReLu.

Due to limitations in generating appropriate loss function graphs with MATLAB, the model was re-implemented using Tensor Flow in Python. This yielded a final accuracy of 76.47%. To address the constraints posed by the small dataset, 5-fold cross-validation was employed, which helped to improve the model's accuracy. Figure 4.8 shows the validation loss over 5 epochs. Further, Validation accuracy has become 76.47% and found a validation loss of 1.49. However, accuracy could be further improved with a larger data set and by fine-tuning the neural network's internal parameters. This was not pursued in this study, as the focus was on demonstrating the methodology.

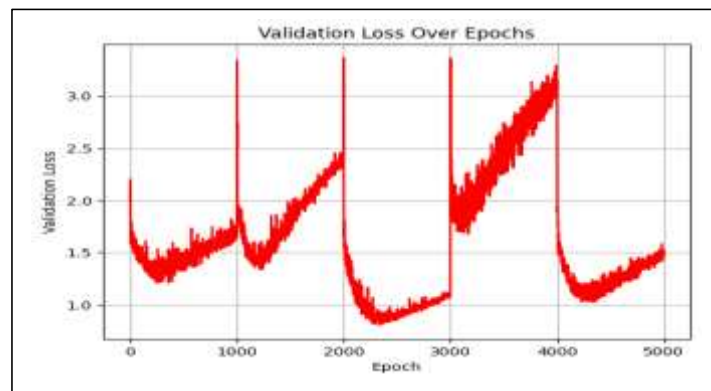


Fig. 4.8: Validation loss over 5 epochs

4.8 Assessing the priorities of risk factors related to different innovator types

Table 4.9 showcases ANP's identification of risk factor priorities across different innovator types. The "Limiting" column presents global priorities for 14 risk factors, while the "Normalized by cluster" column highlights priorities specific to each cluster.

Furthermore, the Consistency Ratios (CR) of these priorities were less than 0.1, indicating acceptable consistency of all priorities. These global priorities guide decision-making by collectively addressing all 14 risk factors.

TABLE 4.9: PRIORITIES OF RISK FACTORS RELATED TO DIFFERENT INNOVATOR TYPES USING ANP

Risk Factors	Creator		Solution Builder		Leverager	
	Normalized By Cluster	Limiting	Normalized By Cluster	Limiting	Normalized By Cluster	Limiting
C1	0.06188	0.03093	0.05669	0.028346	0.06731	0.03365
C2	0.02321	0.01160	0.04461	0.022306	0.0516	0.02579
C3	0.1177	0.05885	0.12057	0.060283	0.11888	0.05943
C4	0.08472	0.04236	0.08317	0.041585	0.08939	0.04469
C5	0.03273	0.01636	0.05143	0.025713	0.03225	0.01612
C6	0.1839	0.09194	0.15469	0.077346	0.16801	0.08400
C7	0.04744	0.02371	0.06663	0.033316	0.04896	0.02448
C8	0.05152	0.02576	0.08774	0.043869	0.0767	0.03835
C9	0.0296	0.01480	0.0357	0.01785	0.0368	0.01840
C10	0.05372	0.02686	0.04998	0.024989	0.03701	0.01850
C11	0.05511	0.02755	0.04632	0.023159	0.04669	0.02334
C12	0.13642	0.06821	0.10743	0.053716	0.1241	0.06204
C13	0.03302	0.01651	0.03979	0.019894	0.03335	0.01667
C14	0.08903	0.04451	0.05526	0.027628	0.06895	0.03447
Intra Organizational	0.28254	0.14127	0.30734	0.153671	0.37444	0.18722
Peripheral	0.18096	0.09048	0.26022	0.130112	0.13468	0.06733
Process	0.20329	0.10164	0.21818	0.109091	0.2264	0.11320
Product	0.33321	0.16660	0.21425	0.107125	0.26448	0.13224

Risk Factors	Expander		Defender		Fast Follower	
	Normalized by Cluster	Limiting	Normalized by Cluster	Limiting	Normalized by Cluster	Limiting
C1	0.0677	0.033863	0.0577	0.028852	0.07393	0.03696
C2	0.0393	0.019681	0.03999	0.019997	0.03327	0.01663
C3	0.1312	0.065643	0.13335	0.066677	0.12276	0.06138
C4	0.1074	0.053743	0.10853	0.054266	0.10472	0.05235
C5	0.0288	0.01444	0.03737	0.018685	0.03427	0.01713
C6	0.1766	0.08832	0.16348	0.081742	0.18066	0.09033
C7	0.0494	0.024726	0.05402	0.027009	0.05962	0.02980
C8	0.0449	0.022488	0.04805	0.024027	0.03908	0.01953
C9	0.0287	0.014392	0.03319	0.016597	0.02814	0.01407
C10	0.0539	0.026987	0.05152	0.025761	0.06164	0.03081
C11	0.0523	0.026149	0.04737	0.023687	0.03976	0.01987
C12	0.1210	0.060542	0.11226	0.056129	0.12134	0.06067
C13	0.0371	0.018551	0.03678	0.01839	0.03198	0.01599
C14	0.0609	0.030476	0.07636	0.038181	0.06883	0.03441
Intra Organizational	0.35954	0.17976	0.33771	0.16885	0.35625	0.17812
Peripheral	0.09639	0.04819	0.13732	0.06865	0.16283	0.08141
Process	0.25673	0.12836	0.23327	0.11663	0.20372	0.10185
Product	0.28734	0.14366	0.2917	0.14585	0.27721	0.13860

Figure 4.9 illustrates a graphical representation of summary of the priorities of 14 technological innovation risk factors based on the organization's innovator type, while

Figure 4.10 illustrates how priorities across main innovation phases vary according to six innovator types.

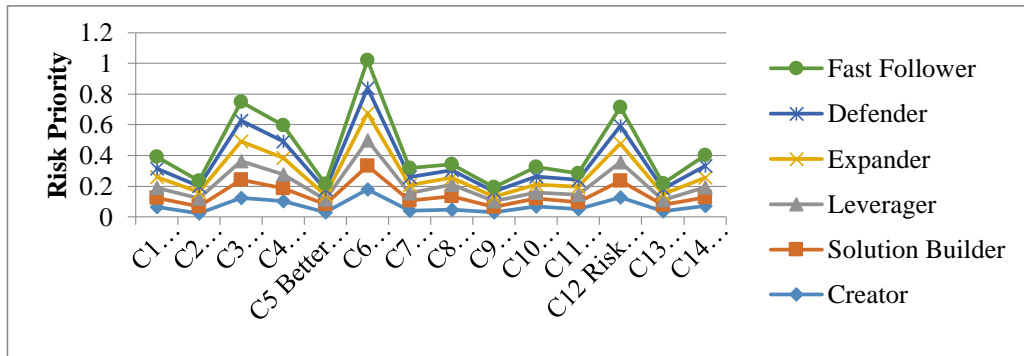


Fig. 4.9: Priorities of 14 technological innovation risk factors related to 6 innovator types

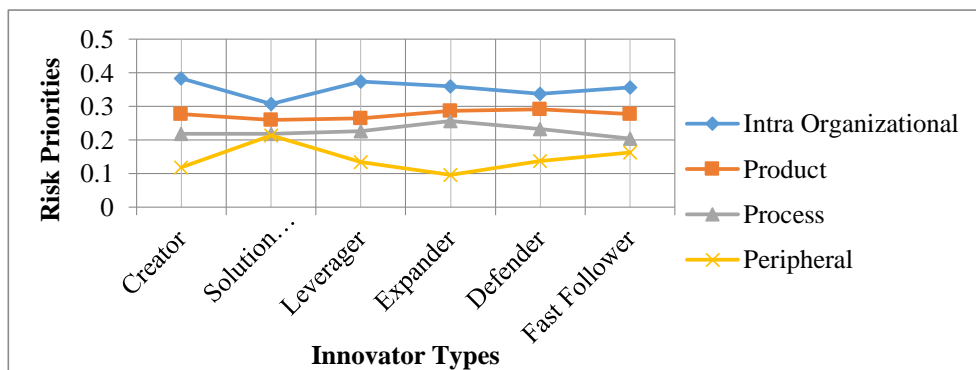


Fig. 4.10: Priorities of main phases of innovation process related to 6 innovator types

The research highlights key risk factors for various innovator types, focusing on redundancy and unprecedented risks (C6), and the need for strong risk management strategies (C12), which are critical across all innovator profiles due to their potential to disrupt innovation. Securing intellectual property rights (C3) and leveraging organizational strengths (C4) are also crucial for long-term success.

Effective risk management is essential for addressing technological innovation risks and ensuring access to necessary resources. Research and Development (R&D) (C14) plays a pivotal role by providing valuable insights for innovation. Different innovator types require tailored strategies: creators prioritize organizational strengths (C1), solution builders focus on information resources (C7), and expanders need to align innovation with strengths (C4) while managing technological risks (C10). Defenders and fast followers emphasize precise information (C7), with defenders focusing on maintaining competitiveness through continuous improvement, and fast followers prioritizing R&D (C14) and organizational strengths (C4) to enhance existing innovations. The insights on risk priorities will make more effective with the findings

of Figure 4.10, which elaborates which phases need more attention according to the innovator type of the organization.

4.9 Assessing the priorities of root causes related to each risk factor

The priorities of root causes for each technological innovation risk factor, as determined by the Super Decision software, are presented in Table 3 of Appendix K. The consistency ratios (CR) for all these priorities were below 0.1, confirming their acceptable consistency [190].

Figures 4.11 through 4.24 visually represent the priorities of root causes associated with each risk factor. “C” Denotes the risk factors and “A” denotes root causes corresponding to each risk factor in the graphs.

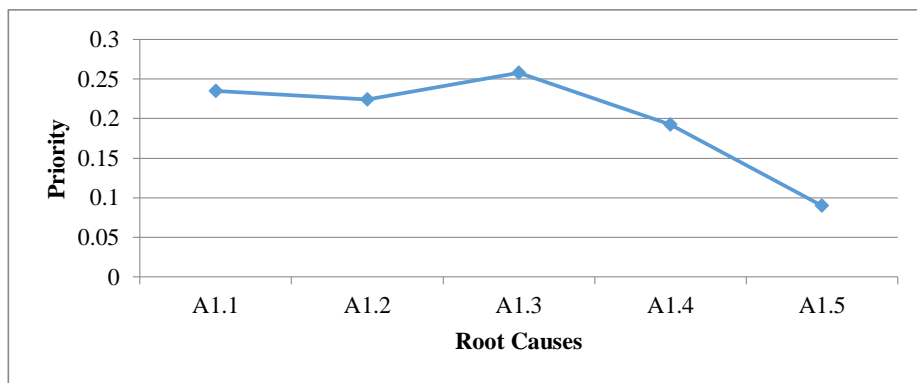


Fig.4.11: Priorities of root causes related to C1

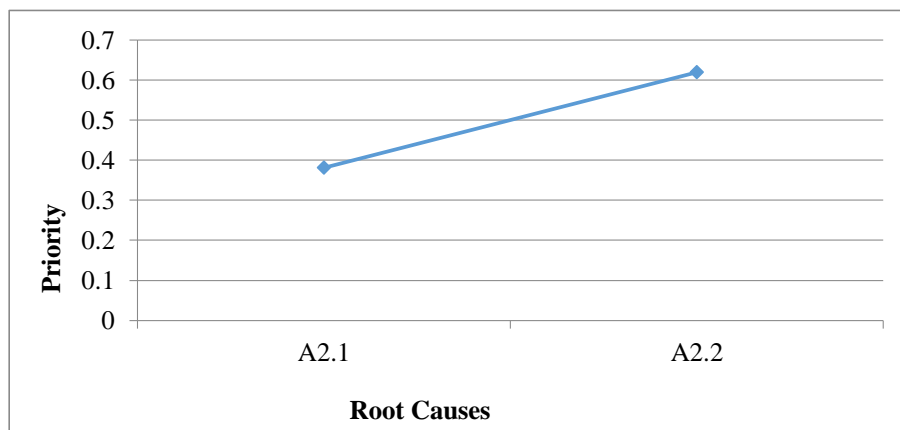


Fig. 4.12: Priorities of root causes related to C2

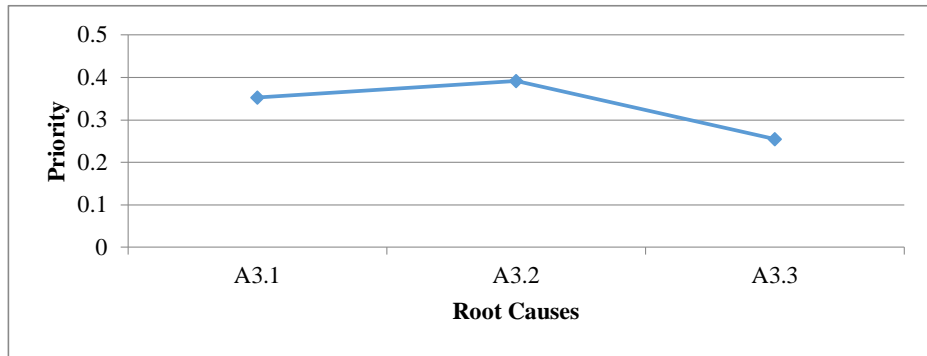


Fig.4.13: Priorities of root causes related to C3

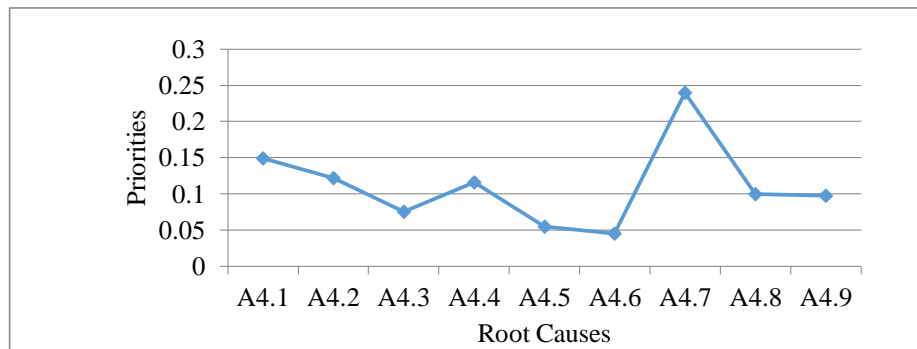


Fig. 4.14: Priorities of root causes related to C4

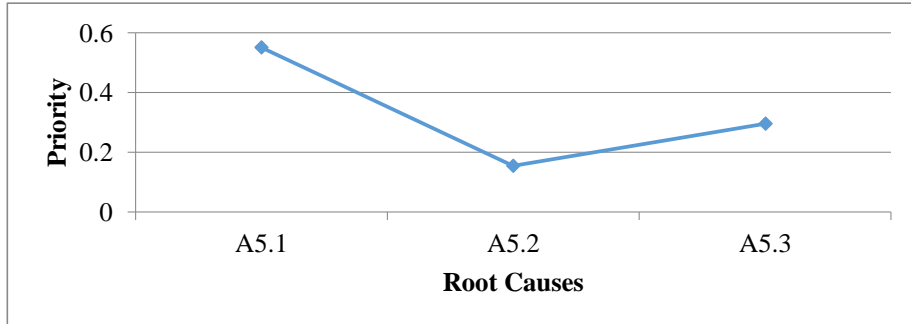


Fig. 4.15: Priorities of root causes related to C5

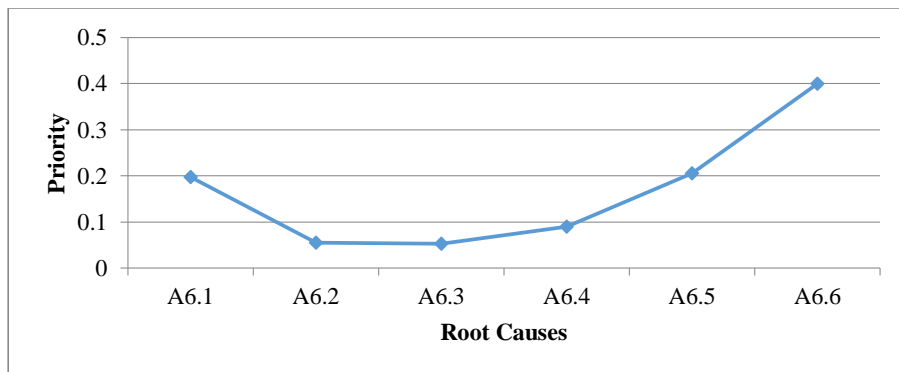


Fig. 4.16: Priorities of root causes related to C6

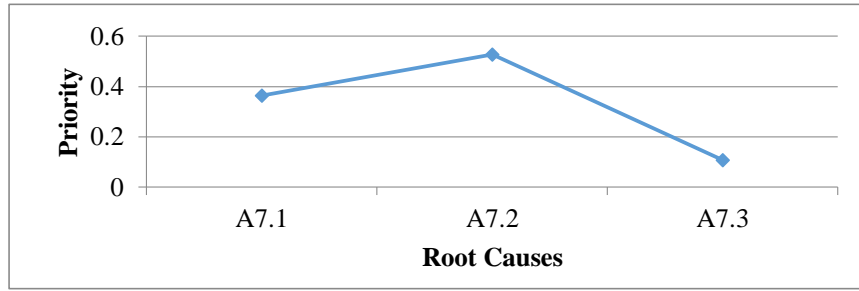


Fig 4.17: Priorities of root causes related to C7

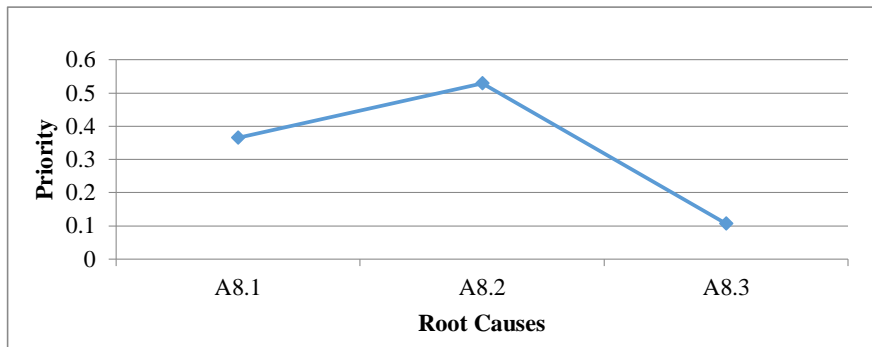


Fig. 4.18: Priorities of root causes related to C8

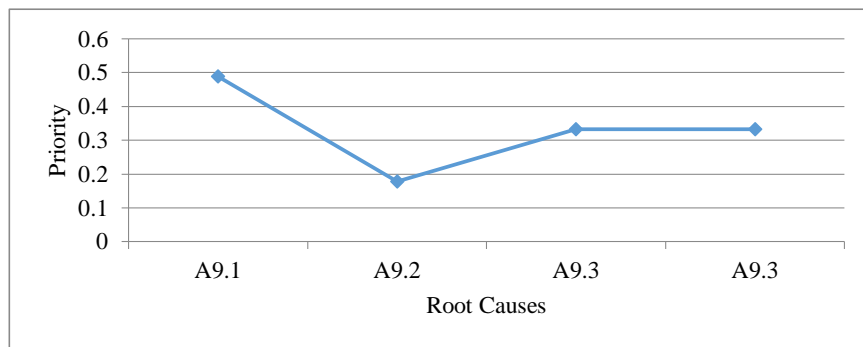


Fig. 4.19: Priorities of root causes related to C9

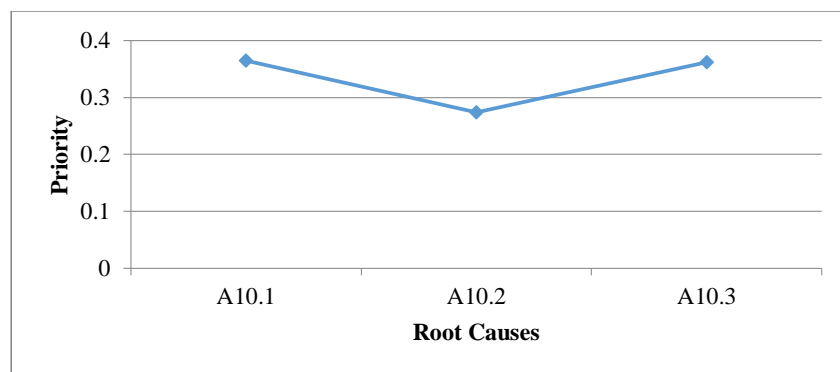


Fig. 4.20: Priorities of root causes related to C10

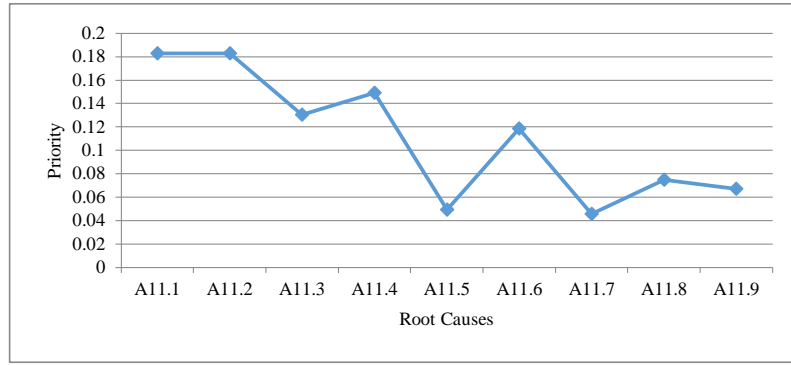


Fig. 4.21: Priorities of root causes related to C11

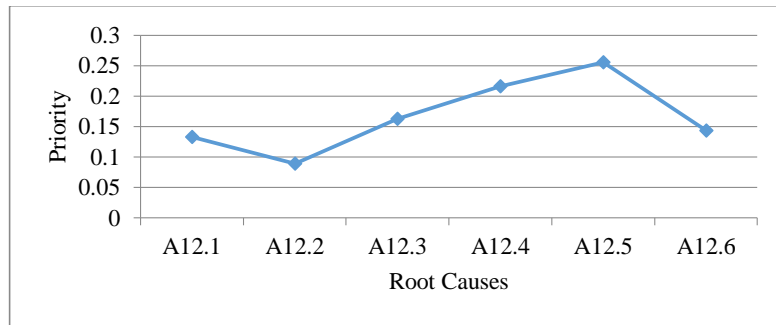


Fig. 4.22: Priorities of root causes related to C12

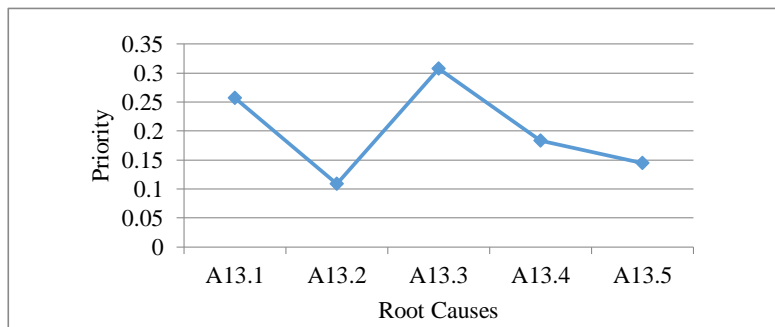


Fig. 4.23: Priorities of root causes related to C13

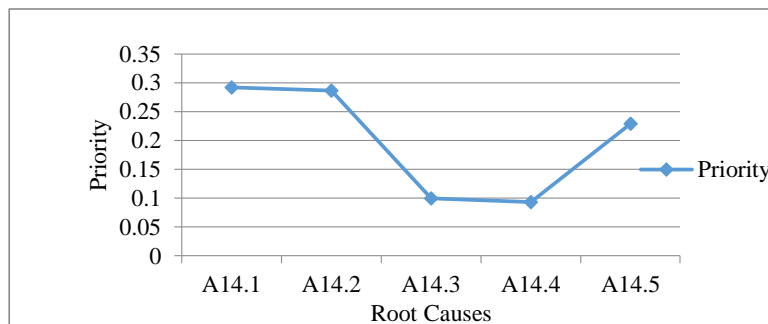


Fig. 4.24: Priorities of root causes related to C14

Organizational structure plays a fundamental role in innovation processes, requiring alignment of innovation strategies with organizational capabilities and long-term

goals, as seen in Figures 4.11 and 4.12. Protecting innovations through proper risk management strategy (Figure 4.22) and measures like patents and NDAs (Figure 4.13) is vital to safeguarding investments. Organizational strengths, such as experiential learning and supplier management (Figure 4.14 and Figure 4.19), are critical for innovation success. Managing external information and technological advancements is crucial for competitiveness (Figure 4.17 and Figure 4.18), while addressing redundancy and unprecedented risks helps maintain stability (Figure 4.16). Precise information and market feedback (Figures 4.17 and 4.15) mitigate risks during product innovation, and managing risks related to raw materials and supplier flexibility (Figure 4.19) ensures operational efficiency.

Adapting to technological advancements (Figure 4.20) and managing risks in process innovation (Figure 4.21) offer competitive advantages. Finally, addressing technical capacity risks (Figure 4.24) and defining the right research and development approach (Figure 4.24) are key to achieving successful innovation outcomes.

4.10 Risk management model for technological innovations in the textile and apparel industry

Figure 4.25 illustrates the risk management model developed for handling technological innovation risks within the textile and apparel industry.

5including technical knowledge and step-by-step procedures for playing the game. Upon completion of the game-play, risks will be effectively managed through optimal utilization of internal resources. The user guide titled "How to Play the Game" has been appended in Appendix K for reference.

4.11 Validation of the risk management model

4.11.1 Feedback of the industry validation process

Industry experts made suggestions on:

1. Identifying the respective departments accountable for addressing each root cause individually.
2. Specifying the resources required to mitigate the root causes of each risk factor individually.
3. Proposing an alternative approach for team members to convene during the pitch-making meeting, considering logistical constraints with attending 14 separate meetings. The user guide has been updated with revised information for points 1 and 2, incorporating the respective departments and required resources in Table 1, in the user guide attached to Appendix K.

Additionally, an alternative suggestion for point 3 proposes forming three teams to collectively address all 14 risk factors, as shown in Table 4.10, which is also included in the Appendix of the user guide.

TABLE 4.10: ALTERNATIVE SUGGESTIONS TO FORM TEAMS FOR THE PITCH-MAKING MEETING

Risk Factors	Teams to be gathered
C1,C2,C6,C7,C13	Senior management team taking organizational decisions, Finance, Marketing, Merchandising, Industrial Engineering, Research and Development (R & D), Supply chain, Production, Planning, Quality, Human Resources (HR)
C3,C4,C5,C8,C10	HR, Planning, Production, Supply Chain, Merchandising, R & D, Industrial Engineering
C9,C11,C12,C14	R & D, Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores, Finance

4.11.2 Validation of the risk management model with System Usability Scale

Based on feedback from five industry experts, attached in the Appendix R, Table 4.13 illustrates the individual System Usability Scores of 5 respondents. The Average System Usability Score was 81, indicating that the developed methodology is acceptable. The SUS score was calculated according to the methodology introduced in the literature [224], which has been elaborated in Appendix K.

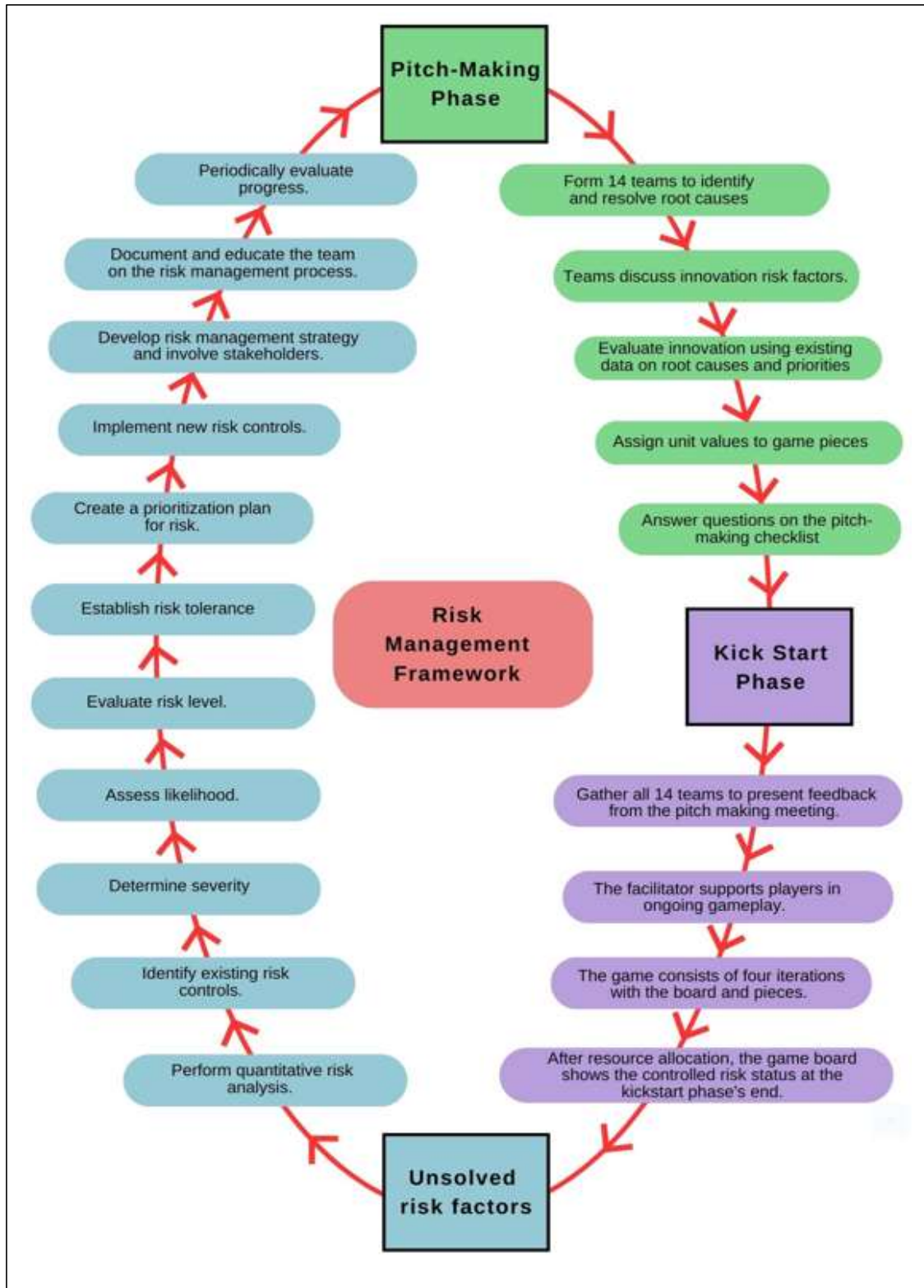


Fig. 4.25: Risk management model

4.12 Discussion

In December 2023, export earnings from Sri Lanka's Apparel and Textile sector experienced a notable decline of 8.64% year-over-year, dropping to US\$ 438.78 million compared to the same period in 2022 [4]. This downward trend persisted into 2024, highlighting ongoing challenges within the industry amidst shifting global market dynamics [225]. This decline is exacerbated by the current economic crisis. Statistics point out three key factors contributing to this downturn: increased lead times, rising costs, and a limited product range. To revitalize the industry's competitive edge in the global market, a strategic approach is imperative. Addressing these issues head-on paves the way for a resilient and thriving future for Sri Lanka's textile and apparel sector.

Numerous researchers and industry experts have shifted their focus toward innovation as a primary research objective [30]. This shift highlights the pivotal role innovation plays in determining an organization's success and longevity, a trend evident even within the textile and apparel industry. The literature delineates 21 distinct concepts of innovation, some of which perform similar functions but are referred to by different names. Through literature-based elucidations, a deeper comprehension of these various innovation concepts emerges, facilitating the selection of the most suitable innovation type aligned with the specific task at hand. This nuanced understanding guides the entire supply chain process, thereby enriching both research endeavours and organizational strategic planning, and bridging a gap in the literature.

Employing Grounded Theory to classify innovation concepts with analogous meanings streamlines the classification process, enhancing the efficacy of decision-making by alleviating the burdensome task of redundant information analysis. Consequently, this refinement contributes to the accuracy and effectiveness of the innovation process. However, the complex interrelationship among innovation concepts, as illustrated by Graph Theory, presents a challenge, as complete isolation during classification proves infeasible. This limitation spotlights the intricacies inherent in innovation concept classification.

Three main phases emerge from the classification of innovation concepts: intra-organizational innovation, peripheral innovation, and sustainable innovation. These phases are instrumental in identifying the pivotal components that exert the greatest influence on innovation outcomes. Additionally, focusing on different innovation concepts depending on the phase of the innovation process improves strategic alignment. Furthermore, heightened attention is warranted towards technological innovation and risk management to optimize the impact of innovation endeavours. Given the multifaceted nature of technological innovation and its associated risks, robust risk management strategies are imperative. However, in the existing literature, while some risk factors and root causes are individually examined, not all were

considered comprehensively, hindering the determination of the big picture. Thus, the findings emphasize potential risk factors and root causes inherent in technological innovations, addressing a gap in the literature where comprehensive analyses are often lacking. This comprehensive examination of risk factors contributes to a deeper understanding of the underlying causes, enriching the existing literature on this subject matter.

Moreover, it is essential to recognize that various business models adopt six distinct strategies for introducing new products to the market, namely creators, solution builders, leveragers, expanders, defenders, and fast followers [92]. However, not every innovative business realizes its full potential, as the chosen innovation strategy plays a pivotal role in determining whether the organization achieves a position of high or low success. This understanding underscores the importance of comprehending the correlation between risk factors and their impact on different approaches of the innovation process.

Leveraging probabilistic outputs, organizations can strategically identify the most appropriate innovator type that aligns with their resources and competencies, allowing for a well-defined progression plan. Despite the potential of Back Propagation Neural Networks to offer quantifiable risk evaluations, challenges such as limited data availability and disparities in data derivation hinder their application.

The Feed Forward Neural Network (FFNN), achieving an accuracy of 60.7% in identifying an organization's innovator type, faced performance challenges primarily due to insufficient training data, which risks poor generalization and over fitting. Data augmentation techniques can mitigate these issues to some extent by enhancing prediction accuracy. Although hyper-parameter tuning—adjusting learning rates, hidden layers, nodes, and activation functions can further improve accuracy, it was not performed in this model due to contextual limitations and practical constraints, with a focus on avoiding over fitting given the small dataset.

The wide neural network developed in MATLAB showed a validation accuracy of 60.7%, compared to 76.47% achieved by the same architecture in Tensor Flow. These discrepancies can be explained by differences in implementation specifics, training procedures, data management, regularization methods, and other facets of the machine learning pipeline, despite having an identical network design.

