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A method to support risk management and resource allocation in projects based on risk acceptance strategy

Ph.D. DISSERTATION

Supervisor: Prof. Elio Padoano, UniTs

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Abstract

Introduction: The main theme of this study is project risk management and it is focused on finding the best solution to accept the risks without deviation from the objectives and uses the opportunities of the uncertainty and risks. To fill the gaps of existing methods in accepting the opportunities that are associated with some risks, a new method has been designed to identify the best alternative way to accept a risk and the best amount and type of resources to allocate this alternative. To assess the risk-taking capability of each alternative, its Stress and Strain in a different situation would be calculated and a Strain-Stress system will be the main result of this analysis. Therefore, opportunities and risks should be evaluated together.

Objectives: The three main objectives are 1) Design a method for evaluating (or measuring) the 'risk-taking capability' of an Organization. 2) Design a method to support decision-making to help the sustainability strategies of a company and simultaneously accept the risks of changes and improvements. 3) Identify the most efficient resource and the amount of resource consumption to make the project ready to accept risk.

Method: To assess the risk-taking capabilities three new concepts are introduced include Risky-Opportunities, Stress, and Strain. Stress and Stain are two original concepts that will be used as indexes to support risk acceptance evaluation and resource allocation. To calculate the values of these new indexes, a multi-criteria method is considered, specifically, the Analytic Network Process (ANP) because ANP models take into explicit consideration mutual influences between elements and feedback effects. According to the ANP procedure, the pair-wise comparison matrix will define the priorities of each element in the clusters. Then for each alternative way of accepting the risks, the stress-strain system will be used to assess the risk-taking capability for each risky opportunity.

Results: The results of this method provide a structured data that practically project managers could use as an index for evaluating (or measuring) the 'risk-taking capability' of an Organization or project; Also, this method is a tool to support sustainability strategies and, at the same time, accept the risks of changes and continuous improvements.

Thesis building blocks

Chapter 1. **Introduction** - a concise introduction to the statement of the problem, importance of the study and gaps, research questions, research objectives, research scope and limits, and general structure of the method.

Chapter 2. **Literature Review – Section 1)** Review of terminology and key background literature on risk management models –the primary study published in proceeding of PEM 2017 international conference (Aghazadeh Ardebili et al., 2017) and this is an extended version of that study include an extensive literature review- **Section 2)** in respect of research main objective no. 4 – Chapter 1.4/Page 5- a literature review have been conducted to extract the attributes of a resilient and sustainable decision. The results published in Sustainability Journal in March 2020 (Aghazadeh Ardebili & Padoano, 2020). https://doi.org/10.3390/su12072602

Chapter 3. **Methodology –** This chapter systematically explains the new method designed in the Ph.D. project. The paper extracted from this section is a "Work in Progress" to submit for IJAHP.

Chapter 4. **Case Study Introduction –** An introduction to the case company including the company functions, issues, and solutions. This section is published in Sustainability Journal in April 2020. (Aghazadeh Ardebili et al., 2020). https://doi.org/10.3390/su12051833

Chapter 5. **Case Study and validation –** using the new method in a real case RO analysis. The extended abstract extracted from this chapter is accepted by a peer-review process on 19 March 2020 to be presented in the 2nd International Conference on Sustainable Production and Consumption and was candidated for publication on the Journal of Sustainable Production and Consumption - Elsevier, as a selected paper of the conference. (However, conference suspended because of COVID-19 emergency)

Chapter 6. **Conclusion –** this chapter reports the theoretical and practical implications of the work and how it advances the field and set out suggestions for future work.

Acknowledgments

I would like to pay my special regards to my supervisor, Elio Padoano, for his guidance through each stage of the process besides inspiring my interest in the development of innovative decision-making methods.

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Trieste, June 2020

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Author Biographical Sketch

Ali Aghazadeh Ardebili is an Iranian Ph.D. Candidate, at the University of Trieste, Italy. BSc on Mechanical Engineering and M.A. degree in system management and productivity; His research interests are risk analysis, project management, sustainability and resilience, decision-making, operation management, and data science. He has 4 patents, and 8 years of experience in international project base and consultant companies. he has selected between the 13 Redefiners of the next 100 years of the world in N100 Symposium 2018 out of 650 applicants from 55 countries. He won the TATA Steel challenge award for a sustainable solution for HYSARNA industrial steel production process. Peace ambassador certified by the global peace chain.