Moreover, a validation loss of 1.49 measures the model's prediction error on the validation dataset, reflecting its effectiveness in determining the most appropriate innovator type for the organization. Improved prediction accuracy can be achieved by optimizing model performance through techniques such as hyper parameter tuning, feature engineering, or leveraging more advanced models, especially when supported by a sufficient dataset.

Since the primary goal of using the FFNN was to assess the feasibility of neural networks for identifying an organization's innovator type, a task not effectively achievable through traditional statistical methods. This neural network model, although separate from the risk management model, acts as a conceptual proof of the approach. Future efforts could focus on enhancing its performance through more comprehensive hyper-parameter tuning and the use of a larger dataset.

Furthermore, a holistic approach to risk management is necessary, encompassing the entire innovation lifecycle from conceptualization to post-launch activities. This comprehensive strategy enables organizations to identify and prioritize specific risk factors based on the phase of the innovation process and the innovator type, thereby facilitating the development of a tailored risk management model specific to the organization's innovator type or product.

The Analytic Network Process (ANP) is utilized as a decision model for data with interdependencies [167]. It effectively determines the priorities of risk factors associated with the innovation process and various innovator types. This approach enhances comprehension of risk factor prioritization by identifying relationships accurately, thereby supporting a balanced risk-reward outcome. Moreover, the study reveals that applying identical risk prioritization across all innovator types is impractical; different approaches tailored to each type are necessary to fully capitalize on innovation efforts.

Understanding the priority shifts is crucial for aligning goals, allocating resources, managing risks, making decisions, fostering collaboration, adapting to changes, engaging stakeholders, and continuously improving strategies. This comprehension empowers businesses to make informed decisions, enhance their innovation endeavors, maximum utilization of resources and navigate the intricate realm of technological innovation efficiently.

Thus, the findings stress the importance of developing a customized risk management strategy based on the unique characteristics of the organization's innovator type. This approach enables organizations to prioritize risks effectively, align internal resources accordingly, and address critical factors prior to pursuing innovative initiatives.

The research provides valuable insights into prioritizing the root causes of the 14 identified risk factors using the ANP. These priorities, illustrated in Figures 4.17 through 4.30, offer a comprehensive view of how various root causes impact risk factors at different stages of the innovation process. This understanding equips organizations with a broader perspective on the potential threats to their innovation efforts and how to address them effectively. As a result, organizations can develop targeted risk management strategies that enhance the likelihood of successful innovation outcomes.

In addition, ANP priorities were derived from insights shared by industry experts, reflecting real-world scenarios in manufacturing organizations. By focusing on the most critical root causes, organizations can allocate resources more efficiently and mitigate challenges more effectively. This understanding is essential for addressing the underlying issues that contribute to risks, leading to more robust and efficient risk management strategies [285].

To enhance risk management in technological innovation, organizations must address the root causes of risk to eliminate associated problems and facilitate smoother innovation. Customizing risk management strategies to the specific needs of each organization and innovation is more effective than a generalized approach. The diversity and level of risk depend on factors such as organizational objectives, human resources, financial capacity, and brand reputation, making a one-size-fits-all approach impractical. Besides organizations differ significantly in how they perceive, assess, and respond to risks, which influences their behavior toward risk acceptance. Hence, both product-specific and organization-specific risk management strategies are essential for maximizing innovation benefits and fostering growth.

Furthermore, confidentiality concerns of organizations hinder the disclosure of critical risk management factors to third parties, posing a significant challenge. Thus, it is imperative to develop a robust risk management model which maintains confidentiality is essential.

The risk management model is developed on core principles from Cooperative Game Theory, Behavioral Game Theory, a collaborative approach, psychological aspects of decision-making, visual representation of problems and the concept of board games. These foundational elements collectively provide a comprehensive model that effectively meets the outlined requirements across the entire risk management process providing practical solutions to the textile and apparel industry.

Further, board games offer a novel, simplified approach to risk management in the textile and apparel industry, promoting flexibility and creativity, while enhancing decision-making accuracy. Visualizing problems through the game board strengthens decision-making, and researchers have discovered that this approach is closely linked to human psychology [245]. Involving both hemispheres of the brain and leveraging diverse expertise during group discussions lead to a greater pool of potential solutions. Besides, the game consists of smaller, closely-knit units, as the size of the group significantly influences the effectiveness of decision-making [249].

The game connects members from all departments involved in the innovation process, bridging the gap between technical and all other teams. This alignment fosters a unified team effort toward the organization's goals. By visualizing problems through the game board and pieces, the entire team gains a comprehensive view of the innovation status, ensuring transparency in decision-making.

Additionally, the game improves the efficient use of organizational resources without concentrating them in a single area. The introduction of specific phases—such as pitch-making, kick-starting, and addressing unresolved risk factors—ensures thorough risk assessment and mitigation, leading to informed decisions and optimal outcomes. Furthermore, providing teams with essential technical knowledge and guidance empowers them to make better decisions and develop a risk management strategy tailored to the organization.

Despite the numerous risks and challenges inherent in the textile and apparel industry, there is a noticeable gap in the literature regarding comprehensive documentation and research on these issues. Furthermore, existing strategies often fall short as they are not tailored to address the industry's multifaceted challenges but rather focus on solving isolated problems. Therefore, this integrated strategy offers a powerful model for enhancing risk management by optimizing resource utilization, ensuring transparency, safeguarding the confidentiality of strategic plans, and maximizing the benefits of technological innovations tailored to the organization. It paves the way for a groundbreaking approach to risk management in the textile and apparel industry, opening new avenues for exploration and advancement

CHAPTER 5

CONCLUSION AND FUTURE RESEARCH

5.1 Conclusion

Enhancing the competitive edge of Sri Lanka's textile and apparel industry on the global stage requires embracing technological innovations. As literature suggests, innovation is the catalyst that turns creative concepts into tangible realities, making it indispensable for the survival and growth of any organization across industries. Strategic application of research findings throughout the innovation process ensures survival and positions organizations among the world's most innovative businesses.

Technological innovation plays a significant role in reshaping the textile and apparel industry, offering fresh perspectives to achieve shorter lead times and cost benefits while providing sophisticated and customized products at reasonable prices, thus enhancing the industry's competitive power in the global market. However, the pursuit of technological innovation also brings significant risks, necessitating the development of a robust risk management model. A one-size-fits-all approach to risk management is inadequate, given the varied organizational contexts and inherent complexities of innovation processes.

The developed risk management model offers a comprehensive approach by integrating key organizational elements such as investments, leadership skills, marketing strategies, human resource management, customer and supplier relationships, and R&D strategies. This tailored approach ensures that each component aligns with the organization's unique strengths and capabilities, enabling effective risk mitigation. By leveraging these resources in a cohesive framework, the model fosters sustainable growth, enhances innovation efforts, and secures a competitive edge in the market.

As part of the research, the findings provide comprehensive insights into various innovation concepts, their classifications, associated risk factors, and their root causes. These insights also highlight the prioritization of these risks. This in-depth understanding equips organizations with the ability to make informed decisions, thereby minimizing uncertainty and improving strategic planning. Moreover, organizations can utilize this knowledge to identify the most appropriate innovator type based on their key competencies, further elevating innovation efforts.

This strategic alignment serves as a potent tool for reducing uncertainty and complexity in innovation endeavours. Moreover, with NN outputs providing probabilities across all six innovator types, organizations gain valuable insights into their strengths and capabilities. This enables them to determine the most suitable innovation approach for expanding their market niche with greater confidence.

Furthermore, the developed risk management model fills critical gaps in the existing literature, offering novel features and benefits. The model ensures the privacy of organizational strategies while enhancing the organization's ability to remain resilient and adaptable in the face of future challenges. In addition, the model incorporates decisive concepts that enhance critical thinking, empowering organizations to reshape their strategies effectively by themselves. The integration of the board gaming concept adds novelty to the research, fostering innovative thinking and creativity within teams. Moreover, this is an interactive model, which brings down disconnect between technical and other teams and brings them all together to harness the full potential of the team. Since, this increases the effectiveness and transparency of the decisions made while empowering team members to make smarter alternatives.

By identifying potential disconnect between different phases of the innovation process, the model promotes a smoother flow and faster adaptation to both internal and external changes. This equips decision-makers with critical information to make effective, informed decisions at the earliest stages, ultimately driving organizational success. Furthermore, the methodology promotes collaboration among team members, leveraging their collective expertise to develop smarter solutions and control biased decisions.

The model's adaptability extends beyond technological innovations in the textile and apparel industry, offering potential applications in other manufacturing domains and inter-departmental technological innovation risk management. Moreover, this model can evolve into a comprehensive risk management model for the entire innovation process by incorporating key risk factors and identifying root causes of marketing and management innovations. By delineating core innovation concepts that encompass all 21 dimensions outlined in the literature, this enhanced model offers a structured approach to managing risks and fostering innovation across the board.

Another significant aspect is the model's ability to accommodate resolving additional risk factors, which are probable with future technological innovations. This can be accomplished by adding more unit cells to the game board, each with its own root causes and priorities. Besides, this is a generalized model, irrespective of the type of innovation and the position of the organization, i.e. whether it's a start-up, developing, or an established organization.

In a nutshell, the developed risk management model transforms risks into opportunities across three main phases of technological innovation in the textile and apparel industry. The model's acceptance, as evidenced by the impressive System Usability Scale rating, underscores its efficacy and potential for widespread adoption. By addressing critical points lacking in the existing literature, the model offers a comprehensive and customized approach to risk management in innovation processes, unlocking massive growth opportunities for organizations.

5.2 Limitations and future research

This research acknowledges several limitations that have already been addressed. Stakeholder decisions, critical to the outcomes, were supported by statistically validated judgments to reduce the potential for bias in interpreting qualitative feedback. To manage challenges in determining risk tolerance and handling unresolved risks, ordinal scales were introduced, enhancing precision in assessing likelihood, severity, and risk levels.

The risk matrices, initially vulnerable to human bias, have been improved through the implementation of team-based decision-making, transparency in action plans, and the use of clear, visible information. Additionally, the neural network's 60.7% accuracy in identifying innovator types has been enhanced through measures such as increasing dataset accuracy and optimizing the network structure via trial and error. Group discussions, which previously risked leaning toward extreme solutions, have been made more effective by forming experienced teams with a shared goal. This approach ensures balanced decisions and reduces bias.

For future advancements, a user-friendly interface could be developed to streamline questionnaire feedback, making it easier for organizations to identify their innovator type. Additionally, improving the accuracy of the neural network through an expanded dataset and hyper-parameter tuning is essential.

There is also potential to transform the risk management model into an online platform, which would support geographically dispersed organizations and foster collaborative teamwork towards shared objectives.

The research findings hold significant promise for broader application across various industries engaged in technological innovation. These insights offer valuable strategic guidance that can drive global growth and success across diverse sectors.

REFERENCES

- [1] International Trade Administration, “Sri Lanka Textiles,” *www.trade.gov*, May 08, 2024. <https://www.trade.gov/country-commercial-guides/sri-lanka-textile>
- [2] Export Development Board, "Industry Capability Report", Export Development Board, Sri Lanka, 2017.
- [3] S. Lawrence, "Reimagining the future of Sri Lanka’s apparel industry | Daily FT", *Ft.lk*, 2021. [Online]. Available:<https://www.ft.lk/columns/Reimagining-the-future-of-Sri-Lanka-s-apparel-industry/4-726821>. [Accessed: 07- Jan- 2022].
- [4] A. R. News-Desk, “Struggles for Sri Lanka’s apparel industry persist amidst decline in orders | Trade Data News Sri Lanka,” *Apparel Resources*, Mar. 22, 2023. <https://apparelresources.com/business-news/trade/struggles-sri-lankas-apparel-industry-persist-amidst-decline-orders/> [Accessed Jan. 20, 2024].
- [5] N. Samarasinghe, S. A. Ariadurai, and M. E. R. Perera, “Facing the Future Challenges of the Sri Lankan Apparel Industry: An Approach based on Porter’s Diamond Model for the Competitive Advantage of Nations,” *Journal of Engineering and Technology* , vol. 3, no. 1, Jan. 2015, doi: [https://doi.org/3\(1\):1-18](https://doi.org/3(1):1-18).
- [6] D. Tagra, “Growing focus on small order size | Apparel Resources,” *Apparel Resources India*, Mar. 15, 2023. <https://in.apparelresources.com/business-news/sourcing/growing-focus-small-order-size/> [Accessed Feb. 24, 2024].
- [7] Ç. Dođru, “Gaining Strategic Advantage through Social and Technological Innovation,” *Leadership Styles, Innovation, and Social Entrepreneurship in the Era of Digitalization*, pp. 25–43, 2020, doi: <https://doi.org/10.4018/978-1-7998-1108-4.ch002>.
- [8] D. M. Redín, G. Cabaleiro-Cerviño, I. Rodriguez-Carreño, and G. Scalzo, “Innovation as a practice: Why automation will not kill innovation,” *Frontiers in Psychology*, vol. 13, Jan. 2023, doi: <https://doi.org/10.3389/fpsyg.2022.1045508>.
- [9] L. Heracleous and A. Papachroni, “Strategic Leadership and Innovation at Apple Inc.,” *Sage*, 2016, doi: <https://doi.org/10.4135/9781526446565>.
- [10] R. McDonald and A. L. Paulson, “AIG in Hindsight,” Apr. 2015, doi: <https://doi.org/10.3386/w21108>.
- [11] G.Krasadakis, "Technology Innovation—Trends and Opportunities", <https://medium.com/ideachain/2018-innovation-trends-and-opportunities-8a5d642fd661>, 2017. [Online]. Available: <https://medium.com/ideachain/2018-innovation-trends-and-opportunities-8a5d642fd661>. [Accessed: 09- Dec- 2019].
- [12] H. Jindal and S. Kaur, “Robotics and Automation in Textile Industry,” *International Journal of Scientific Research in Science, Engineering*

- and Technology*, vol. 8, no. 3, pp. 40–45, May 2021, doi: <https://doi.org/10.32628/ijrsrset21839>.
- [13] R. Dhiman and M. Sharma, “Relation between Labour Productivity and Export Competitiveness of Indian Textile Industry: Co-integration and Causality Approach,” *Vision: The Journal of Business Perspective*, vol. 23, no. 1, pp. 22–30, Feb. 2019, doi: <https://doi.org/10.1177/0972262918821230>.
- [14] P. McGrath, L. McCarthy, D. Marshall, and J. Rehme, “Tools and Technologies of Transparency in Sustainable Global Supply Chains,” *California Management Review*, vol. 64, no. 1, p. 000812562110459, Sep. 2021, doi: <https://doi.org/10.1177/00081256211045993>.
- [15] J. Bowers and A. Khorakian, "Integrating risk management in the innovation project", *European Journal of Innovation Management*, vol. 17, no. 1, pp. 25-40, 2014. Available: <https://citeseerx.ist.psu.edu/viewdoc/download?>. [Accessed 3 June 2018].
- [16] K. Huang, K. Wang, P. K. C. Lee, and A. C. L. Yeung, “The impact of industry 4.0 on supply chain capability and supply chain resilience: A dynamic resource-based view,” *International Journal of Production Economics*, vol. 262, p. 108913, Aug. 2023, doi: <https://doi.org/10.1016/j.ijpe.2023.108913>.
- [17] J. Bowers and A. Khorakian, "Integrating risk management in the innovation project", *European Journal of Innovation Management*, vol. 17, no. 1, pp. 25-40, 2014. Available: <https://citeseerx.ist.psu.edu/viewdoc/download?>. [Accessed 3 June 2018].
- [18] R. Ahmed, “Risk Mitigation Strategies in Innovative Projects,” *Key Issues for Management of Innovative Projects*, 2017, doi: <https://doi.org/10.5772/intechopen.69004>. [Accessed: 01- Dec- 2020].
- [19] “One shoe fail that cost Nike over \$1.1 billion in m-cap; here’s what happened and how Twitter reacted,” *Financialexpress*, Feb. 26, 2019. <https://www.financialexpress.com/business/industry-one-shoe-fail-that-cost-nike-over-1-1-billion-in-m-cap-heres-what-happened-and-how-twitter-reacted-1499054/>
- [20] T. D. Sitaro, “Fast Fashion and Sustainability - The Case of Inditex-Zara,” Senior Thesis, Fordham University, 2020. Accessed: May 01, 2020. [Online]. Available: https://research.library.fordham.edu/cgi/viewcontent.cgi?article=1044&context=international_senior
- [21] Q. R. Xu, Z. Y. Wu, S. P. Zhang and S. Y. Liu, "Total innovation management paradigm for firm innovation system," *2014 IEEE International Conference on Management of Innovation and Technology*, Singapore, 2014, pp. 359-364.
- [22] F. Hermundsdottir and A. Aspelund, "Sustainability innovations and firm competitiveness: A review", *Journal of Cleaner Production*, vol. 280, p. 124715, 2021. Available: <https://doi.org/10.1016/j.jclepro.2020.124715>. [Accessed 4 June 2022].

- [23] A. Luqmani, M. Leach and D. Jesson, "Factors behind sustainable business innovation: The case of a global carpet manufacturing company", *Environmental Innovation and Societal Transitions*, vol. 24, pp. 94-105, 2017. Available: <https://doi.org/10.1016/j.eist.2016.10.007>. [Accessed 7 July 2018].
- [24] R. Macciotta and L. Lefsrud, "Framework for developing risk to life evaluation criteria associated with landslides in Canada", *Geoenvironmental Disasters*, vol. 5, no. 1, 2018. Available: <https://doi.org/10.1186/s40677-018-0103-7>. [Accessed 7 January 2019].
- [25] Export Development Board, "Industry Capability Report", Export Development Board, Sri Lanka, 2022.
- [26] G. Israel2, "Determining Sample Size", *Gjimt.ac.in*, 2017. [Online]. Available: https://www.gjimt.ac.in/wp-content/uploads/2017/10/2_Glenn-D.-Israel_Determining-Sample-Size.pdf. [Accessed: 14- Jun- 2018]
- [27] T. S. Nanjundeswaraswamy and S. Divakar, "Determination Of Sample Size And Sampling Methods In Applied Research," *Proceedings on Engineering Sciences*, vol. 3, no. 1, pp. 25–32, Mar. 2021, doi: <https://doi.org/10.24874/pes03.01.003>.
- [28] A. Embuldeniya, "(PDF) Impact of Apparel Industry on the Economy of Sri Lanka," *ResearchGate*, 2018. https://www.researchgate.net/publication/326543298_Impact_of_Apparel_Industry_on_the_Economy_of_Sri_Lanka
- [29] Hrat Ranaweera, "Uplifting Sri Lankan apparel industry through innovation management to face the challenges in the post MFA era," Jan. 2014.
- [30] S. Ahmad, S. Miskon, R. Alabdan, and I. Tlili, "Towards Sustainable Textile and Apparel Industry: Exploring the Role of Business Intelligence Systems in the Era of Industry 4.0," *Sustainability*, vol. 12, no. 7, p. 2632, Mar. 2020, Available: <https://www.mdpi.com/2071-1050/12/7/2632>
- [31] A. De, S. Gunathilake, H. Munaweera, D. Perera, and L. Gunathilake, "Competitive Edge Through Automation: A Study on the Sri Lankan Apparel Industry." Accessed: Mar. 10, 2022. [Online]. Available: <http://ir.kdu.ac.lk/bitstream/handle/345/5113/1%20Competitive%20Edge%20Through%20Automation.pdf?sequence=1&isAllowed=y>
- [32] J. De Silva, "New Product Development And Innovation Approaches: An Exploratory Study In Sri Lankan Apparel Manufacturing Organizations," *International Journal of Management and Applied Science*, vol. 2, no. 8, pp. 205–210, Aug. 2016, Accessed: Oct. 20AD.[Online].Available:https://www.researchgate.net/publication/308466646_new_product_development_and_innovation_approaches_an_exploratory_study_in_sri_lankan_apparel_manufacturing_organizations/
- [33] "TEXTILE AND APPAREL." Accessed: Jan. 24, 2024. [Online]. Available: https://www.nastec.gov.lk/files/nrdf/8_Textile.pdf

- [34] Harmeet Matharu, Dhanalakshmi, "The Role of Innovation and Creativity in Development of Entrepreneurship", *International Journal of Science and Research (IJSR)* 2017, pp. 437-439.
- [35] N. Seram, J. Nanayakkara, and G. Lanarolle, "Decision-Making in the Front-End of Apparel Innovation: A Study from Sri Lanka," *Fashion Practice*, vol. 11, no. 2, pp. 151–174, May 2019, doi: <https://doi.org/10.1080/17569370.2019.1607225>.
- [36] G. Gunday, G. Ulusoy, K. Kilic, and L. Alpkan, "Effects of innovation types on firm performance," *International Journal of Production Economics*, vol. 133, no. 2, pp. 662–676, Oct. 2011, doi: <https://doi.org/10.1016/j.ijpe.2011.05.014>.
- [37] J. Koehler, "Resource Management | Business Resources | Grantham University," *University of Arkansas Grantham*, May 17, 2019. <https://www.uagrantham.edu/blog/a-guide-to-organizational-resources-and-how-to-manage-them/>
- [38] J. Guo, P. Jiang, J. W. Guo, J. Zhang and R. H. Tan, "Innovation design of existing product based on function recombination," *2012 IEEE International Conference on Management of Innovation & Technology (ICMIT)*, Sanur Bali, 2012, pp. 812-817.
- [39] Rachkara John, Olido Kenneth, Wakwabubi Michael Jackson, "Business Model Innovations of Small and Medium Agribusinesses in Least Developed Markets", *International Journal of Science and Research (IJSR)* 2016, pp. 1938-1942. DOI: 10.21275/ART20176927
- [40] S. Ahmad, S. Miskon, R. Alabdan, and I. Tlili, "Towards Sustainable Textile and Apparel Industry: Exploring the Role of Business Intelligence Systems in the Era of Industry 4.0," *Sustainability*, vol. 12, no. 7, p. 2632, Mar. 2020, Available: <https://www.mdpi.com/2071-1050/12/7/2632>
- [41] N. Tuan, N. Nhan, P. Giang, and N. Ngoc, "The effects of innovation on firm performance of supporting industries in Hanoi, Vietnam," *Journal of Industrial Engineering and Management*, vol. 9, no. 2, p. 413, Apr. 2016, doi: <https://doi.org/10.3926/jiem.1564>.
- [42] X. Dongmei and F. Lili, "Explore the Cultural Roots Leading to Difference of National Innovation Ability - An Empirical Analysis Based on Chinese and German Samples," *2010 3rd International Conference on Information Management, Innovation Management and Industrial Engineering*, Kunming, 2010, pp. 60-6325.
- [43] H. Xu, "A Comprehensive Evaluation Model and Empirical of Apparel Industry Cluster," *2009 Fourth International Conference on Computer Sciences and Convergence Information Technology*, Seoul, 2009, pp. 529-533. doi: 10.1109/ICCIT.2009.166
- [44] Tarun Radadiya, "Advance Technology, New Innovation Utilizes in Warehouse, Logistics and Supply Change Management", *International Journal of Science and Research (IJSR)* 2017, pp. 876-894.

- [45] D. C. Agarwal, Sakshi Chauhan, "E-Banking in India: Innovations, Challenges and Opportunities", *International Journal of Science and Research (IJSR)* 2018, pp. 536-541.
- [46] Bernardus Franco Maseke, "Exploring ICT Innovation Factors among Rural Youth in Namibia", *International Journal of Science and Research (IJSR)* 2016, pp. 873-875. DOI: 10.21275/ART20161650
- [47] D. Wanliang and Z. Huiying, "Rethinking of Innovation Value Evaluation Based on Innovation Ethics," *2010 3rd International Conference on Information Management, Innovation Management and Industrial Engineering*, Kunming, 2010, pp. 464-467.
- [48] Eddyne Yamuremye, Hellen K. Mberia, Caroline Nabuzale, "Influence of Integrated Marketing Communications Tools on Adoption of Telecommunications Innovations", *International Journal of Science and Research (IJSR)* 2018, pp. 836-839. DOI: 10.21275/ART2018293
- [49] Chen Ming, Cui Bibo and Man Haiyan, "Theoretical analysis of the effect of management control method on enterprise innovation model selection," *2012 International Conference on Information Management, Innovation Management and Industrial Engineering*, Sanya, 2012, pp. 192-194.
- [50] D. Wanliang and Z. Huiying, "Rethinking of Innovation Value Evaluation Based on Innovation Ethics," *2010 3rd International Conference on Information Management, Innovation Management and Industrial Engineering*, Kunming, 2010, pp. 464-467.
- [51] W. Chongfeng and C. Yixuan, "Research on Regional Independent Innovation and Open Innovation Optimization Strategy under Innovation Driving Strategy: Taking the biomedical industry of China as an example," *2018 IEEE International Symposium on Innovation and Entrepreneurship (TEMS-ISIE)*, Beijing, 2018, pp. 1-10.
- [52] E. Kaya, F. D. Caliskan and S. Gozlu, "Manufacturing Performance Criteria: An AHP Application in a Textile Company," *PICMET '07 - 2007 Portland International Conference on Management of Engineering & Technology*, Portland, OR, 2007, pp. 1186-1194. doi: 10.1109/PICMET.2007.4349442
- [53] W. Zhu, J. Zhong, K. Wang and K. Yan, "The Research of Enterprises Self-oriented Innovation Related Concepts," *2011 International Conference on Information Management, Innovation Management and Industrial Engineering*, Shenzhen, 2011, pp. 161-164.
- [54] L. Jing and W. Mengting, "The influence factors of enterprise innovation ability construction and the strategy research," *2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 2013, pp. 139-142.
- [55] D. Wanliang and Z. Huiying, "Rethinking of Innovation Value Evaluation Based on Innovation Ethics," *2010 3rd International Conference on Information Management, Innovation Management and Industrial*

- Engineering*, Kunming, 2010, pp. 464-467.
doi: 10.1109/ICIII.2010.432
- [56] B. Zhu and J. Fang, "Evaluation of technology import and re-innovation capabilities of four industries in Fujian Province and analysis of affecting factors," *2012 International Symposium on Management of Technology (ISMOT)*, Hangzhou, 2012, pp. 292-297.
- [57] H. Yuetong and L. Xiaohui, "The Influence of Openness to Innovation Performance," *2011 International Conference on Information Management, Innovation Management and Industrial Engineering*, Shenzhen, 2011, pp. 6-9.
doi: 10.1109/ICIII.2011.9
- [58] Z. Gao, "Analysis of Trust Level How to Affect Innovative Behavior in Technical Innovation Alliance Based on Bryant Play Game," *2009 International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 2009, pp. 322-324.
- [59] K. Ji, J. Dang and K. Nawata, "Does innovation promote exports? Evidence from Chinese manufacturing firms," *2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, Bali, 2016, pp. 666-669.
- [60] Adrian Soemantadiredja, Aida Vitayala, IrmanHermadi," Analysis Adoption of Innovation Go-jek Application", *International Journal of Science and Research (IJSR)* 2017, pp.936-940. DOI: 10.21275/ART2017148
- [61] Sandeep Kaur," A Study on New Innovations in Banking Sector", *International Journal of Science and Research (IJSR)* 2016, pp.1780-1782
- [62] C. Shouyu and L. Wencong, "The Key Factors Affecting Technological Innovation in Shaoxing' Textile Industry," *2009 International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 2009, pp. 137-140.
doi: 10.1109/ICIII.2009.40
- [63]T. Schiederig, F. Tietze, and C. Herstatt, "What is Green Innovation? -A quantitative literature review." Accessed: Jan. 07, 2024. [Online]. Available: <https://tore.tuhh.de/dspace-cris-server/api/core/bitstreams/831ad6e1-ebf1-4edf-ac06-f65083c0f2b7/content>
- [64] M. V. Pai, "A list of attributes which may have significant influence on Innovation: An empirical study in Information Technology Sector," *2014 10th International Conference on Innovations in Information Technology (IIT)*, Al Ain, 2014, pp. 60-64.
- [65] M.R. Menkes, "User Innovation: State of the Art and Perspectives for future Research," *Journal of Entrepreneurship, Management and Innovation*, ISSN: 2299 – 7326, DOI: 10:7341.
- [66] E.V.Hippel, "Chapter 9-Open User Innovation," *Handbook of the Economics of Innovation*, 2010, vol.1, pp 411-427.
- [67] B. Dai, "Research on the Cooperative Innovation Risk Management of Industry-University-Research Institute Based on Meta-synthesis

- Engineering," *2011 International Conference on Information Management, Innovation Management and Industrial Engineering*, Shenzhen, 2011, pp. 514-517. doi: 10.1109/ICIII.2011.269
- [68] J. S. Nadan, "Using innovation science to minimize entrepreneurial risk," *2014 IEEE Innovations in Technology Conference*, Warwick, RI, 2014, pp. 1-7.
- [69] M. Akbari, M. Khodayari, A. Khaleghi, M. Danesh, and H. Padash, "Technological innovation research in the last six decades: a bibliometric analysis," *European Journal of Innovation Management*, vol. 24, no. 5, pp. 1806–1831, Oct. 2020, doi: <https://doi.org/10.1108/ejim-05-2020-0166>.
- [70] Chen Ming, Cui Bibo and Man Haiyan, "Theoretical analysis of the effect of management control method on enterprise innovation model selection," *2012 International Conference on Information Management, Innovation Management and Industrial Engineering*, Sanya, 2012, pp. 192-194.
- [71] J. S. Nadan, "Using innovation science to minimize entrepreneurial risk," *2014 IEEE Innovations in Technology Conference*, Warwick, RI, 2014, pp. 1-7.
- [72] Ajay Balhra, Kiran Rani, "Mapping the Hurdles in Innovation at the Level of Policy and Practice: The Way Ahead", *International Journal of Science and Research (IJSR)* 2016, pp. 464-468.
- [73] R. Mota and J. Oliveira, "Combining innovation and sustainability: an educational paradigm for human development on earth", *Brazilian Journal of Science and Technology*, vol. 1, no. 1, p. 2, 2014. Available: 10.1186/2196-288x-1-2 [Accessed 1 September 2019].
- [74] M. Daksa, M. Yismaw, S. Lemessa and S. Hundie, "Enterprise innovation in developing countries: an evidence from Ethiopia", *Journal of Innovation and Entrepreneurship*, vol. 7, no. 1, 2018. Available: <https://doi.org/10.1186/s13731-018-0085-4>. [Accessed 15 December 2018].
- [75] S. Hussain, S. Lei, T. Akram, M. Haider, S. Hussain and M. Ali, "Kurt Lewin's change model: A critical review of the role of leadership and employee involvement in organizational change", *Journal of Innovation & Knowledge*, vol. 3, no. 3, pp. 123-127, 2018. Available: <https://doi.org/10.1016/j.jik.2016.07.002>. [Accessed 8 January 2019].
- [76] L. Brown and S. Osborne, "Risk and Innovation", *Public Management Review*, vol. 15, no. 2, pp. 186-208, 2013. Available: <https://doi.org/10.1080/14719037.2012.707681>. [Accessed 8 May 2018].
- [77] A. Kustrak Korper, S. Holmlid, and L. Patrício, "The role of meaning in service innovation: a conceptual exploration," *Journal of Service Theory and Practice*, vol. ahead-of-print, no. ahead-of-print, Mar. 2021, doi: <https://doi.org/10.1108/jstp-01-2020-0004>.
- [78] L. Witell, H. Snyder, A. Gustafsson, P. Fombelle and P. Kristensson, "Defining service innovation: A review and synthesis", *Journal of Business Research*, vol. 69, no. 8, pp. 2863-2872, 2016. Available: <https://ideas.repec.org/a/eee/jbrese/v69y2016i8p2863-2872.html>. [Accessed 13 July 2018].

- [79] M. N. Jotabá, C. I. Fernandes, M. Gunkel, and S. Kraus, "Innovation and human resource management: a systematic literature review," *European Journal of Innovation Management*, vol. 25, no. 6, Jan. 2022, doi: <https://doi.org/10.1108/ejim-07-2021-0330>.
- [80] I. Demirkan, "The impact of firm resources on innovation," *European Journal of Innovation Management*, vol. 21, no. 4, pp. 672–694, Oct. 2018, doi: <https://doi.org/10.1108/ejim-12-2017-0196>. [Accessed 13 December 2018].
- [81] D. V. Gowda, K. S. Shashidhara, M. Ramesha, S. B. Sridhara, and S. B. Manoj Kumar, "Recent advances in graph theory and its applications," *Advances in Mathematics: Scientific Journal*, vol. 10, no. 3, pp. 1407–1412, Mar. 2021, doi: <https://doi.org/10.37418/amsj.10.3.29>.
- [82] N. Woolf and C. Silver, *Qualitative Analysis Using ATLAS.ti, NVivo and MAXQDA The Five-Level QDA™ Method*, 1st ed. Routledge, 2018.
- [83] K. Charmaz, and A. Bryant, *Grounded Theory, International Encyclopedia of Education*, 3rd ed. Elsevier, 2010.
- [84] H. Suzana Mediani, "An Introduction to Classical Grounded Theory", *SOJ Nursing & Health Care*, vol. 3, no. 3, pp. 1-5, 2017. Available: https://www.researchgate.net/publication/326279914_An_Introduction_to_Classical_Grounded_Theory. [Accessed 5 August 2018].
- [85] E. Ostertagová, O. Ostertag, and J. Kováč, "Methodology and Application of the Kruskal-Wallis Test," *Applied Mechanics and Materials*, vol. 611, pp. 115–120, Aug. 2014, doi: <https://doi.org/10.4028/www.scientific.net/amm.611.115>.
- [86] R. Müller, F. Strauhs, J. Queiroz and C. Silva, "Cooperative networks for innovation: a panorama of the Brazilian scenario between 2003 and 2011", *RAI Revista de Administração e Inovação*, vol. 14, no. 1, pp. 41-51, 2017. Available: <https://doi.org/10.1016/j.rai.2016.05.003>. [Accessed 16 August 2018].
- [87] Alice Lam, *Innovative Organizations: Structure, Learning and Adaptation*, Available at: <https://www.bbvaopenmind.com/en/articles/innovative-organizations-structure-learning-and-adaptation/> [Accessed: Nov. 10, 2019].
- [88] W. Martin, "How technology has changed the world of work", *World Economic Forum*, 2018. [Online]. Available: <https://www.weforum.org/agenda/2018/04/this-chart-shows-every-major-technological-innovation-in-the-last-150-years-and-how-they-have-changed-the-way-we-work>. [Accessed: 07- Jan- 2019].
- [89] A. Constantinescu and S. Frone, "The role of technological innovation in sustainable economic development," vol. 4, no. 1.1, p. 13, Feb. 2014, Available: https://www.researchgate.net/publication/267748514_The_role_of_technological_innovation_in_sustainable_economic_development

- [90] S. kochar, "Top 9 Technology Trends Reshaping The Fashion Industry In 2021", *Techpacker Blog*, 2021. [Online]. Available: <https://techpacker.com/blog/design/top-7-fashion-technology-trends/>. [Accessed: 17- Jun- 2021].
- [90] B. Harsanto, I. Primiana, V. Sarasi, and Y. Satyakti, "Sustainability Innovation in the Textile Industry: A Systematic Review," *Sustainability*, vol. 15, no. 2, p. 1549, Jan. 2023, doi: <https://doi.org/10.3390/su15021549>.
- [91] V. Pirenne, "The 4 types of innovators: hunters, builders, explorers, and experimenters", *Board of Innovation*. [Online]. Available: <https://www.boardofinnovation.com/blog/types-of-innovators-innovation-matrix/>. [Accessed: 17- Sep- 2020].
- [92] J. Manly, F. Grassl, and T. Wilson, "Which innovation Model is Right foR YouR coMpanY?" Accessed: Jul. 16, 2023. [Online]. Available: https://web-assets.bcg.com/img-src/BCG-Which-Innovation-Model-Is-Right-for-Your-Company-Nov-2017_tcm9-175607.pdf [Accessed 11 September 2018].
- [93] k. Govil, "12 Personality Traits That Successful Content Creators Have In Common | MissMalini", *MissMalini | Latest Bollywood, Fashion, Beauty & Lifestyle News*, 2020. [Online]. Available: <https://www.missmalini.com/2020/07/23/12-personality-traits-that-successful-content-creators-have-in-common/>. [Accessed: 17- Aug- 2020].
- [94] T. Team, "Here's How Nike Is Innovating To Scale Up Its Manufacturing", *Forbes*, 2019. [Online]. Available: <https://www.forbes.com/sites/greatspeculations/2016/05/18/heres-how-nike-is-innovating-to-scale-up-its-manufacturing/>. [Accessed: 07- Jul- 2019].
- [95] Alice Lam, Innovative Organizations: Structure, Learning and Adaptation, Available at: <https://www.bbvaopenmind.com/en/articles/innovative-organizations-structure-learning-and-adaptation/> [Accessed: Nov. 10,2019].
- [96] Q. Xu, J. Chen, Y. Shou, and J. Liu, "Leverage Innovation Capability," *World Scientific*, Oct. 2011, doi: <https://doi.org/10.1142/7855>.
- [97] "Business innovation: Pros and cons of the fast follower approach | 23rd February 2018 | News," *BIE Executive Ltd*, Feb. 23, 2018. <https://www.bie-executive.com/news/business-innovation-pros-and-cons-of-the-fast-follower-approach/bp182/> (accessed 18, 2019).
- [98] Adidas, "adidas aims to end plastic waste with innovation + partnerships as the solutions," *news.adidas.com*, Jan. 28, 2020. <https://news.adidas.com/running/adidas-aims-to-end-plastic-waste-with-innovation---partnerships-as-the-solutions/s/be70ac18-1fc9-45c1-9413-d8abaac2e849>
- [99] A. R. News-Desk, "Top fashion brands like H&M, Zara and Nike called out for greenwashing | Retail News Sweden," *Apparel Resources*, Aug. 25, 2022.

- <https://apparelresources.com/business-news/retail/top-fashion-brands-like-hm-zara-nike-called-greenwashing/>
- [100] T. McKinnon, “The Growth Story Behind lululemon,” *Indigo9 Digital Inc.*, Feb. 13, 2020. <https://www.indigo9digital.com/blog/lululemongrowthstrategy>
- [101] P. Arora, “Strategy that failed the business model of Forever 21 - The Strategy Story,” *TheStrategyStory*, Jun. 28, 2021. <https://thestrategystory.com/2021/06/28/wrong-strategy-in-forever-21-business-model/>
- [102] A. Barrichello, E. G. dos Santos, and R. S. Morano, “Determinant and priority factors of innovation for the development of nations,” *Innovation & Management Review*, vol. 17, no. 3, pp. 307–320, Apr. 2020, doi: <https://doi.org/10.1108/inmr-04-2019-0040>.
- [103] S. Hu, G. Zeng, X. Cao, H. Yuan, and B. Chen, “Does Technological Innovation Promote Green Development? A Case Study of the Yangtze River Economic Belt in China,” *International Journal of Environmental Research and Public Health*, vol. 18, no. 11, p. 6111, Jun. 2021, doi: <https://doi.org/10.3390/ijerph18116111>.
- [104] V. Raghupathi and W. Raghupathi, “Exploring science-and-technology-led innovation: a cross-country study,” *Journal of Innovation and Entrepreneurship*, vol. 8, no. 1, Jan. 2019, doi: <https://doi.org/10.1186/s13731-018-0097-0>.
- [105] M. Uddin, "Big data analysis is key to onboard buyers successfully (Part 1)", *Textile News, Apparel News, RMG News, Fashion Trends*, 2021. [Online]. Available: <https://www.textiletoday.com.bd/big-data-analysis-key-onboard-buyers-successfully-part-1/>. [Accessed: 17- Aug- 2021].
- [106] S. Gerber, “10 innovative technologies with potential impact for business,” *TNW | Contributors*, Nov. 30, 2018. <https://thenextweb.com/news/10-innovative-technologies-with-potential-impact-for-business>
- [107] S. Chaudhary, P. Kumar, and P. Johri, “Maximizing performance of apparel manufacturing industry through CAD adoption,” *International Journal of Engineering Business Management*, vol. 12, p. 184797902097552, Jan. 2020, doi: <https://doi.org/10.1177/1847979020975528>.
- [108] N. Weerasinghe, A. Weerasinghe, Y. Perera, Sanduni Tennakoon, N. M. Rathnayake, and P. Jayasinghe, “Sustainability practices and organizational performance during the COVID-19 pandemic and economic crisis: A case of apparel and textile industry in Sri Lanka,” *Plos one*, vol. 18, no. 7, pp. e0288179–e0288179, Jul. 2023, doi: <https://doi.org/10.1371/journal.pone.0288179>.
- [109] “One shoe fail that cost Nike over \$1.1 billion in m-cap; here’s what happened and how Twitter reacted,” *Financialexpress*, Feb. 26, 2019. <https://www.financialexpress.com/business/industry-one-shoe-fail-that-cost->

nike-over-1-1-billion-in-m-cap-heres-what-happened-and-how-twitter-reacted-1499054/

- [110] X. Wu, L. Chen, Y. Zhou, and X. Ding, "Research in risk assessment for textile and apparel and propose a future research agenda with a conceptual framework," *International Journal of Productivity and Quality Management*, vol. 17, no. 3, p. 273, 2016, doi: <https://doi.org/10.1504/ijpqm.2016.074860>.
- [111]. B. Dai, "An empirical study on influencing factors of the risk of industrial technology innovation strategic alliance: An example of a new-energy industrial alliance," 2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering, Xi'an, 2013, pp. 413-415. doi:10.1109/ICIII.2013.6702961
- [112] G. Thangamani, "Risk Assessment of Product Innovation and Development Using Markov Process Approach", *Ijimt.org*, 2018. [Online]. Available: <http://www.ijimt.org/vol9/813-M780.pdf>. [Accessed: 20- Mar- 2019].
- [113] "Write a marketing plan". [Online]. Available: <https://www.infoentrepreneurs.org/en/guides/write-a-marketing-plan/>. [Accessed: 30-April.-2018].
- [114] "Organizational Innovation", 2019. [Online]. Available: <https://oxfordre.com/business/business/view/>. [Accessed: 17-Nov- 2019].
- [115] T. Segal, "Learn the Common Ways to Measure Risk in Investment Management," *Investopedia*, 2019. <https://www.investopedia.com/ask/answers/041415/what-are-some-common-measures-risk-used-risk-management.asp>
- [116] I. Sidhu, T. Lavian and V. Howell, "R&D models for advanced development & corporate research: Understanding six models of advanced R&D," 2015 IEEE International Conference on Engineering, Technology and Innovation/ International Technology Management Conference (ICE/ITMC), Belfast, 2015, pp. 1-6. doi: 10.1109/ICE.2015.7438653
- [117] B. Savic, Z. Vasijevic and N. Popovic, "The role and importance of strategic budgeting for competitiveness of the agribusiness supply chain", *Ekonomika poljoprivrede*, vol. 63, no. 1, pp. 295-312, 2016. Available: https://www.researchgate.net/publication/302057908_The_role_and_importance_of_strategic_budgeting_for_competitiveness_of_the_agribusiness_supply_chain. [Accessed 23 September 2018].
- [118] X. Li, W. Zhao, Y. Zheng, R. Wang and C. Wang, "Innovative Product Design Based on Comprehensive Customer Requirements of Different Cognitive Levels", *The Scientific World Journal*, vol. 2014, pp. 1-11, 2014. Available: <http://Innovative Product Design Based on Comprehensive Customer Requirements of Different Cognitive Levels>. [Accessed 21 September 2018].
- [119] S. Cho and H. Kim, "Intellectual property rights protection and technological innovation: The moderating effect of internationalization | Emerald Insight", *Emerald.com*, 2017. [Online]. Available:

<https://www.emerald.com/insight/content/doi/10.1108/MBR-04-2017-0019/full/html?skipTracking=true>. [Accessed: 11- Nov- 2019].

- [120] K. Voigt, C. Baccarella, A. Wassmus and O. Meißner, "The effects of customer orientation on the product performance of technological innovations: A comparison between SMEs and large companies," 2011 Proceedings of PICMET '11: Technology Management in the Energy Smart World (PICMET), Portland, OR, 2011, pp. 1-11
- [120] R. Lekamge and N. Ekanayake, "Internal Quality Failures of Apparel Industry: A Case from Sri Lanka," *Open Journal of Business and Management*, vol. 09, no. 05, pp. 2389–2406, 2021, doi: <https://doi.org/10.4236/ojbm.2021.95129>.
- [121] T. Y. Choi and D. R. Krause, "The Supply Base and Its complexity: Implications for Transaction costs, risks, responsiveness, and Innovation," *Journal of Operations Management*, vol. 24, no. 5, pp. 637–652, Nov. 2006, doi: <https://doi.org/10.1016/j.jom.2005.07.002>.
- [122] A. Coad, P. Nightingale, J. Stilgoe and A. Vezzani, "Editorial: the dark side of innovation", *Industry and Innovation*, vol. 28, no. 1, pp. 102-112, 2020. Available: <https://doi.org/10.1080/13662716.2020.1818555>. [Accessed 8 November 2020].
- [123] Y.-C. Yang and J. Hsu, "Organizational process alignment, culture and innovation," *African Journal of Business Management*, vol. 4, no. 11, pp. 2231–2240, Sep. 2010, doi: <https://doi.org/10.5897/ajbm.9000446>.
- [124] V. Kaartemo and A. Nyström, "Emerging technology as a platform for market shaping and innovation", *Journal of Business Research*, vol. 124, pp. 458-468, 2021. Available: <https://doi.org/10.1016/j.jbusres.2020.10.062>. [Accessed 8 December 2021].
- [125] M. Kalantari, M. Rabbani and M. Ebadian, "A decision support system for order acceptance/rejection in hybrid MTS/MTO production systems", *Applied Mathematical Modelling*, vol. 35, no. 3, pp. 1363-1377, 2011. Available: <https://doi.org/10.1016/j.apm.2010.09.015>. [Accessed 8 March 2022].
- [126] Wen Hongmei and Li Shijiao, "Empirical analysis on technological innovation risk in China's financial enterprises based on AHP method," 5th International Conference on Computer Sciences and Convergence Information Technology, Seoul, 2010, pp. 776-780. doi: 10.1109/ICCIT.2010.5711160
- [127] "Sustainability | Free Full-Text | The Role of Stakeholders in the Context of Responsible Innovation: A Meta-Synthesis," *Mdpi.com*, 2019. https://www.mdpi.com/2071-1050/11/6/1766/review_report (accessed Feb. 09, 2025).
- [128] C. Karlsson, "Innovation Adoption and the Product Life Cycle," Publisher: Taylor & Francis, University of Umea, 2015. Available: <https://www.diva-portal.org/smash/get/diva2:792156/FULLTEXT01.pdf>

- [129] R. F. Hurley and G. T. M. Hult, "Innovation, Market Orientation, and Organizational Learning: An Integration and Empirical Examination," *Journal of Marketing*, vol. 62, no. 3, p. 42, Jul. 1998, Available: <https://www.jstor.org/stable/1251742>
- [130] Y. Yang and J. Hsu, "Organizational process alignment, culture and innovation", *Academicjournals.org*, 2010. [Online]. Available: <https://academicjournals.org/journal/AJBM/article-full-text-pdf/F1B459626415>. [Accessed: 07- May- 2019].
- [131] K. Andersson, "Process Innovation Challenges - how to reduce Uncertainty through Discrete Event Simulation", M.Sc., 2017.
- [132] L. Silva, C. Bitencourt, K. Faccin and T. Iakovleva, "The Role of Stakeholders in the Context of Responsible Innovation: A Meta-Synthesis", *Sustainability*, vol. 11, no. 6, p. 1766, 2019. Available: <https://doi.org/10.3390/su11061766>. [Accessed 8 April 2020].
- [133] R. P. J. Rajapathirana and Y. Hui, "Relationship between innovation capability, innovation type, and firm performance," *Journal of Innovation & Knowledge*, vol. 3, no. 1, pp. 44–55, Jan. 2018, doi: <https://doi.org/10.1016/j.jik.2017.06.002>.
- [134] V. Govindarajan and C. Trimble, *The other side of innovation*. Boston, Mass: Harvard Business Review Press, 2010, pp. 101-108.
- [135] H. J. Quesada-Pineda and J. Madrigal, "Sustaining Continuous Improvement: A Longitudinal and Regional Study," *International Journal of Engineering Business Management*, vol. 5, p. 43, Jan. 2013, doi: <https://doi.org/10.5772/56860>.
- [136] K. Abhari and S. McGuckin, "Limiting factors of open innovation organizations: A case of social product development and research agenda," *Technovation*, p. 102526, May 2022, doi: <https://doi.org/10.1016/j.technovation.2022.102526>.
- [137] M. Tajvidi and A. Karami, "Innovation Capacity", *Product Development Strategy*, pp. 125-146, 2015. Available: https://doi.org/10.1057/9781137501394_5. [Accessed 5 November 2018].
- [138] B. Y. Akcali and E. Sismanoglu, "Innovation and the Effect of Research and Development (R&D) Expenditure on Growth in Some Developing and Developed Countries," *Procedia - Social and Behavioral Sciences*, vol. 195, pp. 768–775, Jul. 2015, doi: <https://doi.org/10.1016/j.sbspro.2015.06.474>.
- [139] A. Watt, "16. Risk Management Planning", *Opentextbc.ca*. [Online]. Available: <https://opentextbc.ca/projectmanagement/chapter/chapter-16-risk-management-planning-project-management>. [Accessed: 08- Dec- 2021].
- [140] E. Inha and S. Bohlin, "Review Article Development of innovation products by using Kano model", *Diva-portal.org*. [Online]. Available: <https://www.diva-portal.org/smash/get/diva2:1080938/FULLTEXT01.pdf>. [Accessed: 08- Mar- 2019].

- [141] S. Munikoti, L. Das and B. Natarajan, "Bayesian Graph Neural Network for Fast identification of critical nodes in Uncertain Complex Networks," *2021 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, Melbourne, Australia, 2021, pp. 3245-3251, doi: 10.1109/SMC52423.2021.9658873.
- [142] S. Abby, "Advantages and Disadvantages of Correlational Analysis," *Getrevising.co.uk*, 2015. <https://getrevising.co.uk/grids/advantages-and-disadvantages-of-correlational>
- [143] "Regression Analysis: Types, Importance and Limitations." <https://commercemates.com/regression-analysis/>
- [144] R.-M. Ştefan, "A Comparison of Data Classification Methods," *Procedia Economics and Finance*, vol. 3, pp. 420–425, 2012, doi: [https://doi.org/10.1016/s2212-5671\(12\)00174-8](https://doi.org/10.1016/s2212-5671(12)00174-8).
- [145] N. Woolf and C. Silver, *Qualitative Analysis Using ATLAS.ti, NVivo and MAXQDA The Five-Level QDA™ Method*, 1st ed. Routledge, 2018.
- [146] M. Suyal and P. Goyal, "A Review on Analysis of K-Nearest Neighbor Classification Machine Learning Algorithms based on Supervised Learning," *International Journal of Engineering Trends and Technology*, vol. 70, no. 7, pp. 43–48, Jul. 2022, doi: <https://doi.org/10.14445/22315381/ijett-v70i7p205>.
- [147] T.-T. Huynh-Cam, L.-S. Chen, and H. Le, "Using Decision Trees and Random Forest Algorithms to Predict and Determine Factors Contributing to First-Year University Students' Learning Performance," *Algorithms*, vol. 14, no. 11, p. 318, Oct. 2021, doi: <https://doi.org/10.3390/a14110318>.
- [148] J. Cervantes, F. Garcia-Lamont, L. Rodríguez-Mazahua, and A. Lopez, "A comprehensive survey on support vector machine classification: Applications, challenges and trends," *Neurocomputing*, vol. 408, no. 1, pp. 189–215, Sep. 2020, doi: <https://doi.org/10.1016/j.neucom.2019.10.118>.
- [149] M. D. Guillen, J. Aparicio, and M. Esteve, "Gradient tree boosting and the estimation of production frontiers," *Expert Systems with Applications*, vol. 214, p. 119134, Mar. 2023, doi: <https://doi.org/10.1016/j.eswa.2022.119134>.
- [150] O. Davydova, "10 Applications of Artificial Neural Networks in Natural Language Processing", *Medium*, 2017. [Online]. Available: <https://medium.com/@datamonsters/artificial-neural-networks-in-natural-language-processing-bcf62aa9151a>. [Accessed: 26- Sep- 2020].
- [151] J. A. Sáez, M. Galar, and B. Krawczyk, "Addressing the Overlapping Data Problem in Classification Using the One-vs-One Decomposition Strategy," *IEEE Access*, vol. 7, pp. 83396–83411, 2019, doi: <https://doi.org/10.1109/ACCESS.2019.2925300>.
- [152] C. Bentéjac, A. Csörgő, and G. Martínez-Muñoz, "A comparative analysis of gradient boosting algorithms," *Artificial Intelligence Review*, vol. 54, Aug. 2020, doi: <https://doi.org/10.1007/s10462-020-09896-5>.

- [153] M. M. Mijwel, “Artificial Neural Networks Advantages and Disadvantages,” *Mesopotamian Journal of Big Data*, vol. 2021, pp. 29–31, Aug. 2021, doi: <https://doi.org/10.58496/MJBD/2021/006>.
- [154] D. Rad *et al.*, “A Radial Basis Function Neural Network Approach to Predict Preschool Teachers’ Technology Acceptance Behavior,” *Frontiers in Psychology*, vol. 13, Jun. 2022, doi: <https://doi.org/10.3389/fpsyg.2022.880753>.
- [155] Rémi Souriau, J. Lerbet, H. Chen, and V. Vigneron, “A review on generative Boltzmann networks applied to dynamic systems,” *Mechanical Systems and Signal Processing*, vol. 147, pp. 107072–107072, Jan. 2021, doi: <https://doi.org/10.1016/j.ymsp.2020.107072>.
- [156] S. Ding, H. Zhao, Y. Zhang, X. Xu, and R. Nie, “Extreme learning machine: algorithm, theory and applications,” *Artificial Intelligence Review*, vol. 44, no. 1, pp. 103–115, Apr. 2013, doi: <https://doi.org/10.1007/s10462-013-9405-z>.
- [157] D. Bianchi, R. Calogero and B. Tirozzi, "Kohonen neural networks and genetic classification", *Mathematical and Computer Modelling*, vol. 45, no. 1-2, pp. 34-60, 2007. Available: <https://doi.org/10.1016/j.mcm.2006.04.004>. [Accessed 20 April 2020].
- [158] H. Wang, J. Xiong, Z. Yao, M. Lin, and J. Ren, “Research Survey on Support Vector Machine,” Dec. 2017, doi: <https://doi.org/10.4108/eai.13-7-2017.2270596>.
- [159] "Feed Forward Neural Network", *DeepAI*. [Online]. Available: <https://deepai.org/machine-learning-glossary-and-terms/feed-forward-neural-network>. [Accessed: 28- Feb- 2021].
- [160] R. Bala and D. Kumar, "Classification Using ANN: A Review", *International Journal of Computational Intelligence Research*, vol. 13, no. 72017, pp. 1811-1820, 2017. Available: https://www.ripublication.com/ijcir17/ijcirv13n7_22.pdf. [Accessed 18 February 2020].
- [161] L. D’Arco, H. Wang, and H. Zheng, “DeepHAR: a deep feed-forward neural network algorithm for smart insole-based human activity recognition,” *Neural Computing and Applications*, vol. 35, no. 18, pp. 13547–13563, Mar. 2023, doi: <https://doi.org/10.1007/s00521-023-08363-w>.
- [162] J. M. Benitez, J. L. Castro, and I. Requena, “Are artificial neural networks black boxes?,” *IEEE Transactions on Neural Networks*, vol. 8, no. 5, pp. 1156–1164, Sep. 1997, doi: <https://doi.org/10.1109/72.623216>.
- [163] J. Tu, "Advantages and disadvantages of using artificial neural networks versus logistic regression for predicting medical outcomes", *Journal of Clinical Epidemiology*, vol. 49, no. 11, pp. 1225-1231, 1996. Available: [https://doi.org/10.1016/S0895-4356\(96\)00002-9](https://doi.org/10.1016/S0895-4356(96)00002-9). [Accessed 22 June 2020].
- [164] M. Xiao *et al.*, “Addressing Overfitting Problem in Deep Learning-Based Solutions for Next Generation Data-Driven Networks,” *Wireless*

- Communications and Mobile Computing*, vol. 2021, p. e8493795, Aug. 2021, doi: <https://doi.org/10.1155/2021/8493795>.
- [165] S. Vanbelle, “Comparing dependent kappa coefficients obtained on multilevel data,” *Biometrical Journal*, vol. 59, no. 5, pp. 1016–1034, May 2017, doi: <https://doi.org/10.1002/bimj.201600093>.
- [166] P. E. McKight and J. Najab, “Kruskal-Wallis Test,” *The Corsini Encyclopedia of Psychology*, Jan. 2010, doi: <https://doi.org/10.1002/9780470479216.corpsy0491>.
- [167] S. Kheybari, F. M. Rezaie, and H. Farazmand, “Analytic network process: An overview of applications,” *Applied Mathematics and Computation*, vol. 367, p. 124780, Feb. 2020, doi: <https://doi.org/10.1016/j.amc.2019.124780>.
- [168] P. Costa, N. Santos, P. Cunha, J. Cotter and N. Sousa, "The Use of Multiple Correspondence Analysis to Explore Associations between Categories of Qualitative Variables in Healthy Ageing", *Journal of Aging Research*, vol. 2013, pp.
- [169] Sourial N, Wolfson C, Zhu B, Quail J, Fletcher J, Karunanathan S, Bandeen-Roche K, Béland F, Bergman H. Correspondence analysis is a useful tool to uncover the relationships among categorical variables. *J Clin Epidemiol*. 2010 Jun; 63(6):638-46. doi: 10.1016/j.jclinepi.2009.08.008. Epub 2009 Nov 6. PMID: 19896800; PMCID: PMC3718710.
- [170] N. Salem and S. Hussein, “Data dimensional reduction and principal components analysis,” *Procedia Computer Science*, vol. 163, pp. 292–299, 2019, doi: <https://doi.org/10.1016/j.procs.2019.12.111>. [Accessed: 18- Jun- 2021].
- [171] L. Sauzéat, A. Laurençon, and V. Balter, “Metallome evolution in ageing *C. elegans* and a copper stable isotope perspective,” *Metallomics*, vol. 10, no. 3, pp. 496–503, 2018, doi: <https://doi.org/10.1039/c7mt00318h>. [Accessed: 11- Aug- 2021].
- [172] S. Mahmoud, A. Lotfi, and C. Langensiepen, “User Activities Outliers Detection; Integration of Statistical and Computational Intelligence Techniques,” *Computational Intelligence*, vol. 32, no. 1, pp. 49–71, Jun. 2014, doi: <https://doi.org/10.1111/coin.12045>. [Accessed: 09- Aug- 2021].
- [173] “Interpret all statistics and graphs for Principal Components Analysis,” *support.minitab.com*. <https://support.minitab.com/en-us/minitab/21/help-and-how-to/statistical-modeling/multivariate/how-to/principal-components/interpret-the-results/all-statistics-and-graphs/>. [Accessed: 14- Jul- 2021].
- [174]] M. Linting and A. van der Kooij, "Nonlinear Principal Components Analysis With CATPCA: A Tutorial", *Journal of Personality Assessment*, vol. 94, no. 1, pp. 12-25, 2012. Available: <http://pubmed.ncbi.nlm.nih.gov/22176263/>. [Accessed 23 August 2021].

- [175] Linting M, Meulman JJ, Groenen PJ, van der Kooij AJ. Nonlinear principal components analysis: introduction and application. *Psychol Methods*. 2007 Sep;12(3):336-58. doi: 10.1037/1082-989X.12.3.336. PMID: 17784798
- [176] “Root Cause Analysis - an overview | ScienceDirect Topics,” www.sciencedirect.com. <https://www.sciencedirect.com/topics/computer-science/root-cause-analysis> [Accessed Jan. 31, 2024].
- [177] A. Watt, "16. Risk Management Planning", *Opentextbc.ca*. [Online]. Available: <https://opentextbc.ca/projectmanagement/chapter/chapter-16-risk-management-planning-project-management>. [Accessed: 08- Dec- 2021].
- [178] P. Hibbert et al., "Are root cause analyses recommendations effective and sustainable? An observational study", *International Journal for Quality in Health Care*, vol. 30, no. 2, pp. 124-131, 2018. Available: <https://doi.org/10.1093/intqhc/mzx181>. [Accessed 9 March 2022].
- [179] N. Shrestha, “Factor Analysis as a Tool for Survey Analysis,” *American Journal of Applied Mathematics and Statistics*, vol. 9, no. 1, pp. 4–11, Jan. 2021, doi: <https://doi.org/10.12691/ajams-9-1-2>.
- [180] G. Cristea and D. Constantinescu, “A comparative critical study between FMEA and FTA risk analysis methods,” *IOP Conference Series: Materials Science and Engineering*, vol. 252, p. 012046, Oct. 2017, doi: <https://doi.org/10.1088/1757-899x/252/1/012046>.
- [181] C. Z. Yuan, Y. Zhang, J. Wang, and Tong Yating, “Modeling and evaluation of causal factors in emergency responses to fire accidents involving oil storage system,” *Scientific Reports*, vol. 11, no. 1, Sep. 2021, doi: <https://doi.org/10.1038/s41598-021-97785-4>.
- [182] Y. -C. Liao and H. Langweg, "Events and causal factors charting of kernel traces for root cause analysis," *2015 IEEE Symposium on Computers and Communication (ISCC)*, 2015, pp. 245-250, doi: 10.1109/ISCC.2015.7405523
- [183] M. Ogrizek, A. Kroflič, and M. Šala, “Critical review on the development of analytical techniques for the elemental analysis of airborne particulate matter,” *Trends in Environmental Analytical Chemistry*, vol. 33, p. e00155, Mar. 2022, doi: <https://doi.org/10.1016/j.teac.2022.e00155>.
- [184] K. Kumarapeli, R. Ratnayake and T. Jayawardena, "Quantification of Risks on Technological Innovation using Fuzzy Analytic Hierarchy Process", *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 7, pp. 1230-1237, 2020. Available: <https://www.ijitee.org/wp-content/uploads/papers/v9i7/G5622059720.pdf>. [Accessed 5 May 2020].
- [185] “Risk Identification - an overview | ScienceDirect Topics,” www.sciencedirect.com. <https://www.sciencedirect.com/topics/engineering/risk-identification> [Accessed Aug. 07, 2020].

- [186] M. M. D. Widianta, T. Rizaldi, D. P. S. Setyohadi, and H. Y. Riskiawan, "Comparison of Multi-Criteria Decision Support Methods (AHP, TOPSIS, SAW & PROMENTHEE) for Employee Placement," *Journal of Physics: Conference Series*, vol. 953, p. 012116, Jan. 2018, doi: <https://doi.org/10.1088/1742-6596/953/1/012116>.
- [187] K. Schmidt, I. Aumann, I. Hollander, K. Damm, and J.-M. G. von der Schulenburg, "Applying the Analytic Hierarchy Process in healthcare research: A systematic literature review and evaluation of reporting," *BMC Medical Informatics and Decision Making*, vol. 15, no. 1, Dec. 2015, doi: <https://doi.org/10.1186/s12911-015-0234-7>.
- [188] M. Asadabadi, E. Chang and M. Saberi, "Are MCDM methods useful? A critical review of Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP)", *Cogent Engineering*, vol. 6, no. 1, p. 1623153, 2019. Available: <https://doi.org/10.1080/23311916.2019.1623153>. [Accessed 18 July 2019].
- [189] A. Emrouznejad and M. Marra, "The state of the art development of AHP (1979–2017): a literature review with a social network analysis", *International Journal of Production Research*, vol. 55, no. 22, pp. 6653-6675, 2017. Available: <https://research.aston.ac.uk/en/publications/the-state-of-the-art-development-of-ahp-19792017-a-literature-rev>. [Accessed 2 February 2019].
- [190] A. Görener, *Users.encs.concordia.ca*, 2012. [Online]. Available: http://users.encs.concordia.ca/home/h/h_abaeia/Modular%20Construction/report%20in%20progress/AHP%20&%20ANP/AHP%20&%20ANP.pdf. [Accessed: 05- Jun- 2019].
- [191] İ. Yüksel and M. Dağdeviren, "Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm," *Information Sciences*, vol. 177, no. 16, pp. 3364–3382, Aug. 2007, doi: <https://doi.org/10.1016/j.ins.2007.01.001>.
- [192] P. Costa, N. Santos, P. Cunha, J. Cotter and N. Sousa, "The Use of Multiple Correspondence Analysis to Explore Associations between Categories of Qualitative Variables in Healthy Ageing", *Journal of Aging Research*, vol. 2013, pp.
- [193] N. T. Ismael, A. M. Abdulwahab, F. T. Alrawi and K. A. Alqessi, "Implementing a Super Decisions Software (SDS) in a Transport Sector," *2020 International Conference on Computer Science and Software Engineering (CSASE)*, 2020, pp. 215-220, doi: 10.1109/CSASE48920.2020.9142056.
- [194] J. K. Murnighan, "Game Theory," *The Palgrave Encyclopedia of Strategic Management*, pp. 597–601, 2018, doi: https://doi.org/10.1057/978-1-137-00772-8_416.