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Dedication

This is for you mom, dad, and my beloved abji.

You kept me going on and this work would not have been possible without your support

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During the Ph.D. program, the following papers and presentations have been contributed.

I. Aghazadeh Ardebili A., Padoano E., Rahmani N (2020) Waste reduction for Green Service Supply Chain – The Case Study of a Payment Service Provider in Iran, (ISSN 2071-1050) Sustainability, 12(5), 1833.

II. Aghazadeh Ardebili, A.; Padoano, E. A Literature Review of the Concepts of Resilience and Sustainability in Group Decision-Making. Sustainability 2020, 12, 2602.

III. Aghazadeh Ardebili A. *, Padoano E. (2020) Change Assessment Aim To Transition To Sustainable Service - Case Study Of Quantitative Risky-Opportunity Analysis In A PSP Company, Peer-reviewed abstract in Second International Conference on Sustainable Production and Consumption: Explore interactions between technology, the environment, economy, society and policy, IChemE, 24-25 June 2020, Edinburgh, UK

IV. Aghazadeh Ardebili A. *, Padoano E., Rahmani N (2019) Green Service Providing Supply Chain – Case Study on the Thermal Paper Wastes and Unnecessary Transportations of Payment Service Providers, PEM 2019 - 9th international conference, University of Trieste, Trieste, Italy.

V. Aghazadeh Ardebili A. (2019) Intelligent uncertainty management plan for Information Broadcasting, 3rd SciCAR Conference – where science meets computer-assisted reporting, Dortmund, Germany

VI. Aghazadeh Ardebili A. *, Padoano E., Marco Boscolo (2020) Total Quality Management Elements and Risk Resilience in Operational Level (Submission code: IJRAM-289858) for the International Journal of Risk Assessment and Management (IJRAM).”under peer-review process”

VII. Aghazadeh Ardebili A. (2020) A case study of empirical circularity evaluation from sustainable development goals lens, (manuscript ID is EVI-20-0037) Evaluation. "under peer-review process"

VIII. Aghazadeh Ardebili A., Padoano, (2018) Total quality management as a potential solution to risk management in low-level workers, MOTSP 2018, 10th International Scientific Conference, Management of Technology – Step to Sustainable Production, June 6–8 2018, Primošten, Croatia

IX. Aghazadeh Ardebili A., Grzunov J., Gschider M., Sunkca M. (2018) Novae Village Revitalization - a case study on Mohovo, Danube Future capacity Building training school, "Project Management and Entrepreneurship for Sustainable Development of the Regions in the Danube River Basin", University of Ruse, Bulgaria, September 9th – 16th, 2018

X. Aghazadeh Ardebili A., Padoano E., Jafarzadeh Afshari A., Heidarzadeh P. (2018), Outsourcing risks: a case study of the electricity distribution co. In ira, 8th International Conference "Production engineering, and management For Industry Sustainability", 8th International Conference on Production Engineering and Management, 04.-05. October 2018, Hochschule Ostwestfalen-Lippe Lemgo

XI. Aghazadeh Ardebili A., (2018) Design a method for risk management decision-making in resource allocation and an index for measuring the "risk-taking capability'', Poster presentation, Adaptive Façade 2018, University of Belgrade, Faculty of Architecture, Belgrade, Serbia, Summer 2018

XII. Felimban A., Aghazadeh Ardebili A., Di Bugno M., Lukic N., Patrus M., (2018) Concept proposal of a retrofit scheme for a commercial high-rise building in central Belgrade, Retrofitting facades for energy performance improvement, University of Belgrade, Faculty of Architecture, Belgrade, Serbia, ISBN 978-86-7924207-5 , September 03 - 07, 2018

XIII. Aghazadeh Ardebili A., E. Padoano, F. Harsej (2017), Prepare Organizations to Accept risks: A Feasible Risk management, 7th international conference – Production engineering and management For Industry Sustainability, Pordenone Sep. 2017, University Consortium of Pordenone

XIV. Jurecska L., Kiš M., Tumpa A., Aghazadeh Ardebili A., Gajski G. (2017) PlantPower – Phytoremediation of Contaminated Soils in Former Minefields of the Western Balkan Area, Krems, July 2017, Danube Future Training Capacity Building Proceeding. ISBN: 978-3-903150-38-6

The Author's Contribution to the Publications

Ali Aghazadeh Ardebili is the sole author of the dissertation; however, in included articles in the publication list, there are co-authors.