- [195] Abdallah, "Game theory in entrepreneurship: a review of the literature," *Journal of business and socio-economic development*, Sep. 2023, doi: <https://doi.org/10.1108/jbsed-01-2023-0005>.
- [196] G. Bornstein and I. Yaniv, "Individual and Group Behavior in the Ultimatum Game: Are Groups More "Rational" Players?. Experimental Economics 1", *Experimental Economics*, vol. 1, no. 1, pp. 101-108, 1998. Available: <https://doi.org/10.1023/A:1009914001822>. [Accessed 18 April 2021].
- [197] T. Kawamori, "Partially cooperative games," *Mathematical Social Sciences*, vol. 93, pp. 90–100, May 2018, doi: <https://doi.org/10.1016/j.mathsocsci.2018.03.001>.
- [198] C. F. Camerer, T.-H. Ho, and J. K. Chong, "Behavioural Game Theory: Thinking, Learning and Teaching," *Advances in Understanding Strategic Behaviour*, pp. 120–180, 2004, doi: https://doi.org/10.1057/9780230523371_8.
- [199] K. Miller, "17 Advantages and Disadvantages of Group Decision Making", *FutureofWorking.com*. [Online]. Available: <https://futureofworking.com/5-advantages-and-disadvantages-of-group-decision-making/>. [Accessed: 20- Jun- 2021].
- [200] N. Mukherjee, L. Dicks, G. Shackelford, B. Vira and W. Sutherland, "Comparing groups versus individuals in decision making: a systematic review protocol", *Environmental Evidence*, vol. 5, no. 1, 2016. Available: <https://doi.org/10.1186/s13750-016-0066-7>. [Accessed 5 June 2021].
- [201] R. Bron, M. D. Endedijk, R. van Veelen, and B. P. Veldkamp, "The Joint Influence of Intra- and Inter-Team Learning Processes on Team Performance: A Constructive or Destructive Combination?," *Vocations and Learning*, vol. 11, no. 3, pp. 449–474, Feb. 2018, doi: <https://doi.org/10.1007/s12186-018-9197-z>.
- [202] L. M. Padilla, S. H. Creem-Regehr, M. Hegarty, and J. K. Stefanucci, "Decision making with visualizations: a cognitive framework across disciplines," *Cognitive Research: Principles and Implications*, vol. 3, no. 1, Jul. 2018, doi: <https://doi.org/10.1186/s41235-018-0120-9>.
- [203] A. J. H. Boonen, F. van Wesel, J. Jolles, and M. van der Schoot, "The role of visual representation type, spatial ability, and reading comprehension in word problem solving: An item-level analysis in elementary school children," *International Journal of Educational Research*, vol. 68, no. 4, pp. 15–26, 2014, doi: <https://doi.org/10.1016/j.ijer.2014.08.001>.
- [204] "data visualization - Benelux Intelligence Community," www.bi-kring.nl. <https://www.bi-kring.nl/component/easytagcloud/293-module/423-data-visualization> [Accessed Nov. 03, 2022].
- [205] J. Village, C. Searcy, F. Salustri, and W. Patrick Neumann, "Design for human factors (DfHF): a grounded theory for integrating human factors into

- production design processes,” *Ergonomics*, vol. 58, no. 9, pp. 1529–1546, Mar. 2015, doi: <https://doi.org/10.1080/00140139.2015.1022232>.
- [206] H. Mohajan, “Two Criteria for Good Measurements in Research: Validity and Reliability,” *mpira.ub.uni-muenchen.de*, 2017. <https://mpira.ub.uni-muenchen.de/83458/>
- [207] H. Bridwell, V. Dhingra, D. Peckman, J. Roark, and T. Lehman, “Perspectives on Method Validation: Importance of Adequate Method Validation,” *The Quality Assurance Journal*, vol. 13, no. 3–4, pp. 72–77, Jul. 2010, doi: <https://doi.org/10.1002/qaj.473>.
- [208] L. Leung, “Validity, reliability, and generalizability in qualitative research,” *Journal of Family Medicine and Primary Care*, vol. 4, no. 3, pp. 324–327, 2015, doi: <https://doi.org/10.4103/2249-4863.161306>.
- [209] L. Leung, “Validity, reliability, and generalizability in qualitative research,” *Journal of Family Medicine and Primary Care*, vol. 4, no. 3, pp. 324–327, 2015, doi: <https://doi.org/10.4103/2249-4863.161306>.
- [210] E. Daniel, “The Usefulness of Qualitative and Quantitative Approaches and Methods in Researching Problem-Solving Ability in Science Education Curriculum,” 2016. Available: <https://files.eric.ed.gov/fulltext/EJ1103224.pdf>
- [211] E. F. Juniper, “Validated questionnaires should not be modified,” *European Respiratory Journal*, vol. 34, no. 5, pp. 1015–1017, Oct. 2009, doi: <https://doi.org/10.1183/09031936.00110209>.
- [212] D. Pal and V. Vanijja, “Perceived usability evaluation of Microsoft Teams as an online learning platform during COVID-19 using system usability scale and technology acceptance model in India,” *Children and Youth Services Review*, vol. 119, no. 1, p. 105535, Dec. 2020, doi: <https://doi.org/10.1016/j.chilyouth.2020.105535>.
- [213] S. H. Han, M. Hwan Yun, K.-J. Kim, and J. Kwahk, “Evaluation of product usability: development and validation of usability dimensions and design elements based on empirical models,” *International Journal of Industrial Ergonomics*, vol. 26, no. 4, pp. 477–488, Oct. 2000, doi: [https://doi.org/10.1016/s0169-8141\(00\)00019-6](https://doi.org/10.1016/s0169-8141(00)00019-6).
- [214] M. Schmettow, R. Schnittker, and J. M. Schraagen, “An extended protocol for usability validation of medical devices: Research design and reference model,” *Journal of Biomedical Informatics*, vol. 69, pp. 99–114, May 2017, doi: <https://doi.org/10.1016/j.jbi.2017.03.010>.
- [215] T. Chawla and J. Wood, “Thematic analysis - an overview,” *Sciencedirect.com*, 2021. <https://www.sciencedirect.com/topics/social-sciences/thematic-analysis>
- [216] M. Bengtsson, “How to plan and perform a qualitative study using content analysis,” *NursingPlus Open*, vol. 2, no. 2, pp. 8–14, 2016, doi: <https://doi.org/10.1016/j.npls.2016.01.001>.
- [217] Sage, “Chapter 12: Qualitative Data, Analysis, and Design,” 2011. Available: https://www.sagepub.com/sites/default/files/upm-binaries/43144_12.pdf

- [218] “Software and Qualitative Analysis,” *Behavioural and social science research*. <https://obsr.od.nih.gov/sites/obsr/files/Software-and-Qualitative-Analysis> [Accessed Dec. 01, 2022].
- [219] H. A. Qureshi and Z. Ünlü, “Beyond the Paradigm Conflicts: A Four-Step Coding Instrument for Grounded Theory,” *International Journal of Qualitative Methods*, vol. 19, p. 160940692092818, Jan. 2020, doi: <https://doi.org/10.1177/1609406920928188>.
- [220] “Chapter 13 Qualitative Analysis | Research Methods for the Social Sciences,” *Lumenlearning.com*, 2019. <https://courses.lumenlearning.com/suny-hccc-research-methods/chapter/chapter-13-qualitative-analysis/> [Accessed 2020].
- [221] Ondrej Zizlavsky, “The Development and Implementation of Marketing Information System within Innovation: The Increasing of Innovative Performance,” 2012, pp.61-80, DOI: 10.5772/35298
- [222] “MindTools | Home,” www.mindtools.com. <https://www.mindtools.com/ag6pkn9/root-cause-analysis>
- [223] B. A. Hussein and O. J. Klakegg, “Measuring the Impact of Risk Factors Associated with Project Success Criteria in Early Phase,” *Procedia - Social and Behavioral Sciences*, vol. 119, pp. 711–718, Mar. 2014, doi: <https://doi.org/10.1016/j.sbspro.2014.03.079>.
- [224] R. A. Grier, A. Bangor, P. Kortum, and S. C. Peres, “The System Usability Scale,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 57, no. 1, pp. 187–191, Sep. 2013, doi: <https://doi.org/10.1177/1541931213571042>.
- [225] G. J. Kikwasi, “Critical Success Factors for Effective Risk Management,” *Risk Management Treatise for Engineering Practitioners*, Nov. 2018, doi: <https://doi.org/10.5772/intechopen.74419>.
- [226] H. Taherdoost and M. Madanchian, “Multi-Criteria Decision Making (MCDM) Methods and Concepts,” *Encyclopedia*, vol. 3, no. 1, pp. 77–87, Jan. 2023, doi: <https://doi.org/10.3390/encyclopedia3010006>.
- [227] F. Sitorus, J. J. Cilliers, and P. R. Brito-Parada, “Multi-criteria decision making for the choice problem in mining and mineral processing: Applications and trends,” *Expert Systems with Applications*, vol. 121, pp. 393–417, May 2019, doi: <https://doi.org/10.1016/j.eswa.2018.12.001>.
- [228] J. A. Putra, T. Rakhman, and M. K. Biddinika, “Selection between AHP and TOPSIS for Academic Information Systems Decision Making Model,” *Proceedings of the 2nd International Conference on Applied Science, Engineering and Social Sciences*, 2019, doi: <https://doi.org/10.5220/0009878700860089>.
- [229] L. Hosseini, R. Tavakkoli-Moghaddam, B. Vahdani, S. Mousavi and R. Kia, "Using the Analytical Network Process to Select the Best Strategy for Reducing Risks in a Supply Chain", *Journal of Engineering*, vol. 2013, pp. 1-9, 2013. Available: <https://doi.org/10.1155/2013/375628>. [Accessed 15 August 2019].

- [230] A. Soofi and A. Awan, "Classification Techniques in Machine Learning: Applications and Issues," *Journal of Basic & Applied Sciences*, vol. 13, pp. 459–465, Aug. 2017, doi: <https://doi.org/10.6000/1927-5129.2017.13.76>.
- [231] J. Cai, K. Xu, Y. Zhu, F. Hu, and L. Li, "Prediction and analysis of net ecosystem carbon exchange based on gradient boosting regression and random forest," *Applied Energy*, vol. 262, p. 114566, Mar. 2020, doi: <https://doi.org/10.1016/j.apenergy.2020.114566>.
- [232] R. W. Issitt, M. Cortina-Borja, W. Bryant, S. Bowyer, A. M. Taylor, and N. Sebire, "Classification Performance of Neural Networks Versus Logistic Regression Models: Evidence From Healthcare Practice," *Cureus*, Feb. 2022, doi: <https://doi.org/10.7759/cureus.22443>.
- [233] A. Nicholas Refenes, A. Zaprani, and G. Francis, "Stock performance modeling using neural networks: A comparative study with regression models," *Neural Networks*, vol. 7, no. 2, pp. 375–388, Jan. 1994, doi: [https://doi.org/10.1016/0893-6080\(94\)90030-2](https://doi.org/10.1016/0893-6080(94)90030-2).
- [234] O. Kwon, Harry Hui Xia, and S. Zhang, "A comparison of artificial neural networks and the statistical methods in predicting MBA student's academic performance," *Journal of International Technology and Information Management*, vol. 30, no. 2, pp. 97–119, Jan. 2021, doi: <https://doi.org/10.58729/1941-6679.1485>.
- [235] N. Sharma, R. Sharma, and N. Jindal, "Machine Learning and Deep Learning Applications-A Vision," *Global Transitions Proceedings*, vol. 2, no. 1, Jan. 2021, doi: <https://doi.org/10.1016/j.gltp.2021.01.004>.
- [236] S. Murat H., "A brief review of feed-forward neural networks," *Communications Faculty Of Science University of Ankara*, vol. 50, no. 1, pp. 11–17, 2006, doi: https://doi.org/10.1501/commua1-2_0000000026.
- [237] R. Bala and D. Kumar, "Classification Using ANN: A Review", *International Journal of Computational Intelligence Research*, vol. 13, no. 72017, pp. 1811-1820, 2017. Available: https://www.ripublication.com/ijcir17/ijcirv13n7_22.pdf. [Accessed 18 February 2020].
- [238] T. Gupta, "Deep Learning: Feedforward Neural Network", *Medium*, 2017. [Online]. Available: <https://towardsdatascience.com/deep-learning-feedforward-neural-network-26a6705dbdc7>. [Accessed: 10- Jan- 2020].
- [239] Y. Xu and R. Goodacre, "On Splitting Training and Validation Set: A Comparative Study of Cross-Validation, Bootstrap and Systematic Sampling for Estimating the Generalization Performance of Supervised Learning," *Journal of Analysis and Testing*, vol. 2, no. 3, pp. 249–262, Jul. 2018, doi: <https://doi.org/10.1007/s41664-018-0068-2>.
- [240] A. Gholamy, V. Kreinovich, and O. Kosheleva, "Why 70/30 or 80/20 Relation Between Training and Testing Sets: A Pedagogical Explanation," *Departmental Technical Reports (CS)*, Feb. 2018, Available: https://scholarworks.utep.edu/cs_techrep/1209/

- [241] H. K. Vydana and A. K. Vuppala, "Investigative study of various activation functions for speech recognition," *2017 Twenty-third National Conference on Communications (NCC)*, Chennai, India, 2017, pp. 1-5, doi: 10.1109/NCC.2017.8077043.
- [242] D. Agusdinata and H. Lukosch, "Supporting Interventions to Reduce Household Greenhouse Gas Emissions: A Transdisciplinary Role-Playing Game Development", *Simulation & Gaming*, vol. 50, no. 3, pp. 359-376, 2019. Available: <https://doi.org/10.1177/1046878119848135>. [Accessed 30 June 2021].
- [243] K. B. Jung, S.-W. Kang, and S. B. Choi, "Empowering Leadership, Risk-Taking Behavior, and Employees' Commitment to Organizational Change: The Mediated Moderating Role of Task Complexity," *Sustainability*, vol. 12, no. 6, pp. 1–18, Mar. 2020, doi: <https://doi.org/10.3390/su12062340>
- [244] S. Noda, K. Shirotzuki, and M. Nakao, "The effectiveness of intervention with board games: a systematic review," *BioPsychoSocial Medicine*, vol. 13, no. 1, Oct. 2019, doi: <https://doi.org/10.1186/s13030-019-0164-1>.
- [245] K. Jung, A. Voogt and J. Retschitzki, *Moves in mind*. Taylor and Francis Group.
- [246] R. Murray, "Using Third Parties: A competitive advantage or a cause for concern? - BCS Consulting", *BCS Consulting*, 2018. [Online]. Available: <https://www.bcsconsulting.com/blog/using-third-parties-competitive-advantage-cause-concern/>. [Accessed: 01- Jan- 2019].
- [247] L. Brown and S. P. Osborne, "Risk and Innovation," *Public Management Review*, vol. 15, no. 2, pp. 186–208, Feb. 2013, doi: <https://doi.org/10.1080/14719037.2012.707681>.
- [248] M. Kelly, "Too many chefs: Smaller groups exhibit more accurate decision-making (Proceedings of the Royal Society B)", *New research findings from Princeton University*, 2014. [Online]. Available: <https://blogs.princeton.edu/research/2014/04/23/too-many-chefs-smaller-groups-exhibit-more-accurate-decision-making-proceedings-of-the-royal-society-b/>. [Accessed: 31- Jul- 2018].
- [249] J. Osmani, "The Impact of Group Size on Decision Effectiveness", *European Journal of Marketing and Economics*, vol. 3, no. 2, p. 108, 2020. Available: https://revistia.org/files/articles/ejme_v3_i2_20/Osmani.pdf. [Accessed 5 August 2021].
- [250] A. B. Kao and I. D. Couzin, "Decision accuracy in complex environments is often maximized by small group sizes," *Proceedings of the Royal Society B: Biological Sciences*, vol. 281, no. 1784, p. 20133305, Jun. 2014, doi: <https://doi.org/10.1098/rspb.2013.3305>.
- [251] J. Osmani, "The Impact of Group Size on Decision Effectiveness," *European Journal of Marketing and Economics*, vol. 3, no. 2, p. 108, Oct. 2020, doi: <https://doi.org/10.26417/392x1k97w>. [Accessed: 11- Jun- 2021].

- [252] W. D. Leong *et al.*, “Adaptive Analytical Approach to Lean and Green Operations,” *mpa.ub.uni-muenchen.de*, May 20, 2019. <https://mpa.ub.uni-muenchen.de/95449/> [Accessed Jan. 11, 2024]. [Accessed: 19- Feb- 2019].
- [253] Y. Sun, K. Bi and S. Yin, "Measuring and Integrating Risk Management into Green Innovation Practices for Green Manufacturing under the Global Value Chain", *Sustainability*, vol. 12, no. 2, p. 545, 2020. Available: 10.3390/su12020545.
- [254] H. Landell , “The Risk Matrix as a tool for risk analysis ,” Master’s Thesis, University of Gävle , 2016. Accessed: 2019. [Online]. Available: <https://www.diva-portal.org/smash/get/diva2:944825/fulltext01.pdf> [Accessed: 01- Apr- 2021].
- [255] K. Puszczak, A. Fronczyk and M. Urbański, "Leading indicators and tendency surveys - OECD", *Oecd.org*, 2013. [Online]. Available: <https://www.oecd.org/sdd/leading-indicators>. [Accessed: 14- Jul- 2018].
- [256] A. Etz, “Introduction to the Concept of Likelihood and Its Applications,” *Advances in Methods and Practices in Psychological Science*, vol. 1, no. 1, pp. 60–69, Mar. 2018, doi: <https://doi.org/10.1177/2515245917744314>. [Accessed: 01- Apr- 2022].
- [257] M. A. Benzaghta, A. Elwalda, M. Mousa, I. Erkan, and M. Rahman, “SWOT Analysis applications: an Integrative Literature Review,” *Journal of Global Business Insights*, vol. 6, no. 1, pp. 54–72, Mar. 2021, doi: <https://doi.org/10.5038/2640-6489.6.1.1148>. [Accessed: 01- May- 2021].
- [258] G. Pascarella *et al.*, “Risk Analysis in Healthcare Organizations: Methodological Framework and Critical Variables,” *Risk Management and Healthcare Policy*, vol. Volume 14, no. 14, pp. 2897–2911, 2021, doi: <https://doi.org/10.2147/rmhp.s309098>. [Accessed: 16- Feb- 2020].
- [259] G. Kaya, J. Ward, A. Pearman and J. Clarkson, "Evaluation of the formal risk assessment practice in hospitals in England", *Journal of Risk Research*, vol. 24, no. 6, pp. 771-779, 2020. Available: https://www.researchgate.net/publication/323570642_Good_risk_assessment_practice_in_hospitals/citation/download. [Accessed 8 March 2021].
- [260] "Risk Impact Assessment and Prioritization", *The MITRE Corporation*. [Online]. Available: <https://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management/risk-impact-assessment-and-prioritization>. [Accessed: 14- May- 2021].
- [261] S. Lee and S. Trimi, "Innovation for creating a smart future", *Journal of Innovation & Knowledge*, vol. 3, no. 1, pp. 1-8, 2018. Available: <https://doi.org/10.1016/j.jik.2016.11.001>. [Accessed 2019].
- [262] J. Arnett, B. Goldfinch, and R. Chinta, “Multi-dimensional nature of innovation at Amazon,” *International Journal of Business Innovation and Research*, vol. 15, no. 1, pp. 1–13, 2018, doi: <https://doi.org/10.1504/ijbir.2018.088461>.
- [263] M. Tohidi, M.M. Jabbari, “Innovation as a Success Key for Organizations,” (2014), *Procedia Technology*. pp. 560 – 564. 10.1016/j.protcy.2012.02.122.

- [264] J. Machac, F. Steiner, and J. Tupa, "Product Life Cycle Risk Management," *Risk Management Treatise for Engineering Practitioners*, Nov. 2018, doi: <https://doi.org/10.5772/intechopen.68797>.
- [265] P. Ranong and W. Phuengam, "Critical Success Factors for effective risk management procedures in financial industries", Masters, Umeå University, 2009.
- [266] T. I. Khan, S. A. Raza, and M. Devji, "Reckitt Benckiser's CSR program – capitalizing the rural market," *Emerald Emerging Markets Case Studies*, vol. 11, no. 1, pp. 1–13, Apr. 2021, doi: <https://doi.org/10.1108/eemcs-03-2020-0077>.
- [267] J. O. Meissner, S. Brunswicker, S. Schweikert and P. Wolf, "Scaffolding innovations: Implications of regional innovation barriers for platform-based innovation management improvement," *2008 IEEE International Technology Management Conference (ICE)*, Lisbon, 2008, pp. 1-10.
- [268] S. Dutta, B. Lanvin, and S. Wunsch-Vincent, "Global innovation index 2018," *Semantic Scholar*, 2018. <https://api.semanticscholar.org/CorpusID:169500325> [Accessed Jan. 05, 2024].
- [269] You Lu and Xin Yang, "Design risk management--the guarantee of product innovation," *2008 9th International Conference on Computer-Aided Industrial Design and Conceptual Design*, Kunming, 2008, pp. 1083-1085. doi: 10.1109/CAIDCD.2008.4730750
- [270] C. Kuntonbutr, N. Jaturat, P. Wilairatana and T. Konosu, "The Management Vision for Innovation and Human Resource Development Affecting New Markets and New Products Development," *2017 6th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)*, Hamamatsu, 2017, pp. 231-236.
- [271] J. Machac, F. Steiner, and J. Tupa, "Product Life Cycle Risk Management," *Risk Management Treatise for Engineering Practitioners*, Nov. 2018, doi: <https://doi.org/10.5772/intechopen.68797>.
- [272] T. L. Saaty, "Decision making — the Analytic Hierarchy and Network Processes (AHP/ANP)," *Journal of Systems Science and Systems Engineering*, vol. 13, no. 1, pp. 1–35, Mar. 2004, doi: <https://doi.org/10.1007/s11518-006-0151-5>.
- [273] Julius Golovatchev, Oliver Budde, "Technology and innovation radar - Effective instruments for the development of a sustainable innovation strategy", Management of Innovation and Technology (ICMIT) 2010 IEEE International Conference on, pp. 760-764, 2010
- [274] W. Wei and L. Liping, "Research on the coupling relations between technology innovation and business modes innovation of IOT industry based on SD," *2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 2013, pp. 66-69.

- [275] T. Kogabayev and A. Maziliauskas, "The definition and classification of innovation," *HOLISTICA – Journal of Business and Public Administration*, vol. 8, no. 1, pp. 59–72, Apr. 2017, doi: <https://doi.org/10.1515/hjbpa-2017-0005>.
- [276] P. Fithri, N. A. Riva, L. Susanti and B. Yuliandra, "Safety analysis at weaving department of PT. X Bogor using Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA)," *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)*, Singapore, 2018, pp. 382-385.
doi: 10.1109/IEA.2018.8387129.
- [277] Xinru Liang, Gang Zheng and Qingrui Xu, "The Haier's Tao of innovation: a case study of the emerging total innovation management (TIM)," *IEMC '03 Proceedings. Managing Technologically Driven Organizations: The Human Side of Innovation and Change*, Albany, NY, USA, 2003, pp. 5-9.
- [278] D. C. Agarwal, Sakshi Chauhan, "E-Banking in India: Innovations, Challenges and Opportunities", *International Journal of Science and Research (IJSR)* 2018, pp. 536-541.
- [279] S. Gupta, N. Malhotra, M. Czinkota and P. Foroudi, "Marketing innovation: A consequence of competitiveness", *Journal of Business Research*, vol. 69, no. 12, pp. 5671-5681, 2016. Available: <https://doi.org/10.1016/j.jbusres.2016.02.042>. [Accessed 11 March 2019].
- [280] A. Berglund, "Assessing the Innovation Process of SMEs", Luleå University of Technology Department of Business Administration and Soci, 2007.
- [281] R. Rajapathirana and Y. Hui, "Relationship between innovation capability, innovation type, and firm performance", *Journal of Innovation & Knowledge*, vol. 3, no. 1, pp. 44-55, 2018. Available: <https://doi.org/10.1016/j.jik.2017.06.002>. [Accessed 9 June 2019].
- [282] W. Wei and L. Liping, "Research on the coupling relations between technology innovation and business modes innovation of IOT industry based on SD," *2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering*, Xi'an, 2013, pp. 66-69.
- [283] R. Miller and R. A. Blais, "Modes of innovation in six industrial sectors," in *IEEE Transactions on Engineering Management*, vol. 40, no. 3, pp. 264-273, Aug. 1993.
- [284] Ondrej Zizlavsky, "The Development and Implementation of Marketing Information System Within Innovation: The Increasing of Innovative Performance," 2012, pp. 61-80, DOI: 10.5772/35298
- [285] G. J. Kikwasi, "Critical Success Factors for Effective Risk Management", *Risk Management Treatise for Engineering Practitioners*, 2018. Available: <https://www.intechopen.com/chapters/59672>. [Accessed 19 December 2018].
- [286] Philmckinney, "What Innovation Resources Are Needed to Thrive? | Phil McKinney - Innovation Mentor and Coach," *Phil McKinney - Innovation*

- Mentor and Coach*, Aug. 11, 2016. <https://philmckinney.com/the-law-of-resources-what-does-innovation-need-to-thrive/>
- [287] F. Emprechtinger, "Identification of innovation potential - 6 important triggers for innovation", *Lead-innovation.com*, 2018. [Online]. Available: <https://www.lead-innovation.com/english-blog/identification-of-innovation-potential-6-important-triggers-for-innovation>. [Accessed: 08- Nov- 2018].
- [288] M. Dziallas and K. Blind, "Innovation indicators throughout the innovation process: An extensive literature analysis", *Technovation*, vol. 80-81, pp. 3-29, 2019. Available: <https://www.sciencedirect.com/science/article/pii/S0166497217301402>. [Accessed 15 March 2019].
- [289] M. Slimane, "ScienceDirect.com | Science, health and medical journals, full text articles and books.", *Pdf.sciencedirectassets.com*, 2015. [Online]. Available: <https://pdf.sciencedirectassets.com/277811>. [Accessed: 08- Mar- 2020].
- [290] B. Cooper, "The Importance of Aligning Innovation Strategy with Business Goals - Moves the Needle", *Moves the Needle*, 2019. [Online]. Available: <https://movestheneedle.com/leadership/the-importance-of-aligning-innovation-strategy-with-business-goals/>. [Accessed: 08- Jan- 2020].
- [291] R. Falvey and N. Foster, "The Role of Intellectual Property Rights in Technology Transfer and Economic Growth: Theory and Evidence", *Unido.org*, 2006. [Online]. Available: https://www.unido.org/sites/default/files/2009-04/Role_of_intellectual_property_rights_in_technology_transfer_and_economic_growth_0.pdf. [Accessed: 12- Oct- 2018].
- [292] P. Toner, "Workforce Skills And Innovation: An Overview Of Major Themes In The Literature", OECD Education Working Papers, 2011.
- [293] "Skills for innovation and research", OECD, 2011. [online] pp.9–14. Available at: <https://www.oecd.org/innovation/inno/47164461.pdf>.
- [294] N. Amato, "How to mix innovation and risk management", *FM Magazine*, 2018. [Online]. Available: <https://www.fm-magazine.com/news/2018/apr/mix-innovation-with-risk-management-201818741.html>. [Accessed: 30- Apr- 2020].
- [295] M. Hoegl and H. Gemuenden, "Teamwork Quality and the Success of Innovative Projects: A Theoretical Concept and Empirical Evidence", *Organization Science*, vol. 12, no. 4, pp. 435-449, 2001. Available: https://www.researchgate.net/profile/Hans-Gemuenden/publication/228365985_Teamwork_Quality_and_the_Success_of_Innovative_Projects_A_Theoretical_Concept_and_Empirical_Evidence/. [Accessed 2019].
- [296] A. M. Abdullahi, K. Oyibo, R. Orji, and A. A. Kawu, "The Influence of Age, Gender, and Cognitive Ability on the Susceptibility to Persuasive Strategies,"

- Information*, vol. 10, no. 11, p. 352, Nov. 2019, doi: <https://doi.org/10.3390/info10110352>.
- [297] C. Co, "6 Factors To Consider When Choosing A Supplier | Concrete Supply Co.", *Concrete Supply Co.*, 2018. [Online]. Available: <https://concretesupplyco.com/choosing-supplier-factors/>. [Accessed: 19- Feb- 2019].
- [298] P. Paranikas, G. Whiteford, B. Tevelson and D. Belz, "How to Negotiate with Powerful Suppliers", *Harvard Business Review*, 2015. [Online]. Available: <https://hbr.org/2015/07/how-to-negotiate-with-powerful-suppliers>. [Accessed: 05- Apr- 2019].
- [299] A. Neboian, "How to Convince Your Clients to Embrace Your Innovative Ideas", *Medium*, 2020. [Online]. Available: <https://entrepreneurshandbook.co/how-to-convince-your-clients-to-embrace-your-innovative-ideas-71aa53ea7fee>. [Accessed: 17- May- 2021].
- [300] R. Murray, "Using Third Parties: A competitive advantage or a cause for concern? - BCS Consulting", *BCS Consulting*, 2018. [Online]. Available: <https://www.bcsconsulting.com/blog/using-third-parties-competitive-advantage-cause-concern/>. [Accessed: 01- Jan- 2019].
- [301] A. Datta, D. Mukherjee, and L. Jessup, "Understanding commercialization of technological innovation: taking stock and moving forward," *R&D Management*, vol. 45, no. 3, pp. 215–249, Apr. 2014, doi: <https://doi.org/10.1111/radm.12068>.
- [302] M. Lieberman, "First-Mover Advantage", *The Palgrave Encyclopedia of Strategic Management*, pp. 1-4, 2016. Available: https://www.researchgate.net/publication/311908029_First-Mover_Advantage. [Accessed 8 March 2018].
- [303] T. Caliori, M. Valente and R. Ruiz, "Heterogeneity of demand and product innovation", *Estudos Econômicos (São Paulo)*, vol. 47, no. 1, pp. 5-37, 2017. Available: <https://www.scielo.br/j/ee/a/jz7xSdmSsP5dy7csWHQqYHv/?lang=en>. [Accessed 3 February 2019].
- [304] K. Blind, S. Petersen and C. Riillo, "The impact of standards and regulation on innovation in uncertain markets", *Research Policy*, vol. 46, no. 1, pp. 249-264, 2017. Available: <https://www.sciencedirect.com/science/article/pii/S0048733316301743>. [Accessed 6 June 2018].
- [305] K. Bause, A. Radimersky, M. Iwanicki and A. Albers, "Feasibility Studies in the Product Development Process", *Procedia CIRP*, vol. 21, pp. 473-478, 2014. Available: <https://doi.org/10.1016/j.procir.2014.03.128>. [Accessed 8 December 2018].
- [306] E. Inha and S. Bohlin, "Review Article Development of innovation products by using Kano model", *Diva-portal.org*. [Online]. Available:

<https://www.diva-portal.org/smash/get/diva2:1080938/FULLTEXT01.pdf>.
[Accessed: 08- Mar- 2019].

- [307] Fatiha Naoui-Outini & Nabil El Hilali, 2019. "Innovative suppliers and purchasing function interaction: An exploratory research in the car rental sector," *Journal of Innovation Economics*, De Boeck Université, vol. 0(1), pages 171-192.
- [308] K. Constable, "Rejection Is Part of Entrepreneurship. Here's How to Handle It.," *Entrepreneur*, Jul. 09, 2018. <https://www.entrepreneur.com/leadership/rejection-is-part-of-entrepreneurship-heres-how-to-handle/315946> [Accessed Mar. 31, 2021].
- [309] H. Zhang and V. Aumeboonsuke, "Technological Innovation, Risk-Taking and Firm Performance—Empirical Evidence from Chinese Listed Companies," *Sustainability*, vol. 14, no. 22, p. 14688, Nov. 2022, doi: <https://doi.org/10.3390/su142214688>.
- [310] R. Katila and S. Shane, "When Does Lack of Resources Make New Firms Innovative?," *The Academy of Management Journal*, vol. 48, no. 5, pp. 814–829, 2005, Available: <https://www.jstor.org/stable/20159699>
- [311] R. F. Carço *et al.*, "Raw material quality assessment approaches comparison in pectin production," *Biotechnology Progress*, vol. 35, no. 2, p. e2762, Dec. 2018, doi: <https://doi.org/10.1002/btpr.2762>.
- [312] H. Chang, G. D. Fernando, and A. Tripathy, "An Empirical Study of Strategic Positioning and Production Efficiency," *Advances in Operations Research*, vol. 2015, pp. 1–11, 2015, doi: <https://doi.org/10.1155/2015/347045>.
- [313] Nix, "Why Companies Outsource [with Outsourcing Examples] – NIX United," *NIX United – Custom Software Development Company*, Aug. 24, 2020. <https://nix-united.com/blog/outsourcing-who-does-it-and-why/>
- [314] D. Chatterjee, "Leadership in Innovators and Defenders: The Role of Cognitive Personality Styles," *Industry and Innovation*, vol. 21, no. 5, pp. 430–453, Jul. 2014, doi: <https://doi.org/10.1080/13662716.2014.959314>

APPENDICES

APPENDIX A

Questionnaire QE1, to validate the consistency of classification of innovation concepts

Please indicate the extent to which you agree with the following classification. The classification is based on the definitions of innovation concepts in Table 1.

Scale –

1 – Strongly Disagree

2 – Disagree

3 – Undecided

4- Agree

5 – Strongly Agree

TABLE A1: DEFINITIONS OF THE INNOVATION CONCEPTS

Innovation concept	Summarized interpretations
Product innovation	Product innovation improves existing functions or introduces new ones to meet evolving customer needs. It is driven by technological advances, marketing strategies, cultural trends, and research and development (R&D). R&D plays a crucial role in identifying enhancements and cost-saving opportunities.
Product innovation	Product innovation enhances existing functions or introduces new ones to meet evolving customer needs. It is closely tied to technological advances, marketing strategies, and cultural trends. Research and development (R&D) are integral, helping to pinpoint areas for improvement and identify cost-saving opportunities
Process innovation	Process innovation improves a firm's performance and boosts ROI by using methods like Business Process Re-engineering (BPR), Just In Time (JIT), Total Quality Management (TQM), and Lean Manufacturing.
Technology innovation	Technology innovation drives organizations' survival and growth by generating intellectual property, economic, and social benefits. It is linked with R&D and innovations in products, processes, management,

	culture, and structure. Organizations use technology innovations to optimize resource utilization.
Enterprise innovation	To meet strategic objectives, businesses must enhance operational efficiency by streamlining processes, leading to Business Model Innovation. Effective management control ensures oversight of resources, technology, and personnel, promoting overall business innovation
Human Resource Management innovation (HRM)	Innovation in Human Resource Management (HRM) is essential for company success, enhancing talent recruitment and development. It boosts innovation performance and capability, enabling organizations to unlock employee potential and drive innovation throughout operations.
Service innovation	Service innovation is vital for organizational success. Continuous development and improvement of services allow companies to meet evolving customer needs, leading to higher satisfaction and success
Resource innovation	Resource innovation optimizes an organization's internal and external resources to maximize fund utilization, including finances, inventory, skills, materials, equipment, and IT.
System innovation	System innovation is essential for creating an environment that encourages enterprise innovation. Adopting new systems and processes can streamline operations, cut costs, and generate opportunities for technology innovation
Regional indigenous innovation	Regional indigenous innovation enhances regional competitiveness, market share, and sustainable development by addressing key technical challenges unique to the region.
Green innovation	Green innovation includes energy-saving technologies, waste recycling, pollution prevention, and the development of eco-friendly products and processes. These initiatives enhance a company's environmental performance and competitive edge.
Ecological innovation	Ecological innovation focuses on developing sustainable and eco-friendly products and processes. It emphasizes using renewable resources, reducing waste, and minimizing pollution to mitigate the negative impact of human activities on the environment.
Marketing innovation	Marketing innovation is crucial for a company's survival, growth, and economic success. It involves understanding customer needs and trends to develop effective management concepts and techniques for product and process innovation.
User innovation	User innovation focuses primarily on enhancing customer satisfaction, which is a fundamental aspect of marketing innovation
Strategy innovation	Strategy innovation incorporates technological, marketing, organizational, management, and cultural innovations to create new

	business opportunities and enhance the quality and performance of the firm.
Management innovation	Management innovation links the organization's innovation vision with research and development. It encompasses strategic business model, organizational structure, and HRM innovations, significantly impacting the organization's overall performance.
Institution Innovation	Institutional innovation focuses on an organization's human resource practices aimed at cultivating a culture of innovation among employees. This involves implementing incentive mechanisms, reward systems, and performance management strategies that encourage innovative thinking and actions.
Organizational innovation	Organizational innovation optimizes the structure of an organization to ensure its survival and growth. This includes integrating technology, HRM innovations, and the management vision of the organization
Culture innovation	Culture innovation, integrated with strategy, management, institutional, market, technology, and HRM innovation, promotes sustainable growth and addresses bottlenecks in technological innovation. It fosters a learning culture that stimulates innovative thinking, enhancing employee performance, educational qualifications, motivation, intelligence, teamwork, recognition, and remuneration—all critical factors for a firm's success.
Cooperative innovation	This version succinctly emphasizes how cooperative innovation, through collaborative R&D initiatives, benefits organizations by enhancing innovation capabilities, reducing costs, and improving competitive advantage and long-term sustainability.

Innovation Concepts	P1 - Concepts related to structuring the organization for a sustainable innovation	P2 - Concepts related to External Information needed for a sustainable Innovation	P3 - Concepts related to Implementation of an Innovation
---------------------	---	--	---

- Management Innovation
 - Strategy Innovation
 - Culture Innovation
 - Human Resource Innovation
 - Cooperative Innovation
 - Organizational Innovation
 - Institutional Innovation
-

Enterprise Innovation
Marketing Innovation
User Innovation
Life Cycle Innovation
Business Model Innovation
Technological Innovation
Product Innovation
Process Innovation
System Innovation
Regional Indigenous
Innovation
Service Innovation
Resource Innovation
Green Innovation
Ecological Innovation

APPENDIX B

Summary of normality tests done on feedback of Questionnaire QE1, illustrated in Table B.1 through Table B.21.

TABLE B.1: MANAGEMENT INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.314	321	.000	.763	321	.000
Peripheral	.242	321	.000	.828	321	.000
Sustainable	.252	321	.000	.819	321	.000

TABLE B.2: STRATEGY INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.300	321	.000	.779	321	.000
Peripheral	.244	321	.000	.824	321	.000
Sustainable	.271	321	.000	.801	321	.000

TABLE B.3: CULTURE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.367	321	.000	.666	321	.000
Peripheral	.264	321	.000	.788	321	.000
Sustainable	.260	321	.000	.791	321	.000

TABLE B.4: HUMAN RESOURCE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.379	321	.000	.634	321	.000
Peripheral	.265	321	.000	.784	321	.000
Sustainable	.263	321	.000	.779	321	.000

TABLE B.5: INSTITUTIONAL INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.413	321	.000	.616	321	.000
Peripheral	.268	321	.000	.775	321	.000
Sustainable	.293	321	.000	.764	321	.000

TABLE B.6: ORGANIZATIONAL INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.434	321	.000	.592	321	.000
Peripheral	.261	321	.000	.783	321	.000
Sustainable	.291	321	.000	.766	321	.000

TABLE B.7: ENTERPRISE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.324	321	.000	.761	321	.000
Peripheral	.216	321	.000	.841	321	.000
Sustainable	.236	321	.000	.829	321	.000

TABLE B.8: CO OPERATIVE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.374	321	.000	.696	321	.000
Peripheral	.276	321	.000	.784	321	.000
Sustainable	.300	321	.000	.777	321	.000

TABLE B.9: MARKETING INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.288	321	.000	.756	321	.000
Peripheral	.461	321	.000	.534	321	.000
Sustainable	.254	321	.000	.766	321	.000

TABLE B.10: TECHNOLOGICAL INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.234	320	.000	.830	320	.000
Peripheral	.241	320	.000	.820	320	.000
Sustainable	.331	320	.000	.762	320	.000

TABLE B.11: BUSINESS MODEL INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.270	321	.000	.775	321	.000
Peripheral	.389	321	.000	.644	321	.000
Sustainable	.270	321	.000	.782	321	.000

TABLE B.12: LIFE CYCLE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.217	321	.000	.837	321	.000
Peripheral	.365	321	.000	.712	321	.000
Sustainable	.247	321	.000	.823	321	.000

TABLE B.13: USER INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.258	356	.000	.780	356	.000
Peripheral	.337	356	.000	.697	356	.000
Sustainable	.304	356	.000	.755	356	.000

TABLE B.14: PRODUCT INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.291	321	.000	.703	321	.000
Peripheral	.303	321	.000	.724	321	.000
Sustainable	.519	321	.000	.387	321	.000

TABLE B.15: PROCESS INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Intra-Organizational	.228	321	.000	.830	321	.000
Peripheral	.232	321	.000	.846	321	.000
Sustainable	.327	321	.000	.768	321	.000

TABLE B.16: SYSTEM INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.240	321	.000	.824	321	.000
Peripheral	.262	321	.000	.813	321	.000
Sustainable	.253	321	.000	.769	321	.000

TABLE B.17: REGIONAL INDIGENOUS INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.224	321	.000	.833	321	.000
Peripheral	.238	321	.000	.827	321	.000
Sustainable	.336	321	.000	.758	321	.000

TABLE B.18: ECOLOGICAL INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.253	321	.000	.802	321	.000
Peripheral	.261	321	.000	.795	321	.000
Sustainable	.347	321	.000	.718	321	.000

TABLE B.19: RESOURCE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.299	321	.000	.711	321	.000
Peripheral	.293	321	.000	.724	321	.000
Sustainable	.519	321	.000	.387	321	.000

TABLE B.20: GREEN INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.256	321	.000	.781	321	.000
Peripheral	.247	321	.000	.792	321	.000
Sustainable	.398	321	.000	.667	321	.000

TABLE B.21: SERVICE INNOVATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statisti	df	Sig.	Statisti	df	Sig.
	c			c		
Intra-Organizational	.214	321	.000	.838	321	.000
Peripheral	.223	321	.000	.834	321	.000
Sustainable	.349	321	.000	.747	321	.000

Summary of the hypotheses tests with boxplot images

Kruskal-Wallis hypotheses test results on the classification of innovation concepts

All the 21 innovation concepts have received the below Hypothesis test summary as illustrated in Table B22.

TABLE B22: HYPOTHESIS TEST SUMMARY

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The medians of Response are the same across categories of Category.	Independent-Samples Median Test	.000	Reject the null hypothesis.
2	The distribution of Response is the same across categories of Category.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .050.

Box plot images of 21 innovation concepts are illustrated in Figure B.1 through B

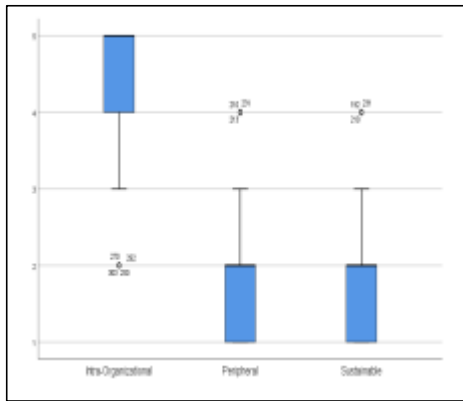


Fig. B.1: Organizational innovation

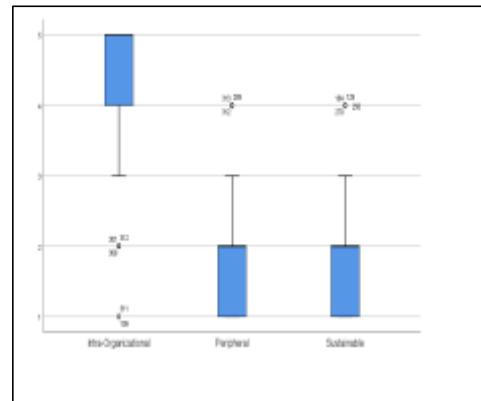


Fig. B.2: Institutional innovation

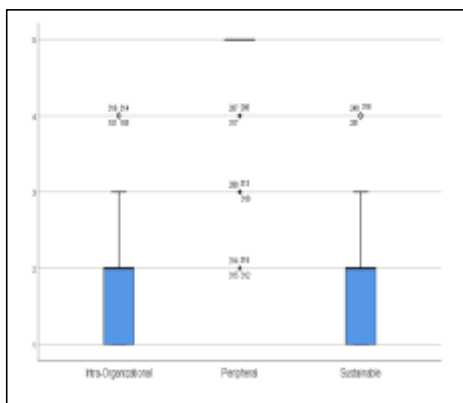


Fig. B.3: Marketing innovation

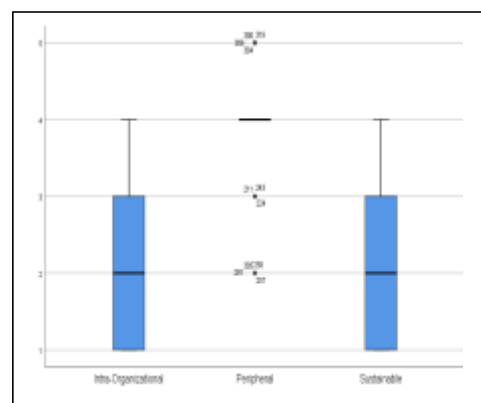


Fig. B.4: Life cycle innovation

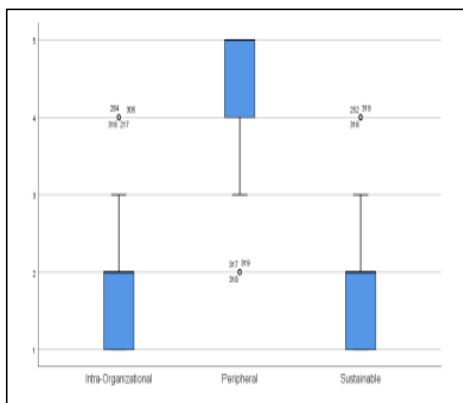


Fig. B.5: Business model innovation

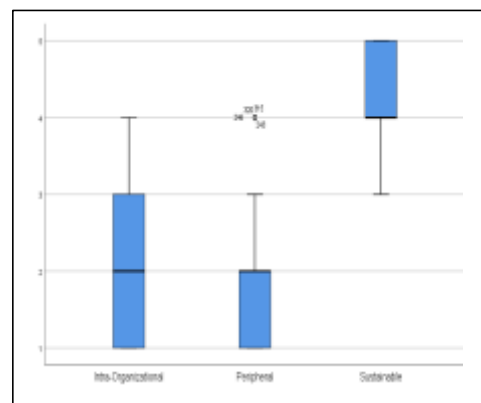


Fig. B.6: Technological innovation

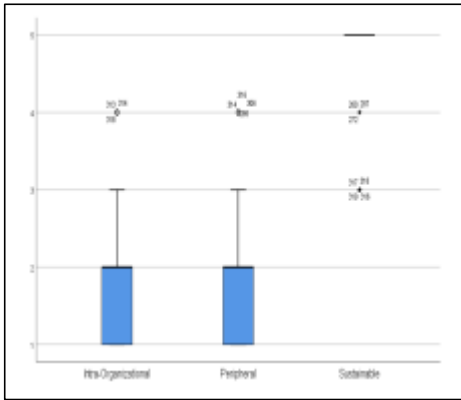


Fig. B.7: Product innovation

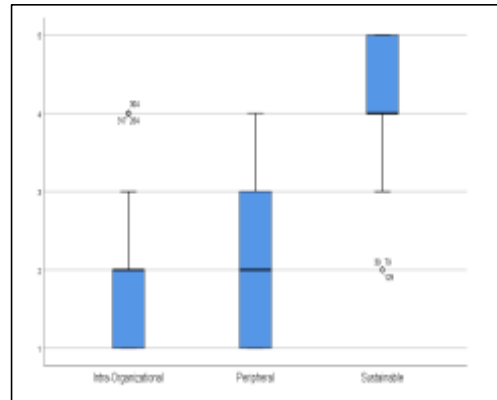


Fig. B.8: Process innovation

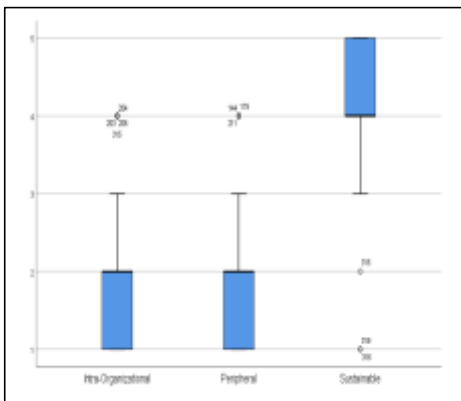


Fig. B.9: System innovation

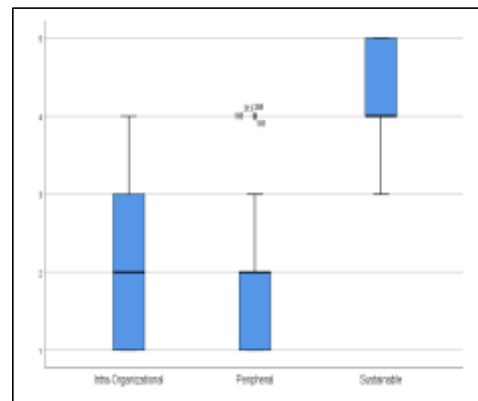


Fig. B.10: Regional indigenous innovation

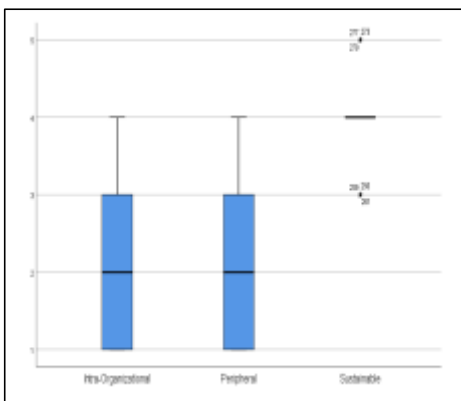


Fig. B.11: Service innovation

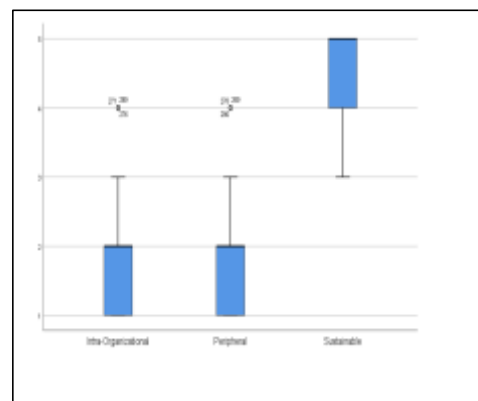


Fig. B.12: Green innovation

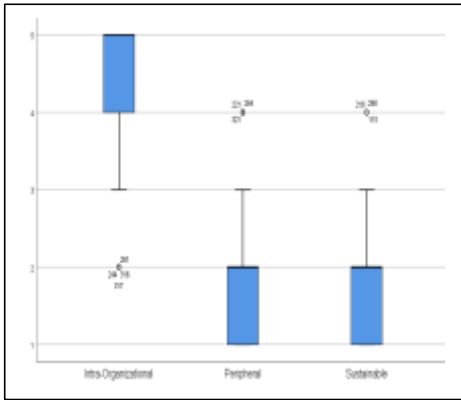


Fig. B.13: Cooperative innovation

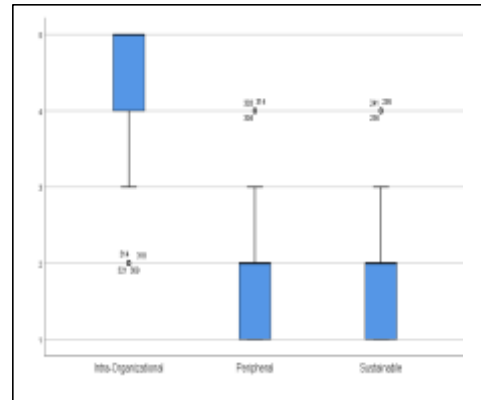


Fig. B.14: Culture innovation

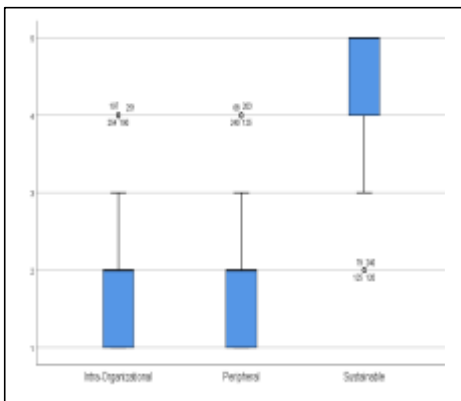


Fig. B.15: Ecological innovation

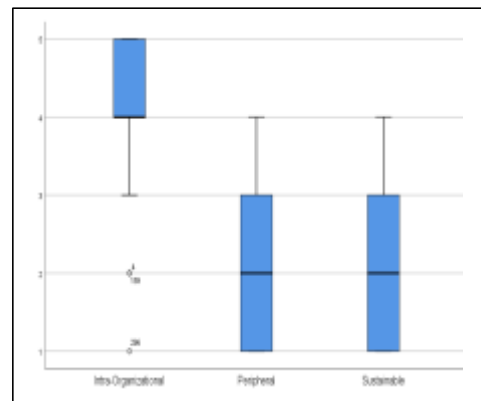


Fig. B.16: Enterprise innovation

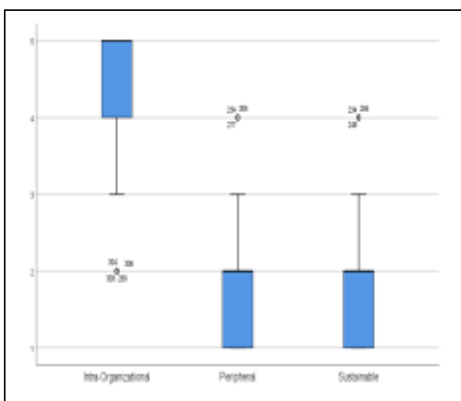


Fig. B.17: Human resource innovation

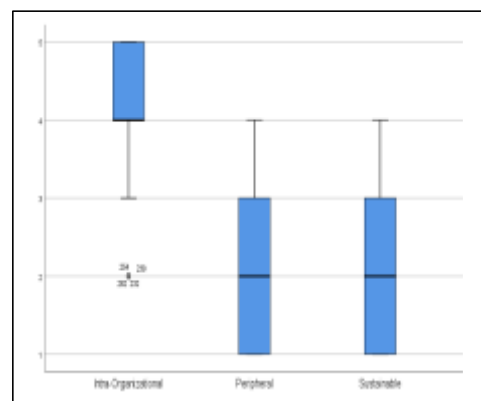


Fig. B.18: Management innovation

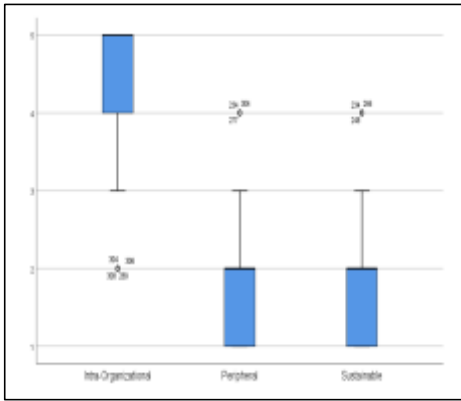


Fig. B.19: Resource innovation

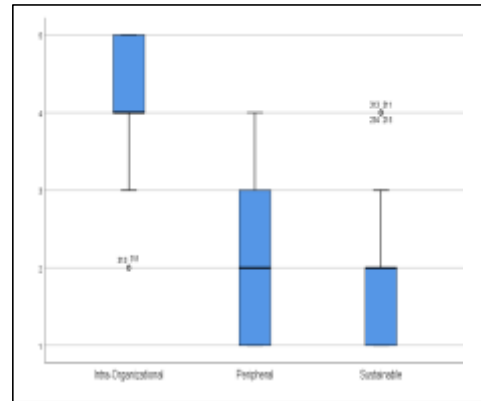


Fig. B.20: Strategy innovation

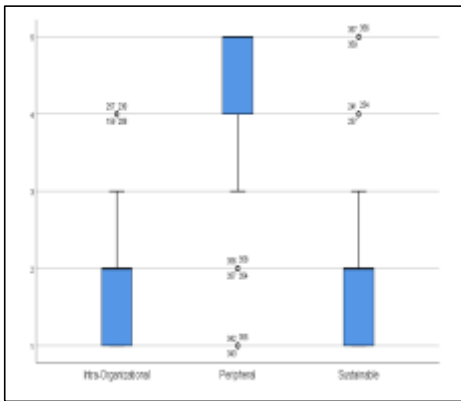


Fig. B.21: User innovation

APPENDIX C

Questionnaire QE2 assesses the industry's willingness to share necessary information for evaluating risks in core innovation concepts.

Please indicate whether the organization is willing to provide the information requested in the 1st column of the table, either with Yes or No.

Information Needed to assess Risk Involved in Core Innovation Concepts	Related innovation concepts	Core	Consent to share information
A: Key business objectives	Management Marketing		
B: Organizational vision on Innovation	Management Marketing		
C: Future plan for the growth of the innovation	Management Marketing Technological		
D: Financial plan on Innovation	Management Marketing Technological		
E: Organizational Strategy in achieving Innovation goals	Management Marketing		
F: Identifying training needs of the team in achieving innovation goals	Management Technological		
G: Analysis of Strengths of the organization in terms of			
H: Competitive advantages of the Organization	Management Marketing		
I: Skills required for the innovation	Technological		
J: Expertise Knowledge required on Innovation	Management, Technological		
K: Special Talents required on Innovations	Technological		
L: Investments needed for Innovation	Management		
M: Skills already available in the team	Management Technological		

N:Analysis of Threats of the organization -

O: Labour Shortages		Management Marketing Technological
P: Legislative Hurdles		Management Marketing
Q: Detrimental developments	Economic/Political	Management Marketing
R: Competitors		Marketing Management Technological
S: Strategy in reaching and identifying the customers and their unmet needs		Marketing Management
T: Defining the Marketing strategy testing on target market		Marketing
U: Power and knowledge of key decision makers		Marketing Management Technological

APPENDIX D

Questionnaire QE3, to validate the consistency of risk factor classification related to different phases of innovation process

Instructions to fill the questionnaire

Please put a tick for the most appropriate innovation phase, related to each risk factor

Number	Risk factors of technology innovation failures	Intra Organizational innovation phase (Structuring the organization for a sustainable	Peripheral innovation phase (Information outside the organization)	Product innovation phase	Process innovation phase
C1	Failure to evaluate the innovation concept based on the company's financial, structural, marketing, and technological capabilities				
C2	The company's long-term goals are not aligned with its innovation strategy				
C3	Violation of intellectual property rights or theft of intellectual property from others				
C4	Lack of organizational strength, including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base				
C5	Failure to adopt improved methods of commercialization and inaccurate market positioning				
C6	Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic				

-
- environment changes, and shifts in national industrial policies) can impact the organization
- C7** Risk of incomplete and inaccurate information, including distorted market data
- C8** Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points
- C9** Material resource risk affects timely delivery of goods
- C10** Risk posed by the emergence of new technologies and technological advancements
- C11** Failure to properly align the development, implementation, and output of the entire process, including incomplete project information and communication issues
- C12** Lack of a robust risk-control mechanism integrated with the company's development plans, strategies, manpower, and financial investments, including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach
- C13** Inadequate technical capacity to support innovation
- C14** Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management
-

APPENDIX E

QE4 - Questionnaire to identify root causes related to 14 risk factors in technology innovations

Please explain the reasons or root causes for the occurrence of these risk factors related to technological innovations

No.	Risks factors of technology innovation failures	Reasons or root causes for the occurrence of these risk factors related to technology innovations
C1	Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities	
C2	The company's long-term goals are not aligned with its innovation strategy	
C3	Violating intellectual property rights or stealing intellectual property from others	
C4	Lack of organizational strength (including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base)	
C5	Failure to adopt better methods of commercialization, inaccurate market positioning	
C6	Redundancy (a profitable innovation today may become obsolete in the near future) and Unprecedented risks - (risks beyond the organization's control, fluctuations in customer demand, social and economic environment, and national industrial policies)	
C7	Information resource risk, including distorted market information	
C8	Failure to generate technological ideas through customer feedback, basic research, and creativity resulted in Innovation failure to address customer pain points	
C9	Material resource risk	
C10	Technological advancements and the emergence of new technologies	

C11	Failure to properly align the development, implementation, and output of the entire process (incomplete project information and communication issues)
C12	Lack of a better risk-control mechanism, which risk management, must be combined with the enterprise's development plan, strategies, manpower, and financial investments, including a lack of risk supervision and control activity throughout the process and failure to adopt the "learning-through-experiment" process
C13	Inadequate Technical Capacity
C14	Issues with the R&D process, sample-to-batch challenges, Inbound and outbound communication issues, as well as inconsistency in project organization and management

APPENDIX F

Questionnaire QE5, to gather input data for the Feed forward Neural Network (FFNN) aimed at assessing the innovator type of an organization

Innovator Type

Please select the Innovator type related to your Innovation

*** Required**

Innovator Type

Mark only one oval.

Creator - High Innovative capabilities and being inquisitive to find gaps

Solution Builder- Looking to the market for inspiration, drawing on observations and deep insight to address customer priorities and problems

Leverager - Create a superior business model and then capitalize on it to sustain their Industry leadership

Expander- Apply their core capabilities in new ways to take over adjacent markets

Defender - Focus on points of advantage in mature or slow changing sectors and innovate defensively to protect their advantage

Fast Follower - Optimize their capabilities across all dimensions in order to quickly respond to and often improve upon competitor's innovations

Factors affecting technological innovation during Intra-organizational innovation phase

Intra-Innovation Phase means structuring the Organization for a sustainable Innovation

C1 - Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities

A1.1 Availability of enough investments for the project

A1.1 Availability of enough investments for the project	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly Satisfied

A1.2. If unavailable, chances of finding the required investments from outside (Loan, joint venture, mortgage, other)

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A1.3. Reviewing the innovation idea by members with appropriate expertise in identifying what would be necessary to implement the idea and what might go wrong?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A1.4 Prior knowledge and experience of the leadership to guide the innovation process?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A1.5. Accuracy of the budgeting process

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

C2 The Company's long-term goals are not aligned with its innovation strategy

A2.1 Considering the company's long term goals when doing the innovation?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A2.2 Required strengths (resources) of the organization in developing the innovation idea to match with company's long term goals

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

C3 Violating intellectual property rights or stealing intellectual property from others

A3.1 Checking the intellectual properties related to this product? Ex: Patent?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A3.2 Securing the innovation with a patent or any other appropriate method?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A3.3 Signing the NDA's (Non-Disclosure Agreements) with necessary personals?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

C4 Lack of organizational strength, including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base

A4.1 Long term availability of critical skill holders in the organization

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.2 Availability of required skills and knowledge of team members?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.3 Actions you have taken to improve your skills and knowledge? (1. Internal training, 2. On the job training, 3. External training with consultants 4. Any other appropriate training), (Skills for innovation and research?)

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.4 Having a proper learning culture in the organization

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.5 The relationship between team members

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.6 Level of convincing operators on process change

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor	Satisfied	Strongly satisfied

A4.7 Availability of time and other resources to go through the process of "learning through experiment"

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A4.8 Facts considered when selecting the Supplier (1. price, 2. lead time, 3. raw material quality, 4. cost benefits, 5. credit terms, 6. accreditations),?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A4.9 Agreement with Supplier holds any chances for negotiation?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

Factors affecting technological innovation during Peripheral innovation phase

Peripheral-Innovation Phase means information required from outside the organization for a sustainable innovation

C5 Failure to adopt improved methods of commercialization and inaccurate market positioning

A5.1 Availability of a proper mechanism to aware customers on products/services

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A5.2 Consulting a 3rd party team with more experiences in the process of commercialization

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A5.3 Deciding the correct market positioning through adequate market research

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

C6 Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic environment changes, and shifts in national industrial policies) can impact the organization

A6.1 Analysis of the information on redundancy or unprecedented risks which can impact the organization

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A6.2 Being the 1st entrant to the market

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A6.3 If no, are there any significant competitors??

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A6.4 Competitive advantages over the competitors of similar product/services (in terms of price, quality, user friendliness, market segment, brand recognition, durability, lead time)?

Strongly dissatisfied – None of the above factors

Dissatisfied – 2 factors

Neither satisfied nor dissatisfied – 3 or 4 factors including the factors 1,2 and 7

Satisfied – 5 to 6 factors including the factors 1, 2 and 7

Strongly satisfied – All factors

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A6.5 Demand pattern of the customers related to the innovation

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A6.6 6 Innovation complying with legislation and other national industrial policies

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

C7 Risk of incomplete and inaccurate information, including distorted market data

A7.1 Conducting a proper target market analysis

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A7.2 Identification of actual requirement of the customer

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A7.3 The outcome of the feasibility study

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

Factors affecting technological innovation during sustainable innovation phase, related to product innovation

Sustainable Innovation phase means implementing a sustainable innovation related to product and process

C8 Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points

A8.1 In cooperating customer feedbacks or market research feedbacks when developing the technological innovation idea

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A8.2 Innovation fulfilling customer expectations

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A8.3 Innovation is capable of competing with current technological trends

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

C9 Risks associated with material availability and quality

A9.1 Raw material quality matching with the customer requirements or any predetermined standards

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

--	--	--	--	--	--

A9.2 Availability of raw material during the bulk

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A9.3 Procedure to handle rejections and replacements of raw material

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

C10 Risk posed by the emergence of new technologies and technological advancements

A10.1 Conducting proper market research on your innovation including current trends and competitors

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A10.2 Any available/upcoming technological advancement related to your product/service?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A10.3 If yes, any harmful effects to the final innovation due to lack of resources to apply the new technology

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

Factors affecting technological innovation during sustainable innovation phase, related to process innovation

Sustainable innovation phase means implementing a sustainable innovation related to product and process

C11 Failure to properly align the development, implementation, and output of the entire process (incomplete project information and communication issues)

A11.1 Failure to properly align the development, implementation, and output of the entire process, including incomplete project information and communication issues

Innovator Type	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

A11.2 Accuracy of defining each phase of the process with clear instructions/information

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A11.3 Deciding the required information to be shared in each phase, with correct people

Innovator Type	Internal Training	On the job Training	External Training with Consultants	All	Other

A11.4 Contribution of the whole process in achieving the required timelines

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A11.5 Contribution of the whole process in achieving the required quality of the innovation

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A11.6 Contribution of the whole process in achieving the required cost savings

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A11.7 Identification of all the stakeholders in the process

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A11.8 Availability of an effective communication channel

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A11.9 Sharing required information and access to the stakeholders

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

C12 Lack of a robust risk-control mechanism integrated with the company’s development plans, strategies, manpower, and financial investments, including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach

A12.1 Availability of an appropriate evaluation mechanism with required control parameters?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A12.2 Who will be reviewing the process (Internally, Third Party, Both)

Do not consider - Strongly Dissatisfied

Not Applicable –Dissatisfied

Internally - Neither Satisfied nor Dissatisfied

Third party – Satisfied

Both internally and third party - Strongly satisfied

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A12.3 Is the process well-controlled against the plan?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor	Satisfied	Strongly satisfied

A12.4 Frequency of analysing the control parameters **Never** – Not at all

Rarely - Not Very Likely

Occasionally - Somewhat Likely

Frequently - Very Likely

Very Frequently - Extremely Likely

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A12.5 Identification of risks involved in this innovation?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A12.6 If done, the success rate of the innovations

0 – 20% - Strongly Dissatisfied

21% - 40% –Dissatisfied

41%- 60% - Neither Satisfied nor Dissatisfied

61% - 80% – Satisfied

81% - 100% - Strongly satisfied

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

C13 Inadequate technical capacity to support innovation

A13.1 Availability of required capacity of resources (machinery and equipment) to be utilized in bulk

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A13.2 If no, how the capacity is being filled (Joint venture, subcontracting, collaboration, purchasing, hiring, other)

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A13.3 Availability of required work-force for a bulk production

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A13.4 Defining the human resource skills requirement to complete the innovation

Innovator Type	Other	Entry Level	Moderate	advanced	More advanced

A13.5 If dissatisfied, having any alternate plans to acquire the required technical skills?

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

C14 Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management

A14.1 Defining the development process in achieving the right product/service?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A14.2 Ability to overcome challenges in the development process?

Innovator Type	Strongly Dissatisfied	Dissatisfied	Neither Satisfied nor Dissatisfied	Satisfied	Strongly satisfied

A14.3 Performing a development trial

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A14.4 Ability to apply the same methods/ development process for bulk production

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

A14.5 Any alternative methods increasing the requirements of costs/ lead time/ special skills and other

Innovator Type	Not at All	Not Very Likely	Somewhat Likely	Very Likely	Extremely Likely

APPENDIX G

Data Visualization illustrated in Table G.1.