In all of the papers that the first name is Ali Aghazadeh Ardebili, - except VI - he is the responsible author.

In poster number IX, in the publication list, Ali Aghazadeh Ardebili has done just the BOCR analyses of the suggested proposal.

In both proposals, XI and VI number IX in the publication list, the risk and uncertainty assessment, schedule, and work breakdown system include work packages – WBS - of the suggested proposals have been done by Ali Aghazadeh Ardebili.

Honors and Awards during Ph.D.

In 2018 he has been titled “N100 Redefiner” between the 13 Redefiners of the next 100 years in Symposium in the Czech Republic out of 650 researchers from 55 countries.

In 2019 he titled as the winner of the “TATA Steel Challenge Award” for a technological sustainable solution based on industry 4.0 for the HYSARNA steel production process.

In 2018 he has been entitled “Peace ambassador” certified by global peace chain for 2 years.

Academic Activities during Ph.D.

Seminar	Webinar "Why modern Risk Analysis software is needed to drive up project delivery performance", collection of Risk Analysis learning materials. Safran Software Solutions AS, Rogland, Norway, Friday 26th April 2019,
Seminar	Organizzato dal Master Gestione della Fabbrica Intelligente in collaborazione con CI-LAM: China-Italy Joint Lab on Advanced Manufacturing
Seminar	Master gestione della fabbrica intelligente, trends and applications in china of advanced manufacturing systems, ci-lam: China-Italy Joint Lab on Advanced Manufacturing. Webinar, venerdì 3 aprile 2020, Universita di Bergamo
Seminar	Inteligenza artificiale opportunità , rischi e precauzioni" . Interverranno Diego Sardon CEO di PRODIGYS e l'avvocato Ariann Neri esperta legal AI, CLAB Trieste, venerdi 21 giugno 2019
Seminar	"La progettazione europea" - dott. E. Boglich; prof.ssa S.Passamonti; dott. G.Chiominto; dott. G.Forestieri, università di Trieste 6-8-27 giugno 2017, per un totale di 4 ore
Seminar	"Tutela e gestione del copyright in ambito accademico", Aliprandi, Simone, Trieste, Italy, 20-Jun-2017
Seminar	Dall'idea alla pratica: un caso di sviluppo imprenditoriale in neuro modulazione - prof.ssa Sara Marceglia. Università di Trieste 22 may 2017
Seminar	La tutela della proprietà intellettuale: strumenti e strategie - dott. C. G.Cristiano Piani, Università di Trieste 22 May 2017
Seminar	"La ricerca bibliografica in ambito tecnico - scientifico e biomedico" - dott.ssa C. Cocever; dott. M. Chiandoni ; dott. A. Deluca. 11-12 luglio 2017, per un totale di 8 ore

Seminar ABC accelerator, a Business accelerator in Ljubljana. 16 April 2018.

Seminar Presentazione aziendale della Bosch, Contamination Lab (CLab) University of Trieste, 20 July 2018

Seminar La tutela della proprietà intellettuale: strumenti e strategie - dott. C. G. Cristiano Piani 8 and 9 March 2018.

Seminar Current Trends in Deep Learning, Dr. Jhilik Bhattacharya, Thapar University, IndiaTue. 26 June2018.