TABLE G.1: DATA VISUALIZATION

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
VAR00001	.353	89	.000	.794	89	.000
VAR00002	.298	89	.000	.795	89	.000
VAR00003	.423	89	.000	.667	89	.000
VAR00004	.393	89	.000	.733	89	.000
VAR00005	.271	89	.000	.802	89	.000
VAR00006	.275	89	.000	.832	89	.000
VAR00007	.404	89	.000	.710	89	.000
VAR00008	.264	89	.000	.788	89	.000
VAR00009	.224	89	.000	.845	89	.000
VAR00010	.317	89	.000	.714	89	.000
VAR00011	.380	89	.000	.712	89	.000
VAR00012	.442	89	.000	.580	89	.000
VAR00013	.314	89	.000	.830	89	.000
VAR00014	.325	89	.000	.820	89	.000
VAR00015	.400	89	.000	.717	89	.000
VAR00016	.362	89	.000	.733	89	.000
VAR00017	.252	89	.000	.854	89	.000
VAR00018	.349	89	.000	.779	89	.000
VAR00019	.385	89	.000	.744	89	.000
VAR00020	.415	89	.000	.652	89	.000
VAR00021	.207	89	.000	.889	89	.000
VAR00022	.326	89	.000	.795	89	.000
VAR00023	.323	89	.000	.822	89	.000
VAR00024	.386	89	.000	.681	89	.000
VAR00025	.379	89	.000	.663	89	.000
VAR00026	.326	89	.000	.786	89	.000
VAR00027	.382	89	.000	.701	89	.000
VAR00028	.252	89	.000	.843	89	.000
VAR00029	.290	89	.000	.845	89	.000
VAR00030	.334	89	.000	.799	89	.000

VAR00031	.398	89	.000	.715	89	.000
VAR00032	.276	89	.000	.768	89	.000
VAR00033	.441	89	.000	.615	89	.000
VAR00034	.295	89	.000	.820	89	.000
VAR00035	.461	89	.000	.575	89	.000
VAR00036	.425	89	.000	.664	89	.000
VAR00037	.344	89	.000	.802	89	.000
VAR00038	.342	89	.000	.796	89	.000
VAR00039	.337	89	.000	.796	89	.000
VAR00040	.214	89	.000	.902	89	.000
VAR00041	.358	89	.000	.759	89	.000
VAR00042	.343	89	.000	.746	89	.000
VAR00043	.441	89	.000	.616	89	.000
VAR00044	.346	89	.000	.756	89	.000
VAR00045	.422	89	.000	.676	89	.000
VAR00046	.335	89	.000	.780	89	.000
VAR00047	.351	89	.000	.771	89	.000
VAR00048	.393	89	.000	.723	89	.000
VAR00049	.385	89	.000	.706	89	.000
VAR00050	.306	89	.000	.820	89	.000
VAR00051	.443	89	.000	.629	89	.000
VAR00052	.364	89	.000	.752	89	.000
VAR00053	.275	89	.000	.782	89	.000
VAR00054	.399	89	.000	.692	89	.000
VAR00055	.166	89	.000	.899	89	.000
VAR00056	.346	89	.000	.754	89	.000
VAR00057	.273	89	.000	.785	89	.000
VAR00058	.432	89	.000	.652	89	.000
VAR00059	.286	89	.000	.833	89	.000
VAR00060	.331	89	.000	.785	89	.000
VAR00061	.372	89	.000	.733	89	.000
VAR00062	.432	89	.000	.617	89	.000
VAR00063	.299	89	.000	.814	89	.000
VAR00064	.382	89	.000	.711	89	.000
VAR00065	.376	89	.000	.748	89	.000

Figure G.1 through G.65 illustrate histograms on 65 Variables (65 root causes used as input to the Neural Network)

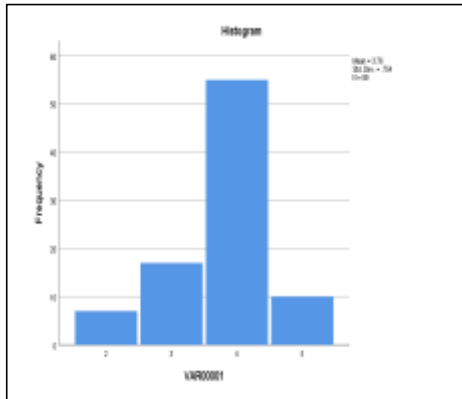


Fig. G.1: Variable V1

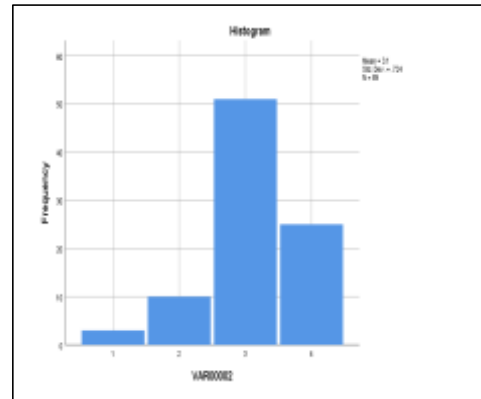


Fig. G.2: Variable V2

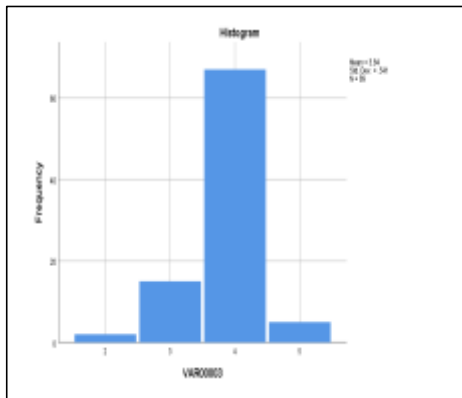


Fig. G.3: Variable V3

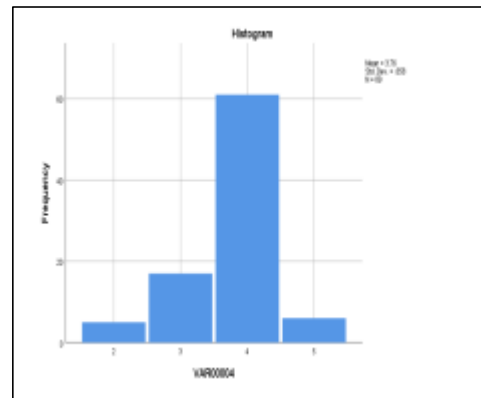


Fig. G.4: Variable V4

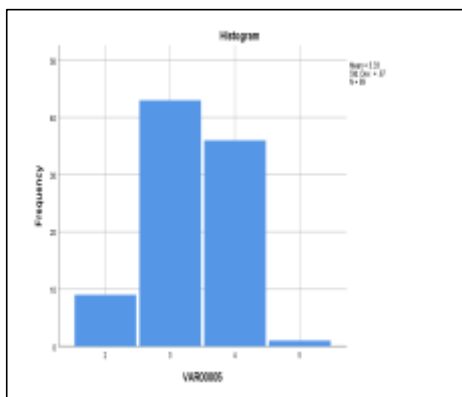


Fig. G.5: Variable V5

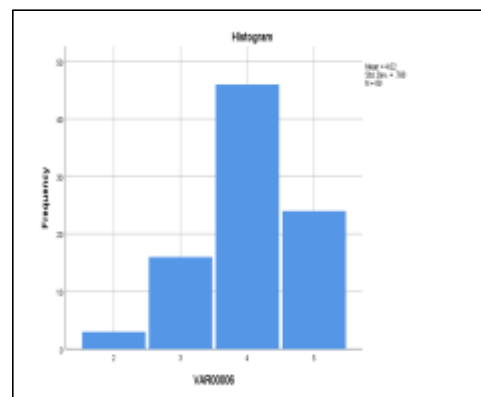


Fig. G.6: Variable V6

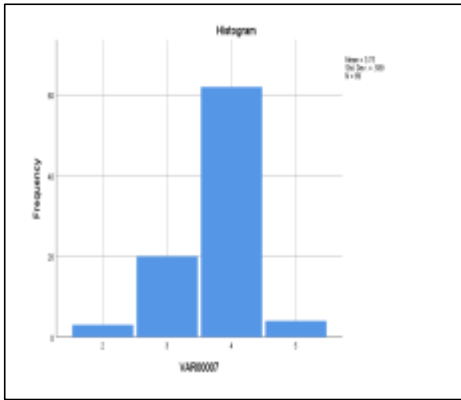


Fig. G.7: Variable V7

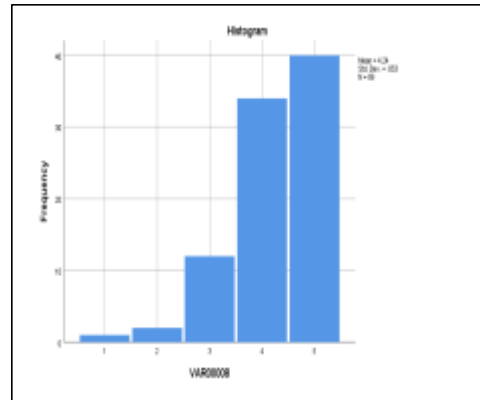


Fig. G.8: Variable V8

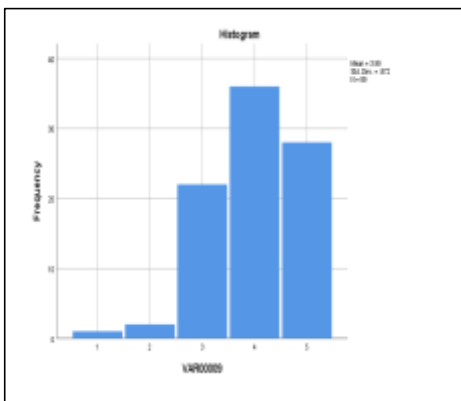


Fig. G.9: Variable V9

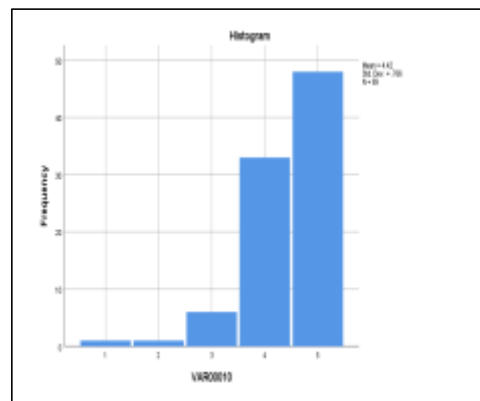


Fig. G.10: Variable V10

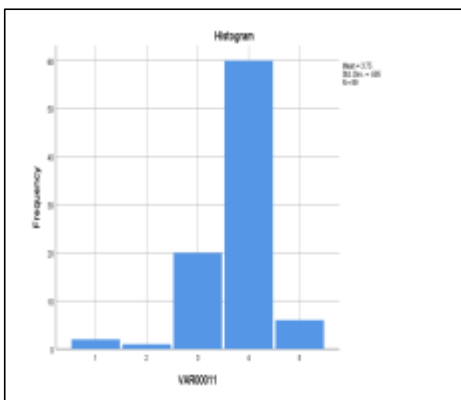


Fig. G.11: Variable V11

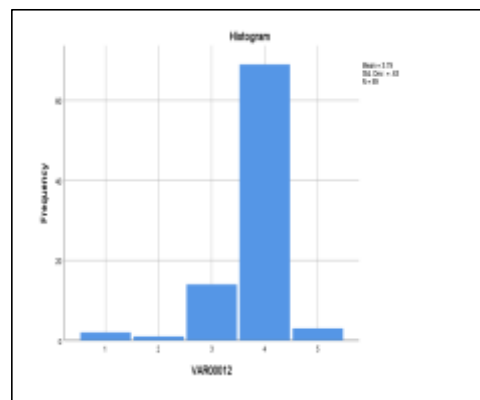


Fig. G.12: Variable V12

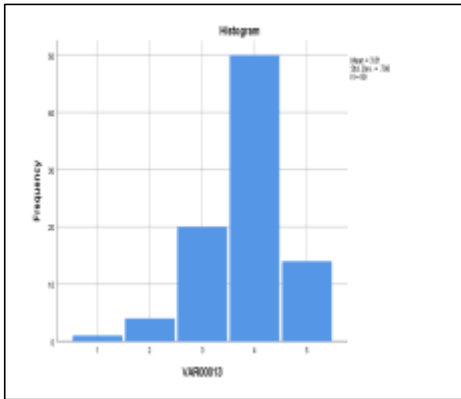


Fig. G.13: Variable V13

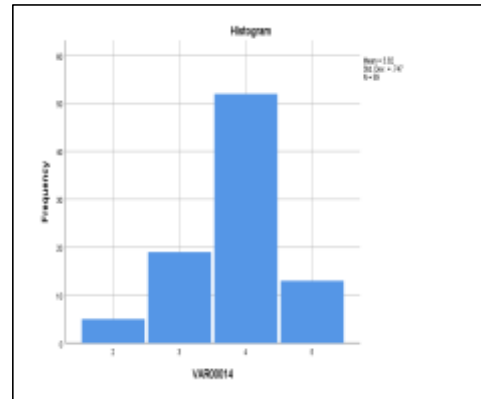


Fig. G.14: Variable V14

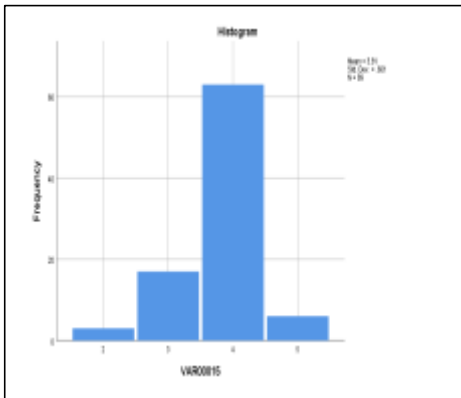


Fig. G.15: Variable V15

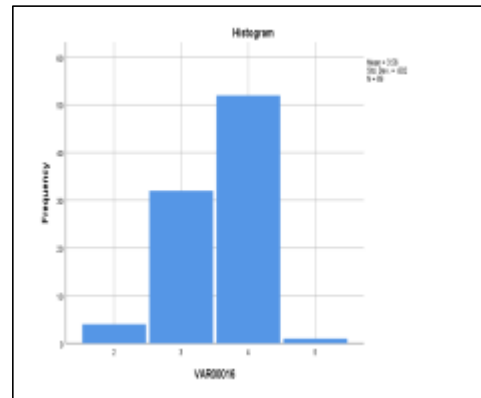


Fig. G.16: Variable V16

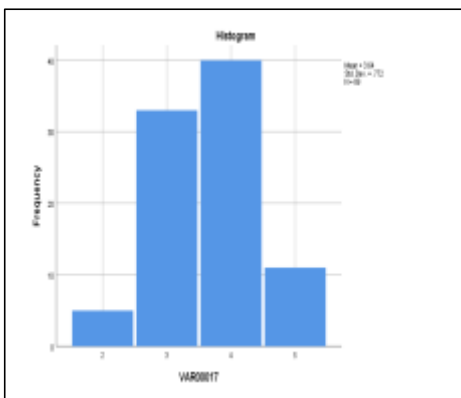


Fig. G.17: Variable V17

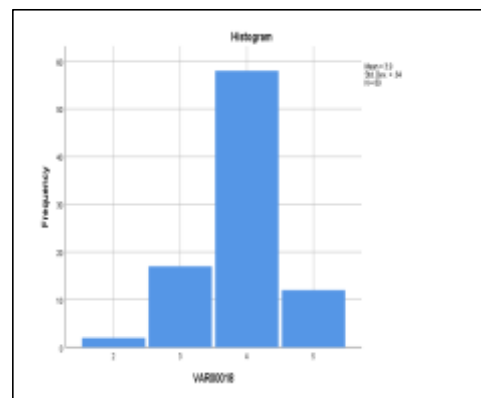
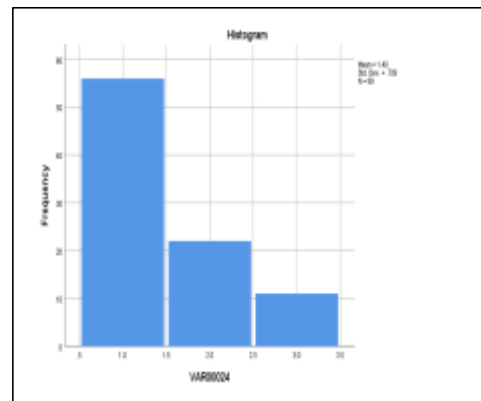
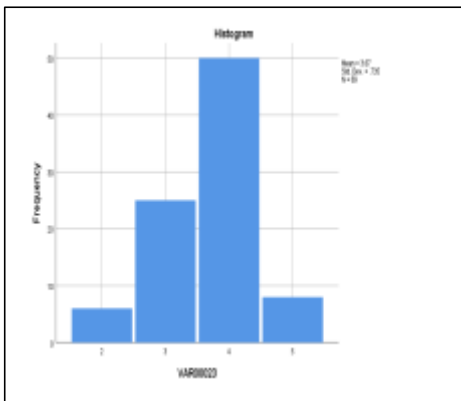
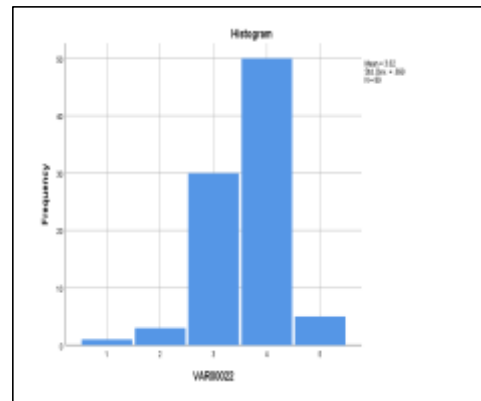
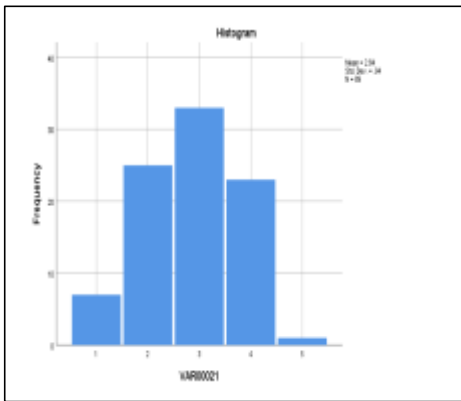
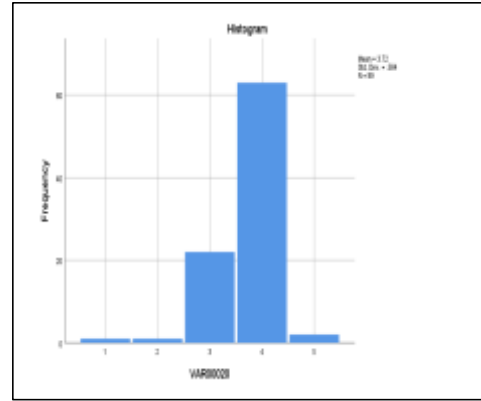
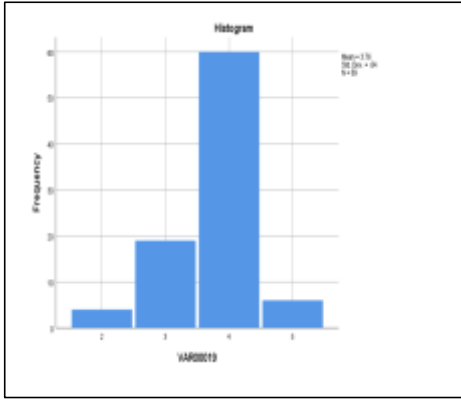


Fig. G.18: Variable V18



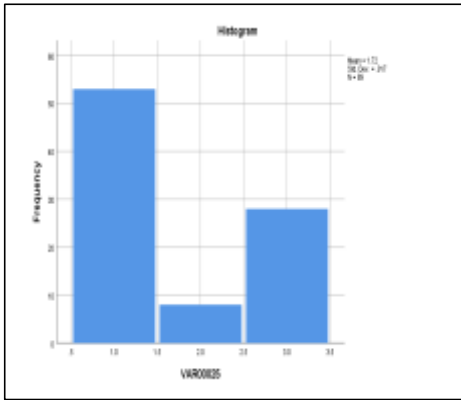


Fig. G.25: Variable V25

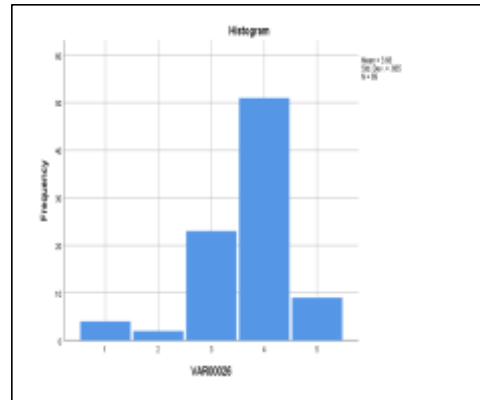


Fig. G.26: Variable V26

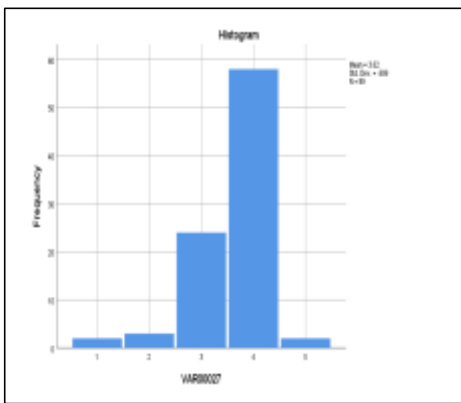


Fig. G.27: Variable V27

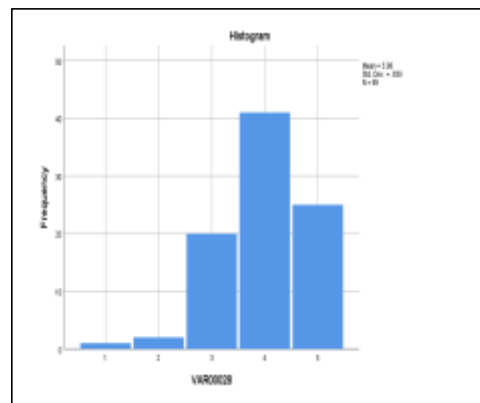


Fig. G.28: Variable V28

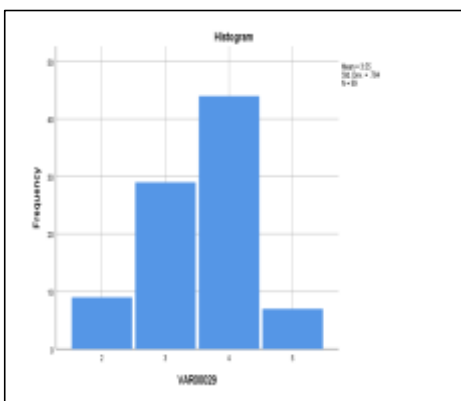


Fig. G.29: Variable V29

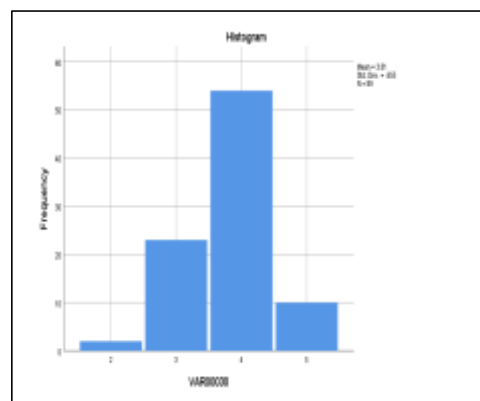


Fig. G.30: Variable V30

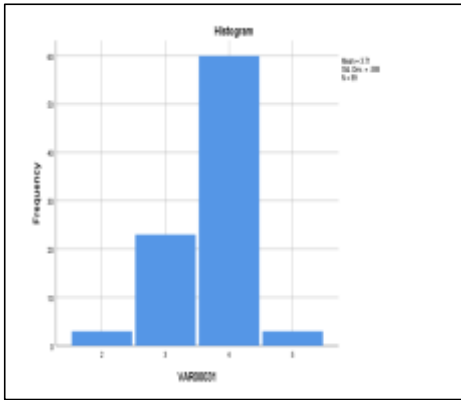


Fig. G.31: Variable V31

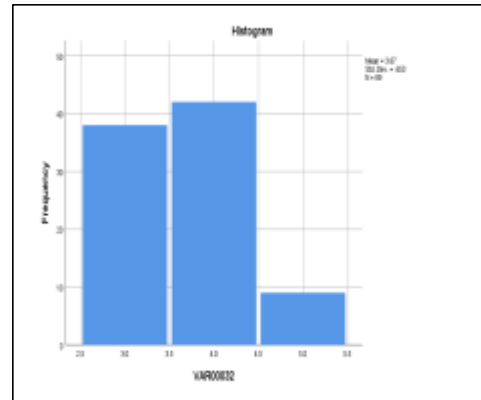


Fig. G.32: Variable V32

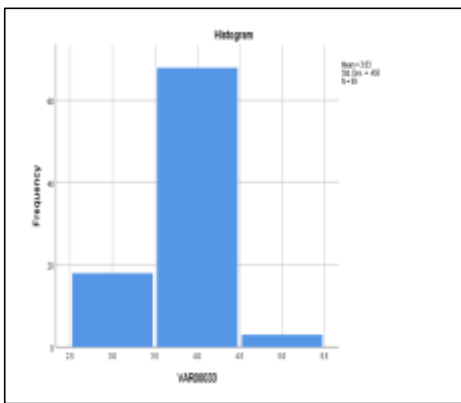


Fig. G.33: Variable V33

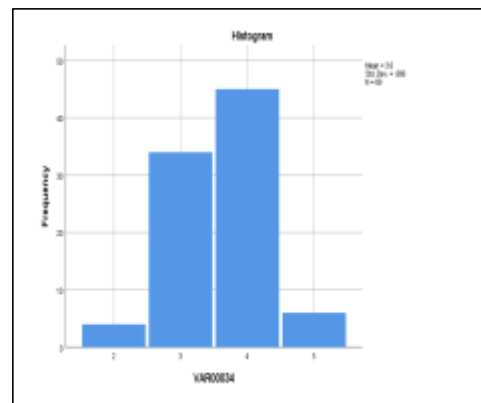


Fig. G.34: Variable V34

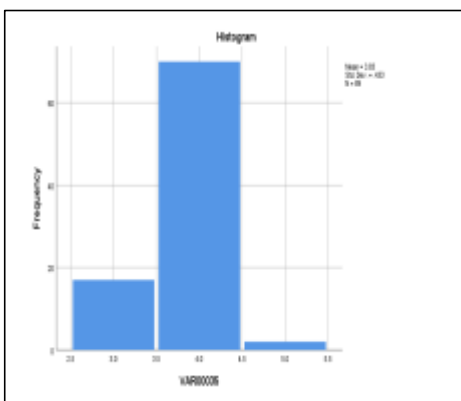


Fig. G.35: Variable V35

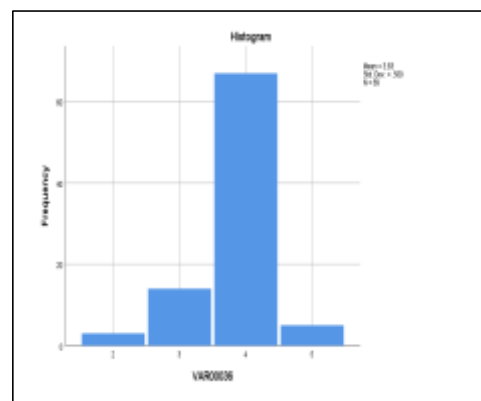
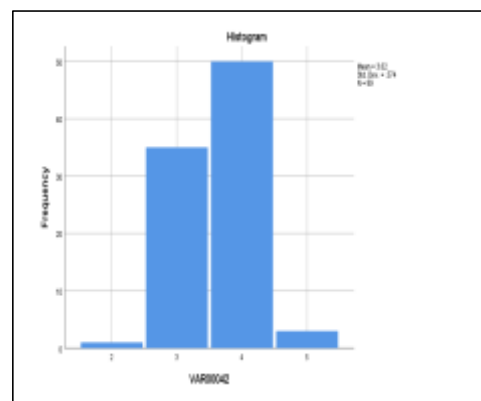
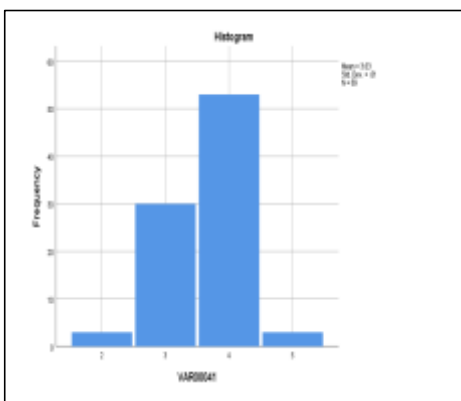
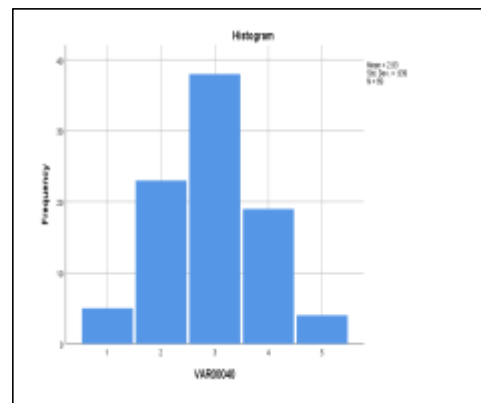
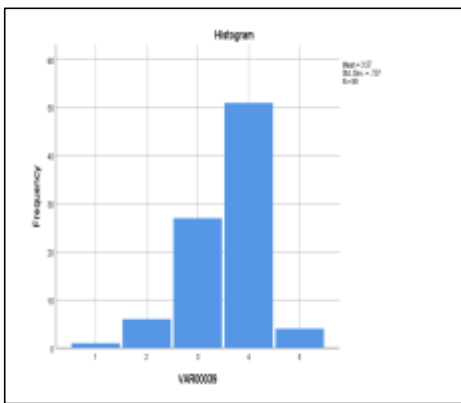
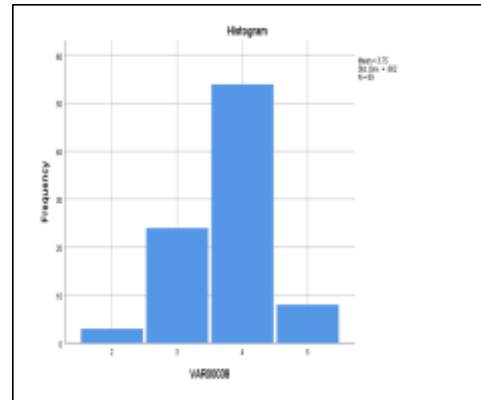
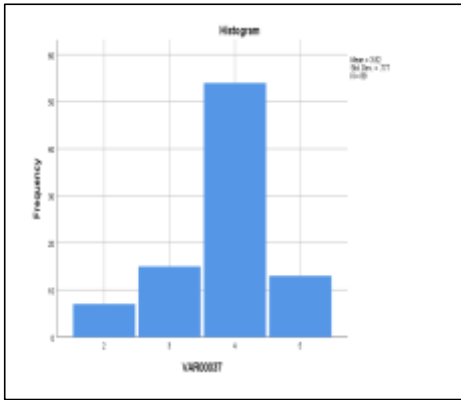
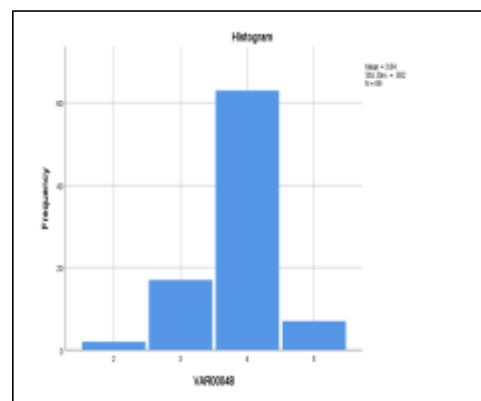
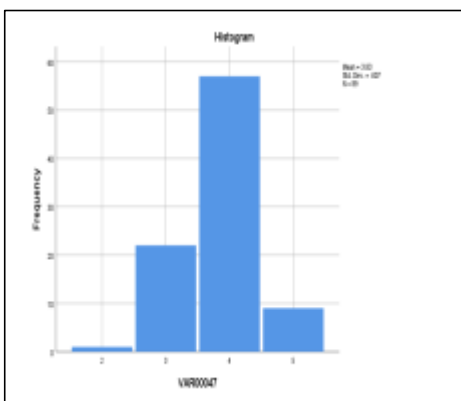
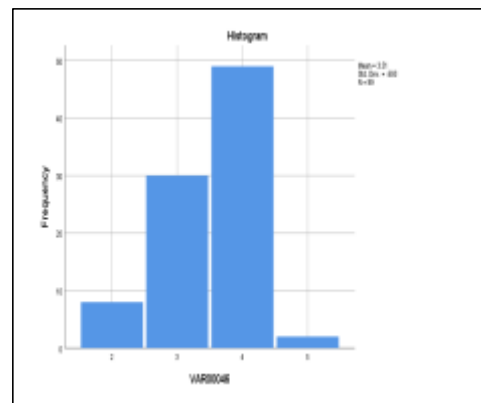
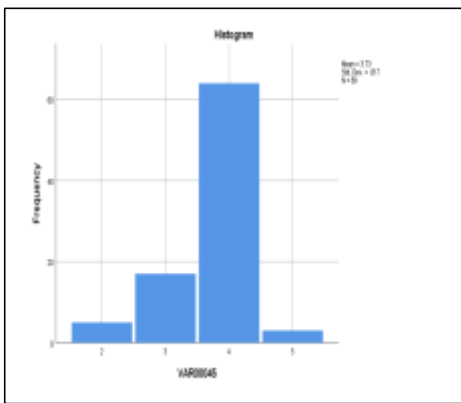
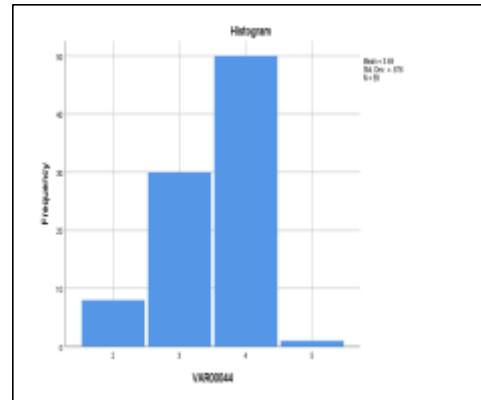
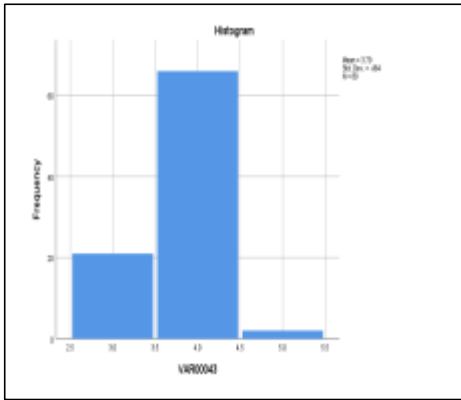


Fig. G.36: Variable V36





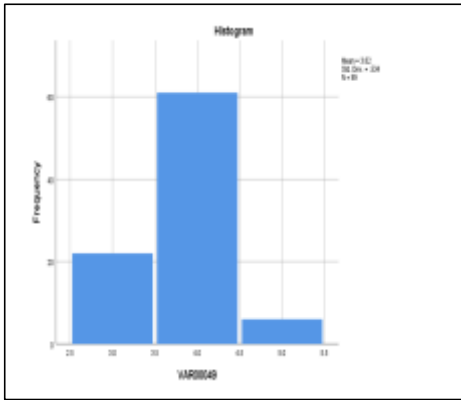


Fig. G.49: Variable V49

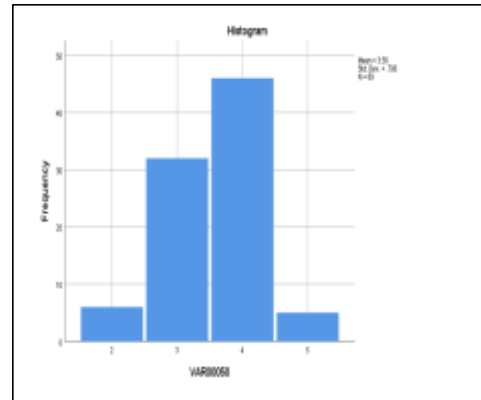


Fig. G.50: Variable V50

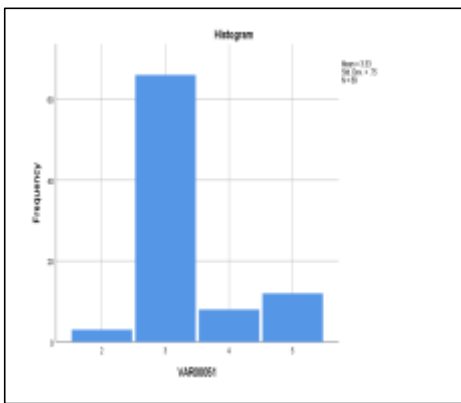


Fig. G.51: Variable V51

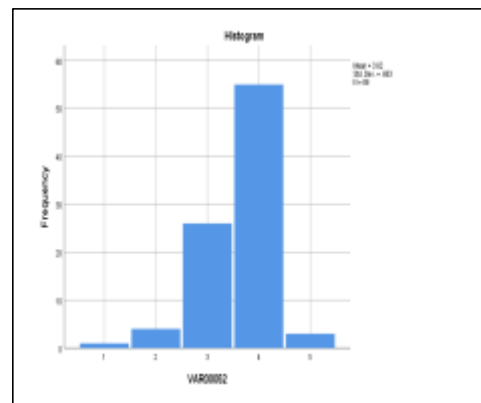


Fig. G.52: Variable V52

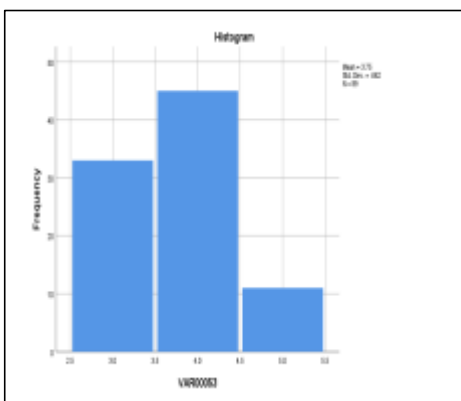


Fig. G.53: Variable V53

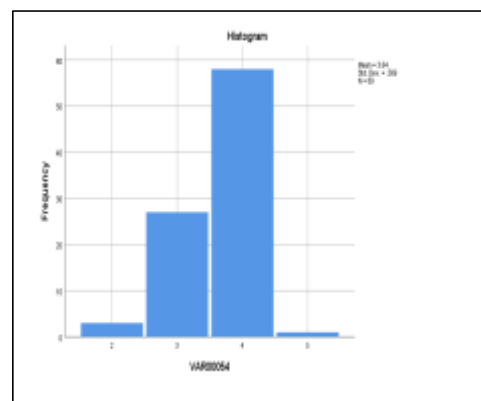
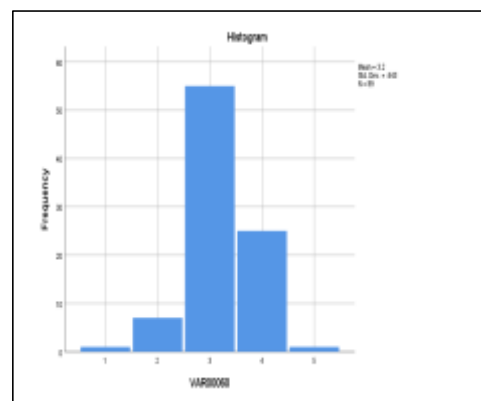
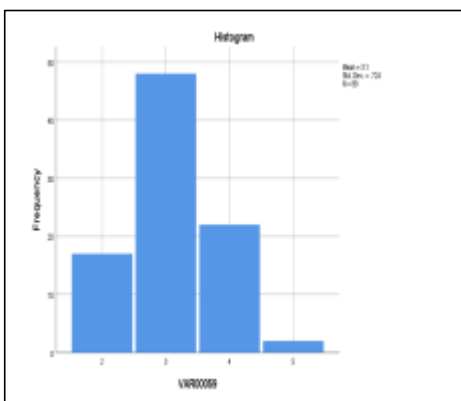
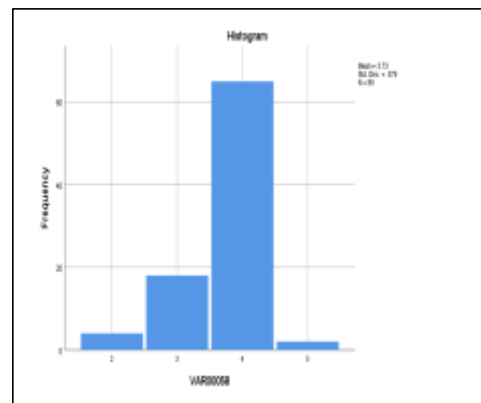
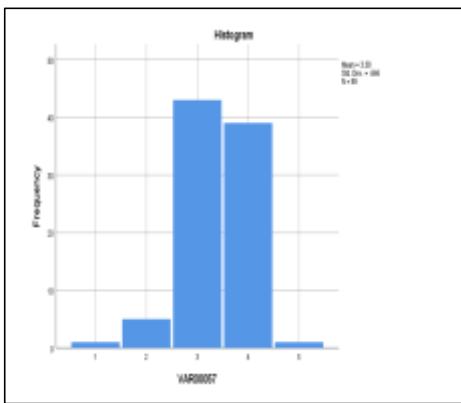
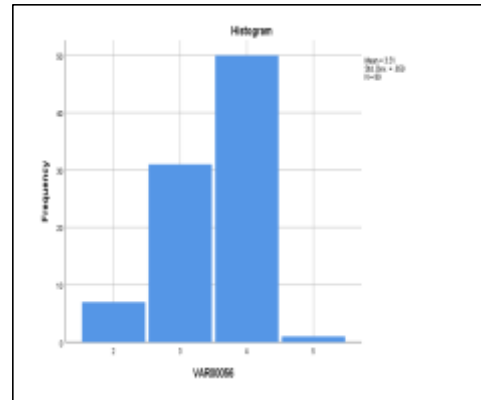
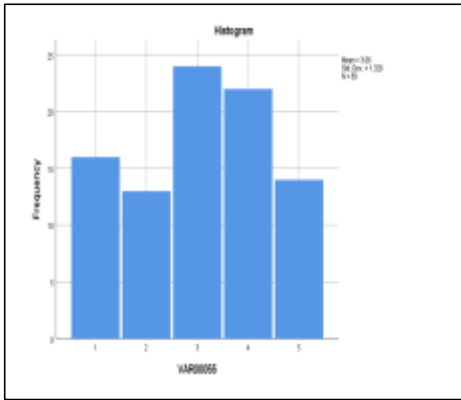
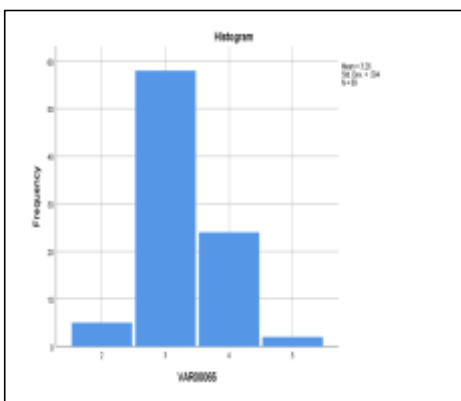
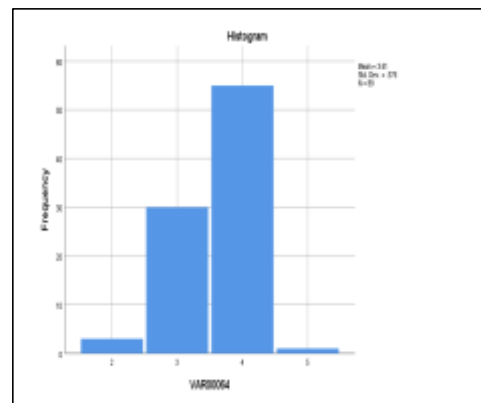
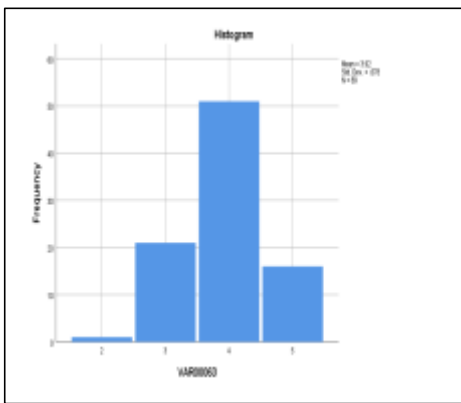
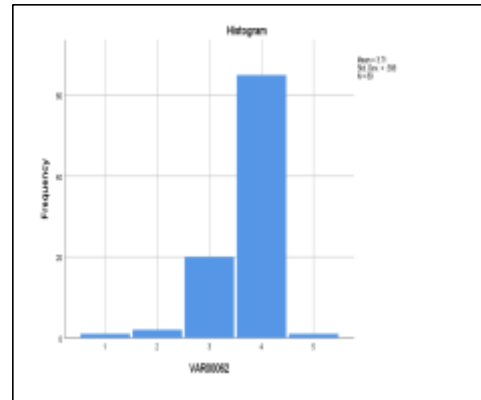
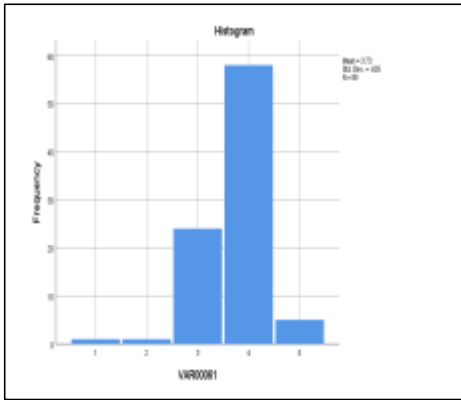


Fig. G.54: Variable V54





APPENDIX H

Neural Network architectures explored to determine the innovator type of the organization are shown in Table H.1.

TABLE H.1: NEURAL NETWORK ARCHITECTURES

Model Number	1	2	3	4	5
Model Type	Medium Neural Network	Medium Neural Network	Optimizable Neural Network	Medium KNN	FineTree
Accuracy	46.1%	42.7%	51.7%	38.2%	49.4%
Prediction Speed	~5400 obs/sec	~1100 obs/sec	~4900 obs/sec	~1600 obs/sec	~4100 obs/sec
Training Time	0.76883 sec	1.3845 sec	38.111 sec	1.6476 sec	1.1906 sec
Number of Fully connected layers	1	1	3 1 st layer – 1-300, 2 nd - 1-300, 3 rd 1-300		
First Layer Size	25	25	50		
Activation Function	ReLu	ReLu	Tanh		
Iteration Limit	1000	1000	1000		
Other Information	Standardize data: Yes Optimizer Options: Hyperparameter options disabled Feature Selection: All features used in the model, All features used in the model,	Optimizer Options: Hyperparameter options disabled Feature Selection: All features used in the model, PCA PCA is keeping	Optimizer Options: Bayesian Acquisition function: Expected improvement per second plus Iterations: 30 Training	Number of neighbors: 10 Distance metric: Euclidean Distance weight: Equal Standardize data: true Optimizer Options: Hyperparameter	Maximum number of splits: 100 Split criterion: Gini's diversity index Surrogate decision splits: Off Optimizer Options

connected layers		@nd Layer -10		
First Layer Size				100
Activation Function		ReLu		ReLu
Iteration Limit	1000	1000		
Other Information	Surrogate decision Off Optimized Hyperparameters Maximum number of splits: 10 Split criterion: Gini's diversity index Hyperparameter Search Range Maximum number of splits: 1-88 Split criterion: Gini's diversity index, Twoing rule, Maximum deviance reduction Optimizer Options Optimizer: Bayesian optimization Acquisition function: Expected improvement per second plus Iterations: 30 Training time limit: false Feature	Learner: SVM Number of expansion dimensions: Auto Regularization strength (Lambda): Auto Kernel scale: Multiclass method: One-vs-One Iteration limit: 100 Optimizer Options Hyperparameter options disabled Feature Selection All features used in the model, before PCA PCA disabled Misclassification Costs Not supported	Regularization strength (Lambda): 0 Standardize data: Yes Optimizer Hyperparameter options disabled Feature Selection All features used in the model, before PCA PCA disabled Feature Selection All features used in the model, before PCA PCA disabled	Standardize data: Yes Optimizer Options Hyperparameter options disabled Feature Selection All features used in the model, before PCA PCA disabled Misclassification Costs Not supported

Selection	All
features used in	the model,
before PCA	223 PCA PCA
disabled	disabled
Misclassification	Costs Cost
matrix:	default

Model Number	10	11	12
Model Type	Trilayered Network	Neural Network	Optimizable Neural Network
Accuracy	37.1%	52.8%	52.8%
Prediction Speed	~4800 obs/sec	~3900 obs/sec	~5600 obs/sec
Training Time	0.87436 sec	47.578 sec	0.94898 sec
Number of Fully connected layers	3 1 st Layer 10 2 nd Layer 10, 3 rd - 10	2, 1 st - 96, 2 nd - 243	1
First Layer Size	10	96	100
Activation Function	ReLu	Sigmoid	Tanh
Iteration Limit	1000	1000	1000

Other Information	Standardize data: Yes Optimizer Options Hyperparameter options disabled Feature Selection All features used in the model, before PCA PCA PCA disabled Misclassification Costs Not supported	Standardize data: Yes Hyperparameter Search Range Number of fully connected layers: 1-3 Standardize data: Yes, No Regularization strength (Lambda): 1.1236e-07-1123.5955 First layer size: 1-300 Second layer size: 1-300 Third layer size: 1-300 Optimizer Options Optimizer: Bayesian optimization Acquisition function: Expected improvement per second plus Iterations: 30 Training time limit: false Feature Selection All features used in the model, before PCA PCA PCA disabled Misclassification Costs Not supported	Standardize data: Yes Optimizer Options Hyperparameter options disabled, Feature Selection All features used in the model, before PCA PCA disabled Misclassification Costs Not supported
-------------------	--	---	---

APPENDIX I

Risk factor interdependencies are shown in Table I.1.

TABLE I.1: RISK FACTOR INTERDEPENDENCIES

Risk factor	Influencing risk factors
C1	C2,C5,C6,C8
C2	C5
C3	C4,C12
C4	C3,C7,C12
C5	C6,C8
C6	C9
C7	C5,C8
C8	C1,C5,C10
C9	C6,C10,C11
C10	C6,C8,C5
C11	C9,C12
C12	C13,C14
C13	C14
C14	C11,C13

C1 through C14, are the risk factors of technological innovations presented in Table 4.5, subsection 4.4 in Chapter 4 (Results).

Figure I.1 presents the interconnections of risk factors using the Graph Theory.

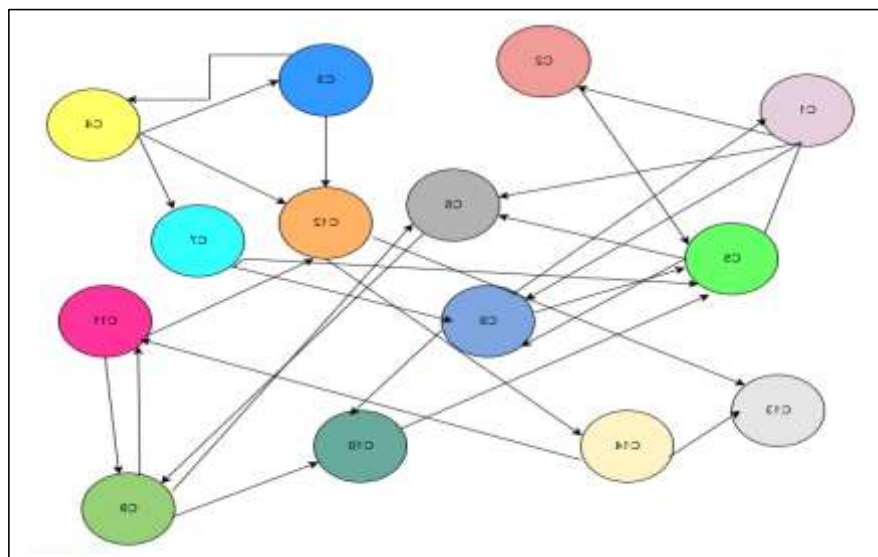


Fig. I.1: Interconnections of risk factors

APPENDIX J

Abbreviations of Figure 3.10

TABLE J.1: ABBREVIATIONS OF FIGURE 3.10

Abbreviation	Description	Abbreviation	Description
N 1.1	Leadership	N8.1	Identify the customer
N 1.2	Resources	N8.2	Current trends
N 2.1	Long term goals	N9.1	Quality of raw materials
N 2.2	Strengths of the organization	N9.2	Flexibility of the supplier
N3.1	Precautions are taken before the commencement	N10.1	Information accuracy
N3.2	Measures to secure the innovation	N10.2	Lack of resources
N4.1	Organizational culture	N11.1	Process accuracy
N4.2	Supplier base	N11.2	Achievements(time, quality, cost savings)
N5.1	Precision of timing	N12.1	Accuracy of risk controlling mechanism
N5.2	Product awareness	N12.2	Risk identification
N6.1	Risks related to customer	N13.1	Resource availability
N6.2	Risks related to laws & regulations	N13.2	Defining the required skills
N7.1	Customer behaviour	N14.1	Defining the process

N7.2	Obtaining information	N14.2	Challenges in bulk
------	-----------------------	-------	--------------------

QE6 - Questionnaire to obtain intensity values for prioritizing root causes related to risk factors using ANP. Determine intensities of pairwise comparisons related to 14 risk factors

Risk Factor - C	Root Cause A1	Root Cause A2	Root cause An
Root Cause A1	1			
Root Cause A2		1		
.....			
Root cause An				1

Table 2: Pairwise comparisons related to intra organizational innovation phase

Innovator Type	Intra Organizational Innovation Phase			
	C1	C2	C3	C4
C1				
C2				
C3				
C4				

Table 3: Pairwise comparisons related to peripheral innovation phase

Innovator Type	Peripheral Innovation Phase		
	C5	C6	C7
C5			
C6			
C7			

Table 4: Pairwise comparisons related to Sustainable innovation phase

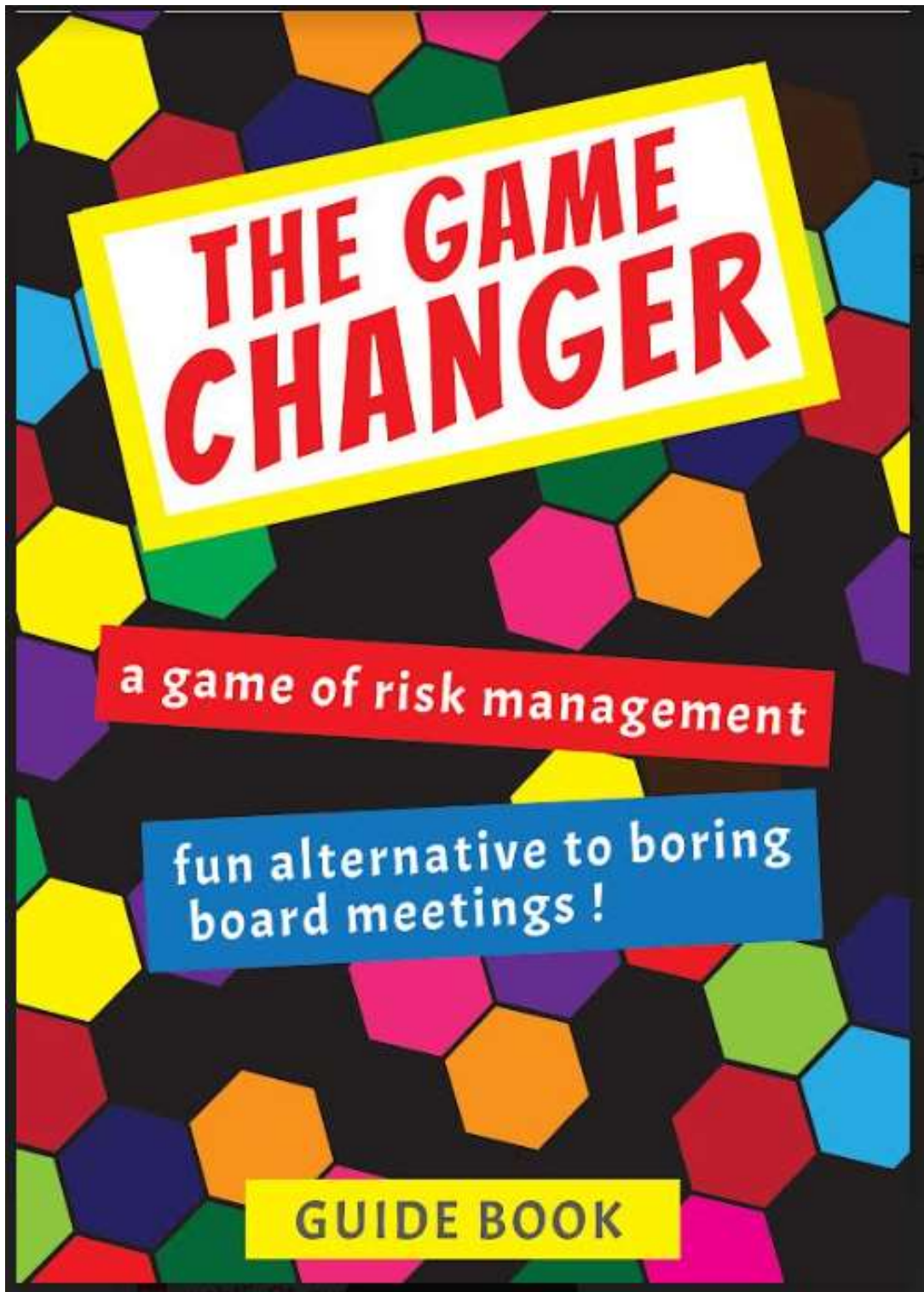
Innovator Type	Product Innovation Phase		
	C8	C9	C10
C8			
C9			
C10			

Table 5: Pairwise comparisons related to peripheral innovation phase

Innovator Type	Process Innovation Phase			
	C11	C12	C13	C14
C11				
C12				
C13				
C14				

APPENDIX K

User Guide



How to Play the Game - The Game Changer

Game of Risk Management

Aim of the game

To find out the most efficient and effective causes of actions to manage technological innovation risks related to textile and apparel industries

In this initiative, participants from various departments collaborate in a game aimed at addressing the root causes of 14 distinct risk factors associated with technological innovations, as detailed in Table 1 in Appendix (User Guide).

Game Elements

- Game board
- Game pieces
- Check list for the Pitch making meeting
- Game Cards bear the information on risk factors, root causes and their priorities

Game Setup

The game consists of 3 main phases as illustrated in Figure 1.

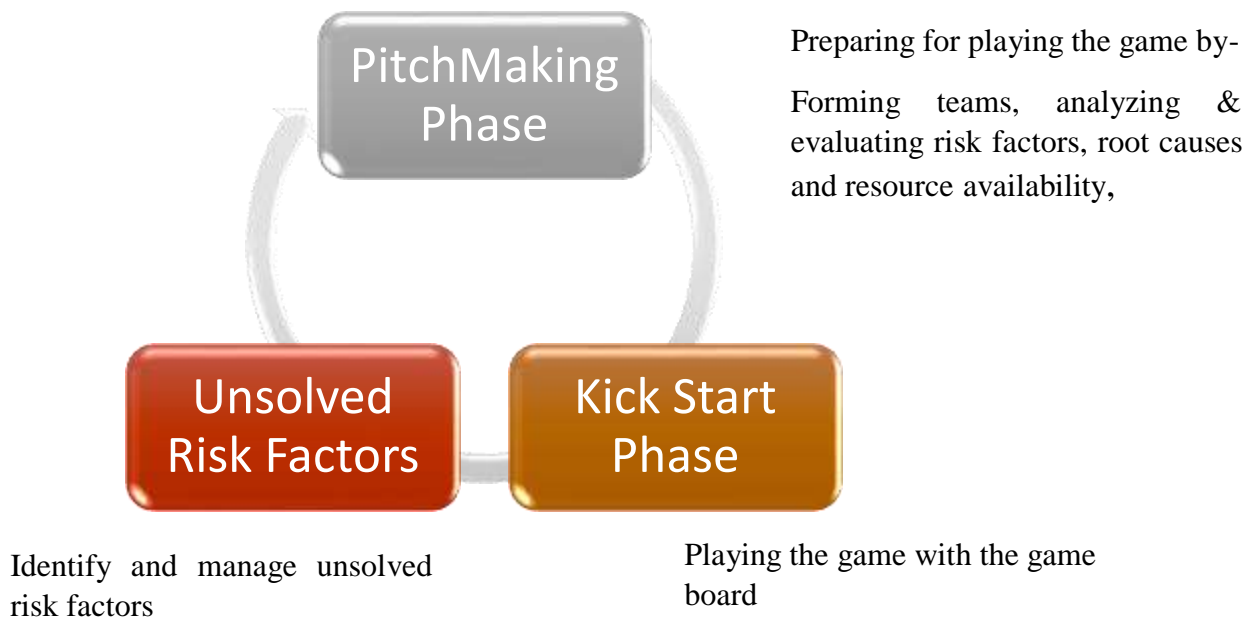


Figure1: Main phases of the game

Figure 2 summarizes the key processes associated with each main phase of the risk management model.

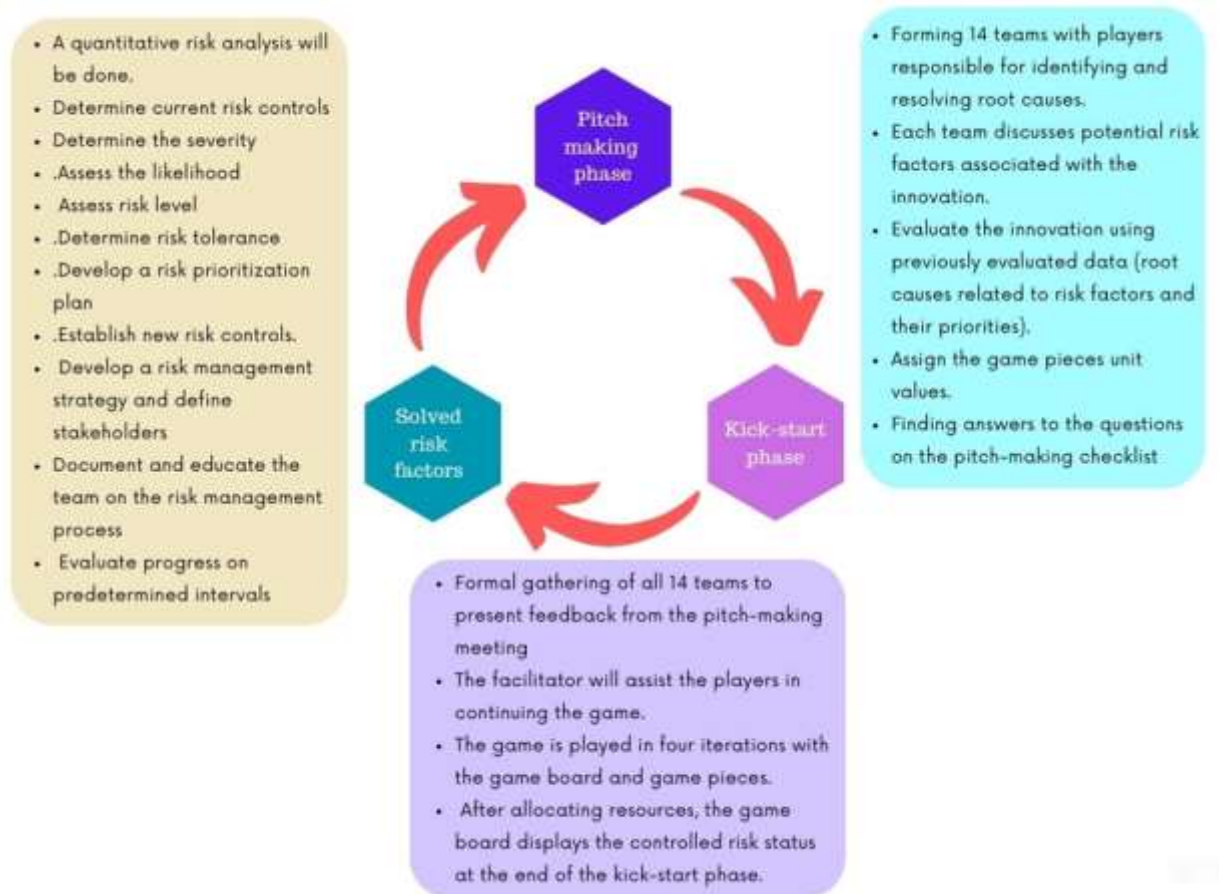


Figure 2: Key processes associated with each main phase of the risk management model

Before starting the game:

- **Players**
Members from different departments participate to play the game
- **Team**
Members tasked with addressing the root causes of 14 risk factors in technological innovations will form teams. There will be 14 teams participating in the game, each focusing on a specific risk factor.

Table 1 in Appendix K (User Guide) lists the departments responsible for addressing each risk factor. These departments may vary by organization. Therefore, teams should be formed based on similar functions rather than department names. For example, one organization might have a merchandising department for supplier orders, while another might assign this task to its supply chain management department.

- **Game Board**

Players play with the game board to manage the risk associated with the organization's technological innovation project.

- The game board, shown in Figure 3, comprises of 14 unit cells, representing 14 risk factors
- Each unit cell, illustrated in Figure 4, contains the main mechanisms need to manage the risk involved. This includes Money, Machine, Man, Method, Material and the Risk Level. (Figure 5)

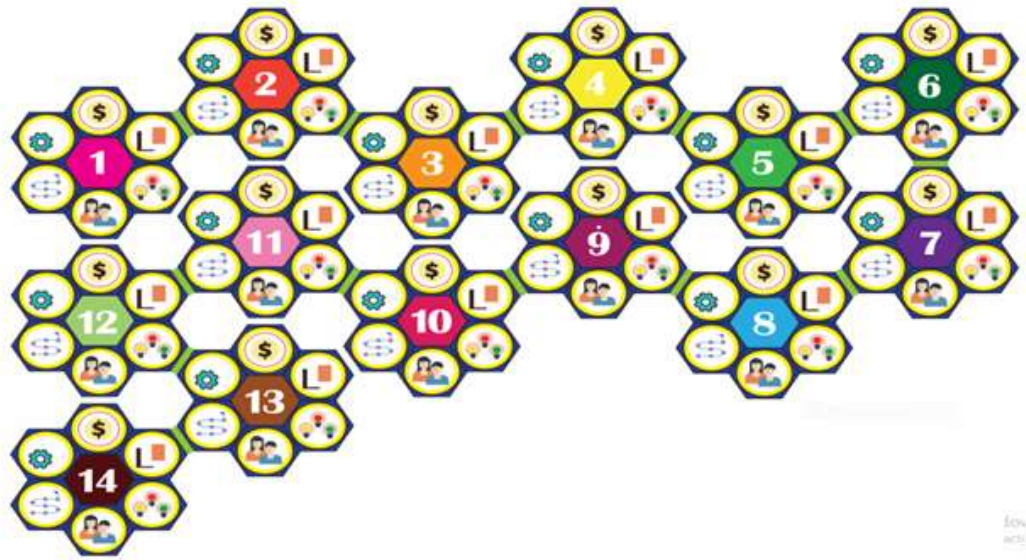


Figure 3: The Game Board



Figure 4: Symbols of main mechanisms



Figure 5: Unit cell of the game board

- The Game Pieces

The game pieces represent the key mechanisms, including Man, Money, Machine, Material, Method, and Risk level, and are used on the board. Each unit cell of the game board features game pieces designed with different shapes to symbolize these factors. The game pieces are color-coded: green for an excess of a resource and red for a deficiency. This color scheme helps teams make informed decisions by providing clear visual cues about resource availability. Figure 5 illustrates the game pieces and their key mechanisms.

- In order to play the game, each team should possess game pieces related to resources plus risk levels.
- Unit value will be assigned to game pieces of the resources by each team.
- A flag, which can be fixed to the game board, is used to put the category of the resource. (Ex. competition, partnership, loan, and mortgage or with other funding method for money)

Figure 6 illustrates the game pieces, related to key mechanisms.

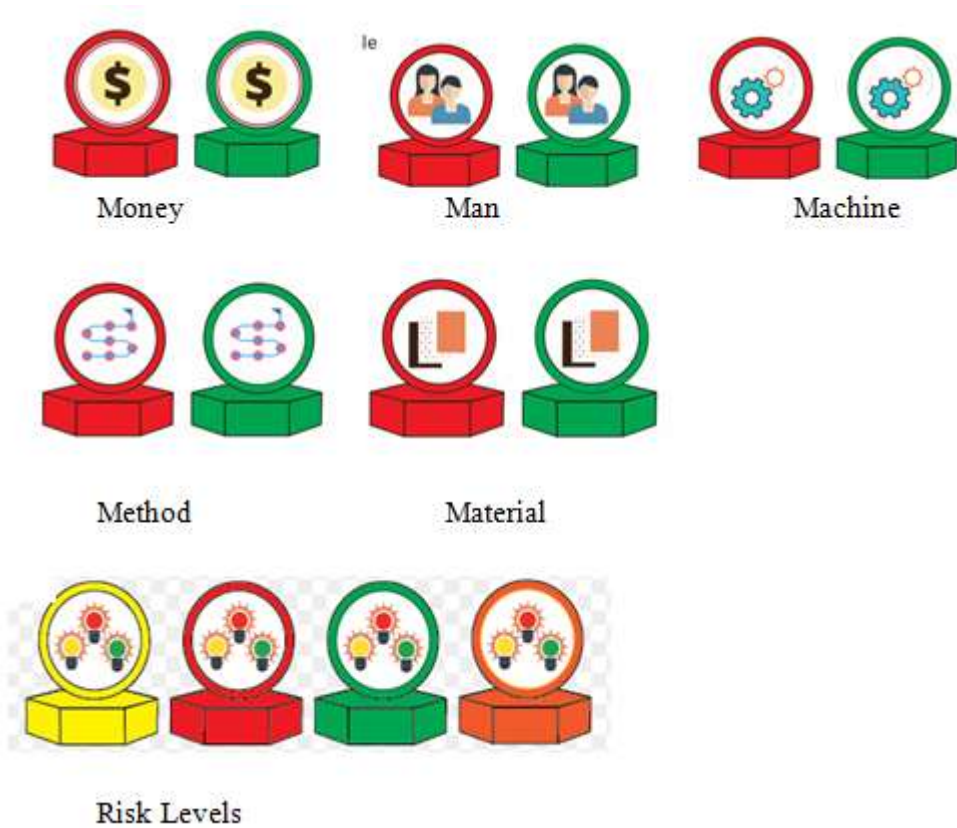


Figure 6: Game pieces

- For Money

Funds for the innovation can be obtained through company investments, joint ventures, partnerships, loans, mortgages, or other funding methods, each represented by game pieces.

- For Man

Different levels of the organizational workforce involved in the innovation process are represented by "Man" in Figure 5. The game piece for "Man" symbolizes:

- Members involved in strategic planning and execution, Ex. C-level executives
- Heads of various departments executing organizational plans and responsible for departments. Ex. Department managers
- Members who executes the tasks, Ex. Assistant managers, senior executives, executives, staff members
- For Machine

This highly depends on the specific innovation. Therefore, customized game pieces can be used for machines, with the machine types specified in the blank area to suit the particular innovation

- For Method

This too cannot be predetermined, as the methods are specific to the innovation and the team needs to define the most appropriated methods on the blank area of the game piece

- For Material

Players have to define materials according to the innovation

- For Risk Level

The team can determine the risk level corresponding to the resources and indicate it using the game pieces below.

In-order to play the game, each team should possess game pieces related to resources plus risk levels. Unit value will be assigned to game pieces of the resources by each team.

Identifying different parameters

Risk factor: A condition, behaviour or other factor that increases the risk

Root cause: A fundamental reason for the occurrence of a problem. In the absence of root causes, the effect of risk factors will be no more there.

Check list of Pitch-Making meeting

Each of the 14 teams will receive a checklist for conducting initial analysis of innovation, resource requirements, and availability. This section defines terms and outlines criteria for parameter analysis.

Check List includes,

1. What could go wrong?
2. What is the worst case scenario?
3. How severe is the risk?
4. How often the risks are likely to happen?
5. What is the risk level?
6. What is the risk tolerance?

7. SWOT analysis
8. Efforts to combat
9. What could prevent this from happening?

Check list -1

What could go wrong?

Possible reasons for deviations from the expected outcome of the innovation

Team may come across (Examples) -

- Final cost may be higher than the expected
- Quality of the product may not be up to the required standards
- Incorrect market positioning
- Issues in product designing

Check list -2

What is the worst case scenario?

The most disastrous situation, which may happen during the innovation process

Examples -

- Inadequate investments
- Unavailability of skilled work force
- Delay in receiving raw materials

Check list -3

How severe is the risk?

Severity is the degree of impact or the highest level damage possible due to an occurrence of a risk.

Evaluate the severity

- This value needs to work out the risk level and determining the risk prioritization plan
- Team needs to select an appropriate scale to assign ranks to the severity
- Below explains the criteria to assign severity ranks to risk factors

Scale and corresponding criteria to determine severity

1	Negligible A risk event which will have a little or no impact on achieving desired organizational goals if happens. In other words, events likely to result in minor impacts to the clients, organization and work force
2	Minor A risk event which will have a little or no impact on achieving desired organizational goals if happens. In other words, events likely to result in minor impacts to the clients, organization and work force
3	Moderate A risk event which will have moderate impact on achieving desired organizational goals if happens. In other words, events likely to result in loss or damage to clients, minor complaints or penalties, Not serious issues to work force.
4	Major A risk event which will have significant impact on achieving desired organizational goals if happens. severe event likely to result in loss of important clients, legal issues, regulatory issue in raw materials, serous issue on workforce
5	Catastrophic A risk event which will have severe impact on achieving desired organizational goals, if happens. In other words, serious technical or performance issues, resulted in higher financial losses to the organization, loss of clients with significant contributions to the earnings of the organization, Penalties, Claims, Critical impact on work force

Check list -4

How often the risk is likely to happen?