Seminar Comunicare la Scienza - 9 novembre 2017

Seminar Seminario dal titolo "Il piano di marketing per lo start up, Contamination Lab (CLab) University of Trieste, 10 April

Seminar Presentazione aziendale della General Electric, Contamination Lab (CLab) University of Trieste, 15 May 2018

Seminar Research communication skills and persuasive communication. How to communicate your research

Course Research topics in Manufacturing and Service Operations Management (M&SOM), February 20, 21, 26, 27and March 03 - 2020, Universita di Bergamo

Course Design Optimization - Methods & Apps, Trieste, Italy, 5-7 June 2017

Course Corso di lingua italiana A1 per stranieri, Eliana Dalmas, Scuola di lingue dell'Università degli studi di Trieste, Nov/Dic 2017

Course Project Management Workshop (PMI-NIC), University of Trieste, Italy 18th may 2017

Course Italia Risk Forum workshop, 14.45- 18.00 pm, 8 Marzo 2018, Reggio Emilia

Course Academic English (40 Hours). General Introduction to Academic English; Writing Abstracts; Oral Presentations

Course	COST TU1403 Adaptive Facades Network - Training School 2018
Course	Business Game, Mib Trieste School of Management. 16 May 2018. Harvard Simulation "Everest",
Course	Corso avanzato di ricerca in "Intellectual and Technology Assets Management: The Logistics of Ideas" - Dr. Roberto Castagno, Università di Trieste, 1-2 February 2018.
Conference Presentation	SciCAR 2019, where science meets computer assisted reporting, Erich-BROst-Institut, TU Dortmund, from 9th to 11th September.
Conference Presentation	7th international conference – Production engineering and management For Industry Sustainability September 28th-29th, 2017
Conference Presentation	PEM 2018 - 8th International Conference on Production Engineering and Management October 4 to October 5, 2018, at the Ostwestfalen-Lippe University of Applied Sciences in Lemgo, Germany
Conference Presentation	MOTSP 2018, 10th-anniversary special edition, Challenges of Industry 4.0, Primošten, Croatia
Summer School	"Introduction to Applied Statistics and R " – Prof. G. Bacaro, Università di Trieste, 12th Jun -19th July, 18 hours.
Summer School	CRISR Summer School su "CyPhy-Hands on Cyber-Physical threats to critical infrastructures",unisalento, Dipartimento di Ingegneria dell'Innovazione, Lecce (Italy), Sept. 25-28, 2019
Summer School	Summer School on Transportation - Mobility Systems for Open and Happy Cities, 29 May-4 June 2019, Aalto University, Finland
Summer School	TOP STARS 2019 Summer School, innovation challenge for Ph.D. Students And Researchers, July 8-17, 2019, University of Trento
Summer School	Aidi summer school 2019, augmented knowledge: A new era of industrial systems engineering, Department of

	Industrial and Mechanical Engineering at the University of Brescia, September 11 – 13th, 2019
Summer School	The Danube: Future Interdisciplinary School 2017, Cultural and social implications of global change on the Danube River Basin - Krems, Austria July 14th–21st, 2017
Summer School	PALM 2018, Product and Asset Lifecycle Management, Lastra a Signa, Firenze (Italy), June 14th-17th 2018
Summer School	The Danube: Future Interdisciplinary School 2018, "Project Management and Entrepreneurship for Sustainable Development of the Regions in the Danube River Basin", University of Ruse, Bulgaria (September 9th – 16th, 2018)
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1 Introduction

1.1 Statement of the problem

A project can be considered as an organized network of activities aimed at achieving a set of goals. Projects are common in the industrial and service sectors. During the lifecycle of projects, some unanticipated events could happen because of internal and external changes in the projects. Therefore, important deviations from the objectives may derive from uncertain future events, which can have positive or negative effects in regard to the objectives during the project life-cycle (C. Snyder, 2013)Usually, those events with pure negative effects are anticipated, where possible, in order to avoid, mitigate or transfer their outcomes. On the other hand, some uncertain events can be associated with threats, but they might concurrently include some opportunities and benefits for the project: these events will be called 'risky-opportunities' (ROs) in this document. In this respect, the question is: "is it possible to take advantage of the positive effects of risky opportunities, but at the same time avoid the negative effects of that event?" It is clear that stakeholders aim to take any existing opportunity that a project opens up.

In this research, a feasible method, supported by a specific procedure, has been designed with the aim to accept ROs. The new method could help the project managers to select which are the best ROs to accept. Then, according to their positive and negative effects, it specifies the necessary actions that must be taken, spending a specific amount of the available resources, to avoid the existing threats in the chosen ROs. The new method is based on the concept of 'risk acceptance' in order to gain opportunities, which makes it different from traditional methods of risk management. The concept of risk acceptance requires a new metric: this is called 'risk-taking capability.' It is different from the existing comprehensive terms 'risk tolerance' and 'risk resilience.' Traditionally, the concept of risk tolerance is used to analyze the capability of a company or project to take the risk according to the existing resources (Fredman, 1996) and investigations have been done to identify the impacts of variables and individual characteristics on risk tolerance (Sung & Hanna, 1997). Conversely, risk-taking capability evaluates the opportunities according to their risks. This study focus on project risk management and the domain of uncertainty and risky-opportunities is the project level.