The extent to which the risks are likely to happen

Evaluate the likelihood

- This value also needs to evaluate risk level and risk prioritization plan
- Likelihood can be expressed as a probability value, a rating or as a frequency
- In this game likelihood value has been taken as a frequency

Scale and corresponding criteria to determine Likelihood

1	<p>Rare</p> <p>Unlikely to occur</p>
2	<p>Unlikely</p> <p>May occur occasionally</p>
3	<p>Possible</p> <p>Likely to occur sometimes</p>
4	<p>Likely</p> <p>More likely to occur several times</p>
5	<p>Almost certain</p> <p>Most certain to occur frequently</p>

Check list -5

What is the risk Level?

Risk Level = Severity * Likelihood

- Risk can be categorized considering the risk level.
- Mapping the risk, referring to risk level is a significant way to influence decision making
- This can be used in determining the risk prioritization plan

Scale and corresponding criteria to determine Likelihood

Level 1	Low Though the contribution or impact of these risks are minimal, these risks too important. But can be addressed after mitigating the major risks of the organization
Level 2	Moderate Risk These are the mid-level risks which are essential in maintain the quality of the project deliverables in the required level.
Level 3	High Risk These risks too need to be addressed quickly, but comparatively low risk than Extreme risks
Level 4	Extremely High Risk This denotes a situation that poses an exceptionally high likelihood of unfavorable events, severe consequences, or significant losses. Such conditions demand prompt attention and action.

Check list -6

What is the risk tolerance?

The level of risk that an organization can accept for an individual risk

Depends on –

- Type of industry
- Objectives
- Financial strength
- Available resources
- Risk Absorption level

Next four steps will analyse and evaluate some important points of the innovation, which is crucial in developing the risk management strategy.

Check list -7

Strengths

Recognize the strengths inherent in the innovation, allowing for a comprehensive understanding of its market behavior. Additionally, leverage the organization's own strengths to maximize effectiveness in the process.

What are the advantages of the new product or service?

- What are the product advantages over similar competitors in market?
- What strength points do people see in the product or service?
- What are the product's unique selling factors?
- Knowledge and experience
- Creativity
- Reputation, etc.

There may be additional strengths available with the articular organization.

Check list -7

Weaknesses

These are the possible weaknesses the teams may identify

- What weakness could be improved in the design?
- What issues should be avoided?
- What are the factors that reduce your sales?
- Does the production process have limited resources?
- Less experience in the required area
- Budget allocations

Check list -7

Opportunities

Team needs to analyse opportunities of the innovation

- What are the opportunities for the new product?
- What are the trends to take advantage of?
- How can we turn strengths into opportunities?
- Are there any changes in the market or government which can lead to opportunities?
- A unique project idea

Check list -7 SWOT

Threats

Team needs to identify possible threats to the innovation

- Who are the existing or potential competitors?
- What are the factors that can put business into risk?
- What issues can threaten the product on the market?
- Will there be any shifts in consumer behaviour, government or market that can affect the product success?

Check list -8

Efforts to combat

Determine the actions required to mitigate or manage threats, while improving strengths and exploring opportunities.

In the root cause management process, all SWOT aspects will be managed.

Check list -9

What could prevent this from happening? Team needs to analyse and determine on action plans to manage risks involved in the innovation.

Starting the game

Pitch Making Phase



Players prepare for the game play during the Pitch-making phase

A facilitator, proficient in the gaming process, need to be assign to guide and ensure smooth progress throughout the game. Teams need to assign unite values for the game pieces representing Money, Machine, Man and Material.

During the Pitch –making phase, players will:

1. Form 14 teams for 14 risk factors

- Each risk factor should be addressed by a dedicated team comprised of members from various departments, tasked with resolving pertinent root causes. Number of players may be varying with the type of risk factor and the root causes.
- At times when separate departments are unavailable, personnel responsible for the task can be selected instead. Occasionally, individuals may undertake multiple tasks, with one person handling two or three responsibilities.
- In-order to save time, an alternative plan has been suggested in Table 2 of Appendix of User Guide (Attached in Appendix K), for team meet ups.

2. Identify risk factors and root causes

Teams go through the previously identified root causes related to the risk factor assigned to them. Refer to Table 1 in the Appendix of the User Guide (attached in Appendix K)

3. Analyze how pre evaluated priorities of root causes related to risk factors applicable to the innovation

Teams go through the priorities generated on root causes related to risk factors of technological innovations

Pre-determined priority values of each root cause is given (Refer Table 3 in Appendix K) to the Teams, which they can obtain an idea on how root causes contribute to each risk factor, referring to pre evaluated priorities of root causes

4. Analyze and evaluate risk factors, root causes and resource availability related to each root cause (Money, Man, Machine, Material, Method, according to the Pitch making meeting check list. (Figure 7)

Pitch Making Meeting Check List
Risk factor :
1. What could go wrong?
2. How severe is the Risk? Criteria to assess severity
3. What is the worst-case scenario?
4. How likely is the risk to occur? Criteria to assess the likelihood
5. What is the risk tolerance?
6. Strengths and Weaknesses of the innovation
7. Efforts to combat
8. Threats and opportunities of the innovation
9. What could prevent this from happening?

Figure 7: Pitch making meeting check list

Kick- Start Phase



Kick start phase determines how to deal with root causes and risk factors of technological innovations

Now the teams have the game board and game pieces, where 14 teams can play on the game board with the own game pieces.

- All teams meet up formally to discuss on 14 risk factors
- They share their views, thoughts, ideas with rest of the teams, to come up with an effective and efficient risk management strategy and effective utilization of internal resources
- This phase consists of 4 rounds
- **1st round**

Each team initially locate game pieces on the relevant risk factor of the game board according to the findings of the Pitch making meeting

After 1st round, the Game board represents the current status of the resource allocation on all 14 risk factors

- **2nd round**

Each team explains the rationale behind the discussions and justify them

- **3rd round**

Each team negotiate on others decisions and questions on them

- **4th round**

Based on the negotiations, adjust the resource allocation and finalize it by each team. Here the teams can interchange resources to make obtain a balance status

After 4th round, Game board represents the controlled risk status after reallocation of resources

Unsolved Risk Factors



Even after completing the Kick-start phase, some of the risk factors may remain unsolved. Hence, 3rd phase of the game deals with solving the unsolved risk factors related to the technological innovations.

1. Identify current risk controls

Current risk controls are the activities already taken to detect, prevent or mitigate the risks involved.

Current controls can be categorized into 3 main groups.

- Effective controls
- Ineffective controls
- Neither effective nor ineffective

2. Estimate Risk Level with a Risk Matrix

A risk matrix can be used to assess risk level.

$$\text{Risk Level} = \text{Severity} * \text{Likelihood}$$

Likelihood ↑	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Severity →				

Example – Risk Level of a risk factor with Severity 3 and Likelihood 2, is 6

Numbers inside the matrix represent risk levels (Figure 8)

Figure 8: Risk levels of a risk matrix

3. Managing different risk levels

Boundaries of the risk levels may vary, all depending on the organization. Team has to define the boundaries marked with blue arrows, based on the risk acceptance level of the organization. Accordingly, team can define risk management approach corresponding to 4 risk levels (Figure 9)

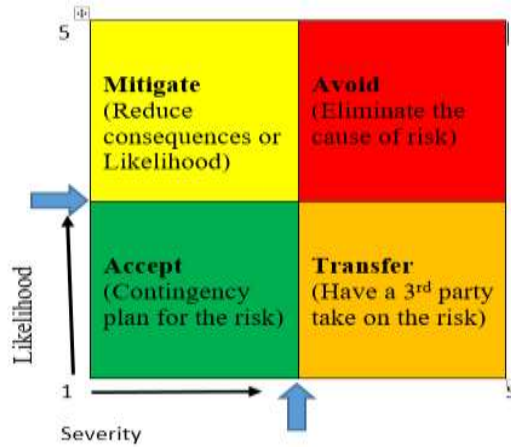


Figure 9: Different risk levels based on severity and likelihood values

These risk levels can be managed through –

- Accepting
- Avoiding
- Mitigating
- Transferring

Team needs to decide on

- Middle value of severity and likelihood scales, which connects the different risk levels with actions
- Which risk levels should accept, avoid, mitigate or transfer
- This depends on the risk tolerance levels of the organization

4. Develop the Risk Matrix

Team can colour the risk matrix to visualize Risk Levels, and this is subjective to vary according to the organization.



A generalized risk matrix with different risk levels has been illustrated in Figure 10.

		Severity				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Figure 10: Risk Matrix with different risk levels

5. Risk Prioritization Plan

- Risk prioritization plan helps to decide which risks need prior attention
- Through risk prioritization, team determines –
 1. Basis for resource allocation
 2. Manages the realization of risk events with either high severity or high probability of occurrence
- Risk prioritization matrix can be setup to give extra weight to consequences than the likelihood
- This is considering the fact that, severity is more important than the likelihood for the risks with same risk levels, as introduced in the literature.
- Below illustrates a generalized risk prioritization matrix, where “P1” represents the most prioritized risk while “P25” represents the least. (Figure 11)

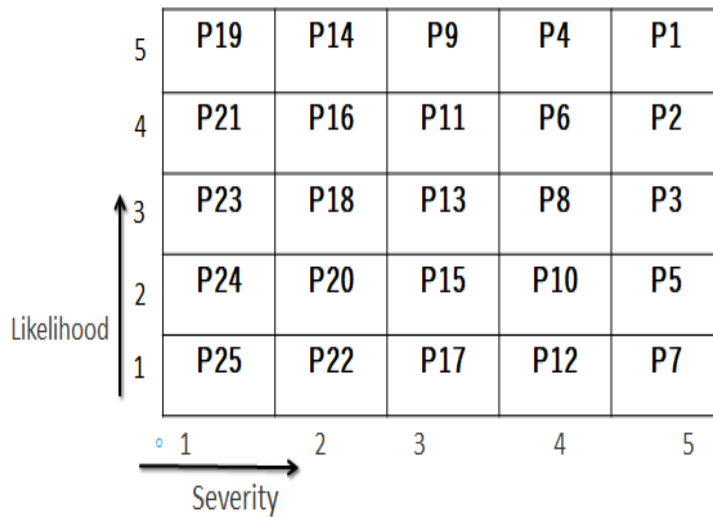


Figure 11: Risk Prioritization based on severity and likelihood values

6. How to Rank Different Possibilities

- A generalized risk prioritization plan incorporating priority numbers of risk levels and managing actions (Figure 12)
- This may vary according to the risk management criteria selected by the organization

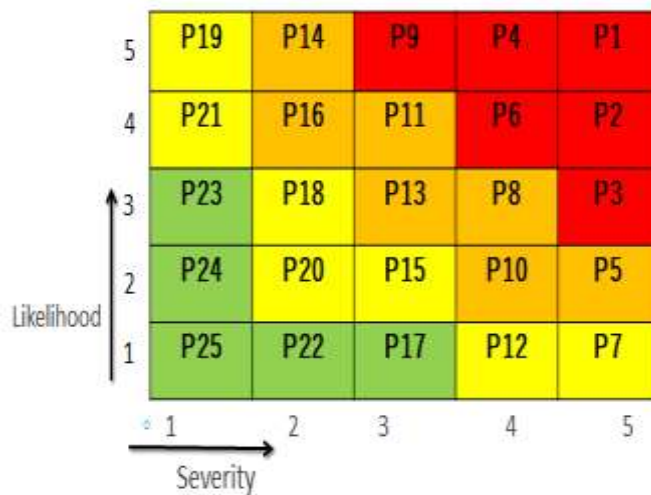


Figure 12: Risk prioritization with risk management actions

What's next?

7. Define new risk controls

- Define new risk controls for the risk factors identified during the risk management process.

- Analyze the already set controls before setting the new controls for –
 1. Their contributions to the process
 2. Any unproductive controls
- The new controls need to be tested for their effectiveness. It is required to create a corrective plan for the controls having deficiencies.

8. Documentation of the risk management process and educate the team on risk management strategy and actions to be taken

- Documenting the risk management strategy and the action plans
- Aware the team on this
- Risk management strategy includes –
 1. clear introduction to the risks
 2. Action plans
 3. Stake holders of the actions
 4. Clear instructions of risk assessment method
 5. Time intervals to review and monitor the process
 6. Assumptions made during the process
 7. Limitations of the risk management strategy

9. Monitoring and reviewing the process at predefined intervals

- Risk management is an iterative process.
- Team needs to monitor and review the process continuously , for a continuous improvement in the risk management framework
- This provides insight on improving the overall risk management strategy

How to do this?

- Maintaining a risk register, this helps to identify –
 - a. New and existing risks
 - b. Changes to be done on controls
 - c. Effectiveness of the risk evaluation methods
- Setup timelines for frequencies for both monitoring and reviewing process

Winning the game

Here, all 14 teams will be collaboratively strived to win the same goal of innovation of the organization.

To decide whether you are in the final stage of the game, make sure to:

- Allocate resources among 14 teams effectively and efficiently

- Determine the risk management strategy and the action plans for managing 14 risk factors of the technological innovation

How to determine whether the risk management strategies implemented will be effective?

Since all the risks cannot be eliminated completely, in general, there are always be some level of risks remain with the innovation process, which is called the residual risk

Definition –

The risks remain after applying the control measures

- Residual risk can be calculated with

Residual Risk = (Risk before applying control measures – Risk after applying control measures)

Risk can be calculated with the risk matrix as illustrated in evaluation of risk level using severity and likelihood, as illustrated in Figure 13.

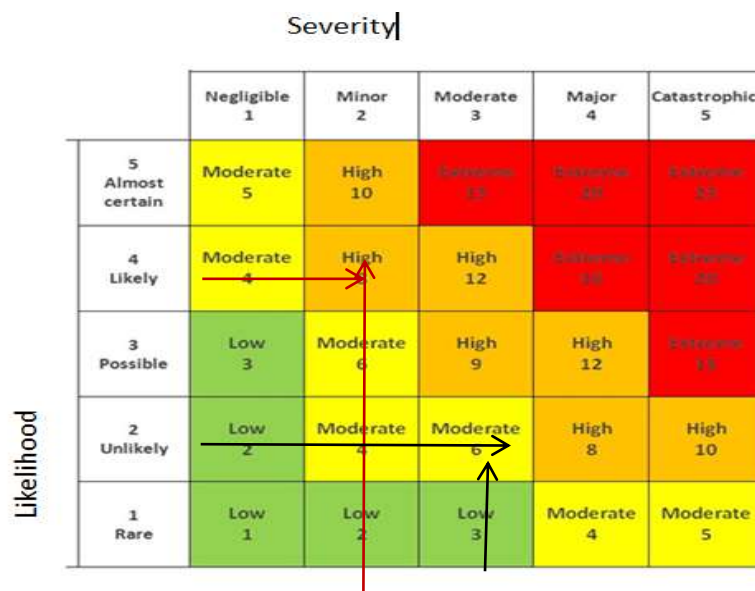


Figure 13: Calculating residual risk

Example –

According to the equation,

Residual Risk = (Risk before applying control measures – Risk after applying control measures)

Risk level before applying control measures = (2*4) = 8 →

Risk level after applying control measures = (3*2) = 6 →

Residual Risk = (8-6) = 2

There is a reduction in the risk level after applying control measures.

Monitoring and reviewing process needs to be continued to find out action plans to reduce the remaining risk as well.

APPENDIX (User Guide)

TABLE 1: DEPARTMENTS ACCOUNTABLE FOR SOLVING RISK FACTORS AND ROOT CAUSES OF TECHNOLOGICAL INNOVATION FAILURES WITH THE REQUIRED RESOURCES

Risk Factor	Root Causes and required resources	Departments Accountable for solving risk involved
1.0 Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities	1.1 Availability of enough investments for the project (Money)	Senior management team taking organizational decisions
	1.2 If unavailable, finding the required investments from outside (Loan, Joint Venture, Mortgage, Other) (Money, Man)	Senior management team taking organizational decisions
	1.3 Reviewing the innovation idea by members with appropriate expertise in identifying what would be necessary to implement the idea and what might go wrong (Man, Money, Method, Machine, Material)	Senior management team taking organizational decisions , Finance, Marketing, Merchandising, Industrial Engineering, Research and Development (R & D), Supply chain , Production, Planning, Quality,

		Human Resource (HR)
	1.4 Prior knowledge and experience of the leadership to guide the innovation process (Man)	Senior management team taking organizational decisions ,Finance, Marketing, Industrial Engineering, Merchandising, Research and Development (R & D), Supply chain , Production, Planning, Quality, Human Resource (HR)
	1.5 Accuracy of the budgeting process (Man)	Senior management team taking organizational decisions ,Finance
2.0	2.1 Considering the company's long term goals when doing the innovation (Man)	Senior management team taking organizational decisions
The company's long-term goals are not aligned with its innovation strategy	2.2 Required strengths (resources) of the Organization in developing the innovation idea to match with company's long term goals (Man, Money, Material, Machine, Method)	Finance, R & D , HR, Merchandising, Marketing, Production, Supply chain
3.0	3.1 Checking the intellectual properties related to this Product? Ex: Patent (Man, Material- i.e. for information)	R & D , Merchandising Team or any other team who
Violating intellectual property rights or		

stealing intellectual property from others	<p>3.2 Securing the innovation with a patent or any other appropriate method (Man, Material- i.e. for information)</p> <p>3.3 Signing the NDA's (Non-Disclosure Agreements) with necessary personals (Man, Material- i.e. for information)</p>	responsible to check related information Team accountable Team accountable
4.0 Lack of organizational strength (including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base)	<p>4.1 Long term availability of critical skill holders in the organization (Man, Method)</p> <p>4.2 Availability of Required skills and knowledge of team members (Man)</p> <p>4.3 Actions taken to improve skills and knowledge? (Internal Training, On the job training, External training with consultants, Any other appropriate training) (Man, Money, may be Machine, Material, Method which needed for the training)</p> <p>4.4 Maintaining a proper learning culture in the organization (Man, Material - which represents information)</p> <p>4.5 The relationship between team members (Man)</p> <p>4.6 Level of convincing operators on process changes (Man)</p> <p>4.7 Availability of time and other resources to go through the process of "Learning through Experiment" (Man, Money, Machine, Material, Method)</p>	HR, Industrial Engineering, R & D HR, Industrial Engineering,, R & D, Planning HR Senior management team taking organizational decisions , HR, HR Industrial Engineering,, Production, Quality, R & D HR, Senior management team taking organizational decisions, R & D

	<p>4.8 Facts considered when selecting the Supplier (Price, Lead Time, Raw Material Quality, Cost benefits, Credit Terms, Accreditations) (Man, Material) – Here material represents required information</p>	Supplier Chain, Merchandising
	<p>4.9 Agreement with Supplier holds any chances for negotiation (Man, Material) – Here material represents required information</p>	Supplier Chain, Merchandising
<p>5.0 Failure to adopt better methods of commercialization, inaccurate market positioning</p>	<p>5.1 Availability of a proper mechanism to aware customers on Products/Services (Man , Money, Material)</p> <p>5.2 Consulting a 3rd party team with more experiences for the process of commercialization (Man, Money, Material)</p> <p>5.3 Deciding the correct market positioning through adequate market research (Man, Money, Material)</p>	<p>Merchandising, Marketing, R & D</p> <p>Merchandising, Marketing</p> <p>Merchandising, Marketing</p>
<p>6.0 Redundancy (a profitable innovation today may become obsolete in the near future) and Unprecedented risks - (risks beyond the organization's control, fluctuations in customer demand, social and economic environment, national industrial policies)</p>	<p>6.1 Analysis of the information on redundancy or unprecedented risks which can impact the organization (Material)</p> <p>6.2 Are you the 1st entrant to the market (Material)</p> <p>6.3If No, Are there any significant competitors? (Material)</p> <p>6.4Competitive Advantages over the competitors of similar product/Services (in terms of Price, Quality, User Friendliness, Market Segment, Brand Recognition, Durability, Lead Time) (Material)</p>	<p>Senior management team taking organizational decisions, Merchandising</p> <p>Merchandising, marketing</p> <p>Merchandising, marketing</p> <p>R & D , merchandising, Supply chain,</p>

	6.5 Demand pattern of the customers related to the innovation (Material)	Merchandising , marketing
	6.6 Innovation complying with legislations and other national industrial policies (Material)	R & D, Merchandising
7.0 Information resource risk, including distorted market information	7.1 Conducting a proper target market analysis (Material)	Marketing, Merchandising
	7.2 Identification of actual requirement of the customer (Material)	Merchandising, R & D
	7.3 Outcome of the feasibility study (Material)	Merchandising, R & D
8.0 Failure to generate technological ideas through customer feedback, basic research, and creativity resulted in Innovation failing to address customer pain points	8.1 In cooperating customer feed backs or Market research feed backs when developing the technological Innovation idea (Material)	Marketing, Merchandising, R & D
	8.2 Innovation fulfilling the customer expectations (Material)	Marketing, Merchandising, R & D
	8.3 Innovation is capable of competing with current technological trends (Material)	Marketing, Merchandising, R & D
9.0 Material resource risk	9.1 Raw material quality matching with the customer requirements or any predetermined standards (Material, Method)	Supply Chain, Merchandising, R & D
	9.2 Availability of Raw material during the bulk (Material)	Supply Chain, Merchandising

	9.3 Procedure to handle rejections and replacements of Raw Material (Material, Man, Method)	Supply Chain, Merchandising, Raw Material Inspection
10.0 Technological advancements and the emergence of new technologies	10.1 Conducting a proper market research on your innovation including current trends and competitors (Material) 10.2 Any available/Upcoming technological advancement related to your product/Service (Man, Machine, Material, Method, Money) 10.3 If yes, any harmful effects to the final innovation due to lack of resources to apply the new technology (Material)	Marketing, Merchandising R & D, Industrial engineering, Production R & D, merchandising, Industrial engineering
11.0 Failure to properly align the development, implementation, and output of the entire process (incomplete project information and communication issues)	11.1 Accuracy of defining the whole process of the innovation program (Man, Machine, Material, Method, Money) 11.2 Accuracy of defining each phase of the process with clear instructions/information (Man)	R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, stores R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores

11.3 Deciding the required information to be shared in each phase, with correct people (Man, Material)	R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores
11.4 Contribution of the whole process in achieving the required timelines (Material)	R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores
11.5 Contribution of the whole process in achieving the required Quality of the Innovation (Material)	R & D , Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality,
11.6 Contribution of the whole process in achieving the required Cost Savings (Material)	R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores, Finance
11.7 Identification of all the stakeholders in the process (Man , Material)	R & D , Planning, or any relevant team doing this

	<p>11.8 Availability of an effective communication Channel (Material, may be Machine)</p>	<p>R & D , Planning, Merchandising</p>
	<p>11.9 Sharing required information and access to the stakeholders (Material, Man)</p>	<p>R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores, Finance</p>
<p>12.0 Lack of a better risk-control mechanism, which risk management, must be combined with the enterprise's development plan, strategies, manpower, and financial investments, including a lack of risk supervision and control activity throughout the process and failure to adopt the "learning-through-experiment" process</p>	<p>12.1 Availability of an appropriate evaluation mechanism with required control parameters (Material, Method, may be Money and Man for implementing the process)</p>	<p>R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw Material stores, Finance</p>
	<p>12.2 Who will be reviewing the process (Internally, Third Party, Both) (Man)</p>	<p>Department managers need to assign relevant stake holders</p>
	<p>12.3 Is the process well controlled against the plan (Material, Method)</p>	<p>Department managers need to assign relevant stake holders</p>
	<p>12.4 Frequency of analysing the control parameters (Material, Method)</p>	<p>Department managers need to assign relevant stake holders</p>

		12.5 Identification of risks involved in this innovation ((Material, Method)	Department managers need to assign relevant stake holders
		12.6 If done, Success rate of the innovations (Material, Method)	Department managers need to assign relevant stake holders
13.0	Inadequate Capability Technical	13.1 Availability of required capacity of resources (Machinery and Equipment) to be utilized in bulk (Machine)	Industrial Engineering, Planning, Production, Merchandising, R & D
		13.2 If No, How the capacity is being filled (Joint Venture, Subcontracting, Collaboration, Purchasing, Hiring, Other) (Man, Money, Material)	Senior management team taking organizational decisions , Industrial Engineering, Planning, Production, Merchandising, R & D
		13.3 Availability of required work-force for a bulk production (Man, Method)	Planning, R & D , Production, HR, Industrial Engineering
		13.4 Defining the Human Resource skills and Technical skills of the team required completing the innovation (Man, Method, May be Money if need to hire)	Industrial Engineering, Planning, Production, R & D
		13. 5 If Dissatisfied, Do you have any alternate plans to acquire required technical skills (Man, Method, Money)	Senior management team taking organizational decisions, HR

14.0 Issues with the R&D process, sample-to-batch challenges, Inbound and outbound communication issues, as well as inconsistency in project organization and management	14.1 Defining the development process in achieving the right product/Service (Man, Method, Material, Machine, Money)	R & D, Industrial Engineering, Merchandising, Supply chain, Quality
	14.2 Ability to overcome challenges in the development process (Man, Method, Material, Machine, Money)	R & D, Industrial Engineering, Merchandising, Supply chain, Quality
	14.3 Performing a development trial (Man, Method, Material, Machine, may be Money)	R & D
	14.4 Ability to apply the same methods/ development process for bulk production (Man, Method, Material, Machine)	R & D , Production , Quality, Industrial Engineering
	14.5 Any alternative methods increasing the requirements of costs/ lead time/ special skills and other (Material , Money, Man, Method , Machine)	R & D , Production , Quality, Industrial Engineering

TABLE 2: TEAMS TO BE GATHERED

Risk Factors	Teams to be gathered
1, 2, 6, 7, 13	Senior management team taking organizational decisions , Finance, Marketing, Merchandising, Industrial Engineering, Research and Development (R & D), Supply chain , Production, Planning, Quality, Human Resource (HR)
3,4,5,8,10	HR, Planning, Production, Supply Chain, Merchandising, R & D, Industrial Engineering
9.11.12.14	R & D , Supply Chain, Planning, Merchandising, Industrial Engineering, Raw Material Inspection, Cutting, Production, Quality, Raw material stores, Finance

TABLE 3: PRIORITIES OF ROOT CAUSES CORRESPONDING TO EACH RISK FACTOR, AS DETERMINED USING ANP

Risk Factor	Root Causes	Priorities
C1 Failure to evaluate the innovation concept based on financial, structural, marketing, and technological capabilities	A1.1 Availability of enough investments for the project	0.2350
	A1.2 If unavailable, chances of finding the required investments from outside (Loan, joint venture, mortgage, other)	0.2244
	A1.3 Reviewing the innovation idea by members with appropriate expertise in identifying what would be necessary to implement the idea and what might go wrong	0.2576
	A1.4 Prior knowledge and experience of the leadership to guide the innovation process	0.1928
	A1.5 Accuracy of the budgeting process	0.0903
C2 The company's long-term goals are not aligned with its innovation strategy	A2.1 Considering the company's long term goals when doing the innovation	0.3810
	A2.2 Required strengths (resources) of the organization in developing the innovation idea to match with company's long term goals	0.6191
C3 Violating intellectual property rights or stealing intellectual property from others	A3.1 Checking the intellectual properties related to this product? Ex: Patent	0.3533
	A3.2 Securing the innovation with a patent or any other appropriate method	0.3920
	A3.3 Signing the NDA's (Non-Disclosure Agreements) with necessary personals	0.2547
C4 Lack of organizational strength, including human resources, financial resources, leadership, contracts, brand recognition, and a skilled supplier base	A4.1 Long term availability of critical skill holders in the organization	0.1491
	A4.2 Availability of required skills and knowledge of team members	0.1221
	A4.3 Actions you have taken to improve your skills and knowledge? (1. Internal training, 2. On the job training, 3. External training with	0.0755

	consultants 4. Any other appropriate training), (Skills for innovation and research, 2011)	
	A4.4 Having a proper learning culture in the organization	0.1159
	A4.5 The relationship between team members	0.0549
	A4.6 Level of convincing operators on process change	0.0455
	A4.7 Availability of time and other resources to go through the process of "learning through experiment"	0.2396
	A4.8 Facts considered when selecting the Supplier (1. price, 2. lead time, 3. raw material quality, 4. cost benefits, 5. credit terms, 6. accreditations),	0.1000
	A4.9 Agreement with Supplier holds any chances for negotiation	0.0975
	A5.1 Availability of a proper mechanism to aware customers on products/services	0.5506
C5	A5.2 Consulting a 3rd party team with more experiences in the process of commercialization	0.1544
Failure to adopt improved methods of commercialization and inaccurate market positioning	A5.3 Deciding the correct market positioning through adequate market research	0.2950
	A6.1 Analysis of the information on redundancy or unprecedented risks which can impact the organization	0.1976
C6	A6.2 Being the 1st entrant to the market	0.0549
Innovation may become obsolete due to redundancy, and unprecedented risks (including customer demand fluctuations, social and economic environment changes, and shifts in national industrial policies) can impact the organization	A6.3 If no, are there any significant competitors?	0.0525
	A6.4 Competitive advantages over the competitors of similar product/services (in terms of price, quality, user friendliness, market segment, brand recognition, durability, lead time)	0.0895
	A6.5 Demand pattern of the customers related to the innovation	0.2051
	A6.6 Innovation complying with legislation and other national industrial policies	0.4003

C7 Risk of incomplete and inaccurate information, including distorted market data	A7.1	Conducting a proper target market analysis	0.3651
	A7.2	Identification of actual requirement of the customer	0.5282
	A7.3	The outcome of the feasibility study	0.1067
C8 Failure to generate technological ideas through customer feedback, basic research, and creativity leads to innovation that does not address customer pain points	A8.1	In cooperating customer feedbacks or market research feedbacks when developing the technological innovation idea	0.3651
	A8.2	Innovation fulfilling customer expectations	0.5282
	A8.3	Innovation is capable of competing with current technological trends	0.1067
C9 Risks associated with material availability and quality	A9.1	Raw material quality matching with the customer requirements or any predetermined standards	0.4893
	A9.2	Availability of raw material during the bulk	0.1781
	A9.3	Procedure to handle rejections and replacements of raw material	0.3326
C10 Risk posed by the emergence of new technologies and technological advancements	A10.1	Conducting proper market research on your innovation including current trends and competitors	0.3647
	A10.2	Any available/upcoming technological advancement related to your product/service	0.2739
	A10.3	If yes, any harmful effects to the final innovation due to lack of resources to apply the new technology	0.3616
C11 Failure to properly align the development, implementation, and output of the entire process, including incomplete project	A11.1	Accuracy of defining the whole process of the innovation program	0.1830
	A11.2	Accuracy of defining each phase of the process with clear instructions/information	0.1830
	A11.3	Deciding the required information to be shared in each phase, with correct people	0.1303

information and communication issues	A11.4	Contribution of the whole process in achieving the required timelines	0.1491	
	A11.5	Contribution of the whole process in achieving the required quality of the innovation	0.0491	
	A11.6	Contribution of the whole process in achieving the required cost savings	0.1184	
	A11.7	Identification of all the stakeholders in the process	0.0455	
	A11.8	Availability of an effective communication channel	0.0746	
	A11.9	Sharing required information and access to the stakeholders	0.0670	
	C12 Lack of a robust risk-control mechanism integrated with the company's development plans, strategies, manpower, and financial investments, including insufficient risk supervision and failure to adopt a "learning-through-experiment" approach	A12.1	Availability of an appropriate evaluation mechanism with required control parameters	0.1329
		A12.2	Who will be reviewing the process (Internally, Third Party, Both)	0.0892
		A12.3	Is the process well-controlled against the plan	0.1632
A12.4		Frequency of analysing the control parameters	0.2160	
A12.5		Identification of risks involved in this innovation	0.2553	
A12.6		If done, the success rate of the innovations	0.1434	
C13 Inadequate technical capacity to support innovation	A13.1	Availability of required capacity of resources (machinery and equipment) to be utilized in bulk	0.2567	
	A13.2	If no, how the capacity is being filled (Joint venture, subcontracting, collaboration, purchasing, hiring, other)	0.1086	
	A13.3	Availability of required work-force for a bulk production	0.3076	
	A13.4	Defining the human resource skills needed Technical skills of the team required completing the innovation	0.1828	
	A13.5	If dissatisfied, having any alternate plans to acquire the required technical skills	0.1444	

C14 Issues with the R&D process, challenges in scaling from sample to batch production, inbound and outbound communication problems, and inconsistency in project organization and management	A14.1 Defining the development process in achieving the right product/service	0.2921
	A14.2 Ability to overcome challenges in the development process	0.2867
	A14.3 Performing a development trial	0.0993
	A14.4 Ability to apply the same methods/ development process for bulk production	0.0930
	A14.5 Any alternative methods increasing the requirements of costs/ lead time/ special skills and other	0.2289

APPENDIX L

Table L.1 depicts the SUS questionnaire used to obtain feedback for Industry validation

TABLE L.1: FEED BACK RECEIVED FROM 5 RESPONDENTS

Questions	Responses of Industry Professionals Using 5 point Likert Scale				
	R1	R2	R3	R4	R5
1. I think that I would like to use this system frequently.					
2. I found the system unnecessarily complex.					
3. I thought the system was easy to use.					
4. I think that I would need the support of a technical person to be able to use this system.					
5. I found the various functions in this system were well integrated.					
6. I thought there was too much inconsistency in this system.					
7. I would imagine that most people would learn to use this system very quickly.					
8. I found the system very cumbersome to use.					
9. I felt very confident using the system.					
10. I needed to learn a lot of things before I could get going with this system.					

Calculating System Usability Score [224]

Step1: Convert the scale into number for each of the 10 questions

Step 2: For odd numbered questions (1, 3, 5, 7, 9),

[User rating]-1

For even numbered questions (2, 4, 6, 8, 10),

5-[User rating]

Step 3: Add up the point of 10 questions into a user's total points

[Total points from user 1] * 2.5 = User 1's System Usability Score

Repeat the steps 1 to 3 on all users and average the scores of all users to get the System Usability Score. Interpretation of System Usability Score shown in the Table L.2.

TABLE L.2: Interpretation of System Usability Score

SUS score	Grade	Rating
>80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51-68	D	Poor
<51	E	Awful

TABLE L.3: SUS of individual respondents

Respondent	System Usability Score
R1	82.5
R2	85
R3	77.5
R4	77.5
R5	82.5

Average Score 81.