1.2 IMPORTANCE OF THE STUDY AND GAPS

Nowadays all markets are highly competitive. Any company needs to consider continuous development to stay in the market, and development needs changes. On the other hand, sustainability strategies are corporate responsibility strategies that arrange a framework to focus investment and drive performance in a project. These strategies are heading to transform into a necessity instead of an advantage; and again it needs different changes in the project. Considering future uncertainty of all these mandatory and sometimes undesirable changes, a company needs simultaneously accept some risks, take some changes and improvements to stay vibrant and sustainable during development to open up new lines and get higher efficiency and effectiveness. These changes could include innovative ways to do the jobs, creative activities to increase productivity and even following new demands of the growing market. Classical methods of uncertainty analyses will not respond to new needs because they did not design for this aim. Consequently, to fulfill all of these future goals in an uncertain future, new methods are necessary.

The 'risky-opportunities' (ROs), which are future uncertain events, mostly avoided by decision-makers because of think out of potential threats, and emphasize its consequences. The results of literature review –that will be reported in Chapter 2- shows that it happens because the existing risk management tools are designed considering two pre-assumption:

- One risk response for each risk and not a combination of responses
- Consider only one of the positive or negative effects of the risk and not a combination of both effects.

It means that, during risk analyses, decision-makers try to find the eminent effect of the risk on project objectives. Then they consider the risk as a potential threat or a potential opportunity. Regarding the characteristics of the existing methods, final decisions are usually biased to choose to avoid the risk as one of the risk response strategies.

Different management tools are already available, which some of them will be introduced in Chapter 2 –Literature Review-. However, qualitative tools are not designed for accepting RO, which its opportunities far outweigh the threats. Project managers always try to avoid any deviation from the objectives of the project, therefore, a quantitative method is required to convince decision makers that the risk response will provide most of the positive effects of risk and limit the threats.

To accept the risk three elements are important, first, the resource consumption during the risk response; second, the effect of the response on

the company itself, and third, the combination of different risk response strategies to gain the highest efficiency.

In any project, different resources are available. However, in existing quantitative risk management tools only the cost of the risk response is considered. In the existing quantitative risk management tools, the effect of the risk response on the project is not taken into consideration. These responses could include activities, policies, options, decisions, and alternatives. None of the existing quantitative risk response tools is flexible enough to consider a combination of the risk response strategies.

In summary, there is a gap in the existing quantitative methods of risk management to consider the threats, the available resources, and gain the positive effects of risky opportunities.

1.3 RESEARCH QUESTIONS

This research aims to answer four questions:

1. How could the risk-taking capability be assessed?

2. How could the risk-taking capability be increased?

3. Is it possible to use quantitative tools to support decision-making with the aim to accept the risk without negatively affecting the company's sustainable strategy?

4. How to select the kind and quantity of resources that should be employed to accept the risk?

This study is going to propose an innovative methodology which consist of a set of coordinated methods with the specific aim of risk acceptance. Theoretical base of this research is to employ a quantitative decision making support tool to assess the risk-taking capability of a company and then, find the most effective way to increase it. The methodology could help the managers to choose the most advantageous risky opportunity to accept after introducing some changes in the processes or activities by spending a specific amount of the available resources.

1.4 RESEARCH OBJECTIVES

There are four main objectives for this research include:

1. Design a method, which considers a combination of the risk response strategies and the concept of risky-opportunity during the analyses.

2. Identify the most efficient resource and the amount of resource consumption to make the project ready to accept risk.

3. Design a method for evaluating (or measuring) the 'risk-taking capability' of an Organization.

4. Design a method to support decision-making with the aim to help the sustainability strategies of a company and simultaneously accept the risks of changes and improvements.

Secondary objectives of this study include:

1. Introduce a method for making the best decision for the reduction of the negative effects of the risks and change them into an opportunity – if the risk is so intense and has a deep impact.

2. Introduce a method to motivating the companies in all sectors with the idea of using the positive effects of uncertainty.

3. Introduce a method that could be beneficial for continuous improvement by taking risky opportunities.

1.5 RESEARCH SCOPE AND LIMITS

The scope of the research is project level and it is limited to identify and analyses the ROs within a single project, not at portfolio level.

The software tools are limited to the existing two software. Super decision Version 3.2 is used for quantitative calculations of BOCR analyses and the calculation of the Stress and Strain indicators besides drawing the systems could be done in MicROsoft Excel. (Future studies could aim to provide a new software which does all of the calculations and drawings)

1.6 GENERAL STRUCTURE OF THE METHOD

In this study, the aim is to design a decision support tool with an index which is named risk-taking capability. This term is different from Tolerance and Resilience. Because in traditional terms the focus is on reducing the consequences of the risk. But in this method, the focus is on eliminating the negative effects of a risk with making some changes and exploit the positive effects of uncertain events.

In order to assess risk-taking capabilities, three new concepts are introduced: Risky-Opportunities, Stress, and Strain. These terms are also different from the existing terms such as risk. Because of the objectives of the study, these new terms to use is necessary.

Stress and Stain will be used as indexes and going to be designed according to requirements of this method to find a quantitative method for risk acceptance evaluation and resource allocation. The new method needs to consider a combination of the risk response strategies and the concept of risky-opportunity during the analyses; concurrently it should support decision-making with the aim to accept the risks of changes and improvements. To calculate the parameters of these new indexes, a multi-criteria method is considered, specifically, the Analytic Network Process (ANP) because ANP models take into explicit consideration mutual influences between elements and feedback effects. According to the ANP procedure, the pair-wise comparison matrix will define the priorities of each element in the clusters. Then for each alternative way of accepting the risks, the stress-strain system will be used to assess the risk-taking capability for each risky opportunity.

In the remainder of the study, literature review which was done to realize the gaps and real situation of risk acceptance tools will be explained in chapter 2; chapter 3 is focused on the methodology of designing the new decision-support tool, and chapter 4 will elucidate the validation of the new method through employing it in a real case.

1.7 INFORMATION FLOW AND ARTICLES COHISION

The literature review of this thesis has been done in two different stages. This chapter presents the two stages in separated sections. The first section represents the review of terminology and foundational background literature on the key terms in the risk management body of knowledge. The results disclose that the evolutionary trend of risk management tools is toward establishing the culture of risk acceptance, Nevertheless a quantitative method has not been searched out for this aim yet. The first step to design a new method with the aim of accepting the risks, is to identify its characteristics. Speaking about risk and future uncertainty, the outcome of the new method should support a resilient and sustainable decision. The second section of the literature review chapter corresponds to the attributes of resilient and sustainable decision making in the presence of the risk.

The designed method, called Risky Opportunity Analysis Method (ROAM), and the outline of the steps of the method are illustrated in the methodology chapter. To validate the designed method, a real case was selected to support a decision in order to accept a risky-opportunity (RO) looking ahead of taking advantage of positive effects of the RO. A PSP company was selected to simulate the implementation of the ROAM; the case study includes the analysis of socio-economic and socio-ecologic transition towards providing a green supply chain in PSP company. Because all of the solutions for this transition are associated with some threats, it was deemed appropriate to use ROAM as a decision support tool. Chapter 4 is devoted to illustrating how ROs are identified for the case study. Chapter 5 represents the case study that conducted to employ the ROAM in a PSP company. This chapter systematically explains how the method can be implemented to analyze a real problem.

1.8 CONCLUSION

After the the identification of the gaps and necessity of having a quantitative method to accept the risks, the Risky-Opportunity Analysis Method (or ROAM) is presented and analyzed in this thesis; the method considers a combination of the risk response strategies and the concept of Risky-Opportunity (RO) during the analyses to take advantage of the opportunities which are associated with some threats. To this aim four new concepts will be introduced and elaborated in detail in the next chapters: Stress, Strain, Combinational Risk Response Strategy, and RO.

2 Literature Review

In this chapter the evolution of risk acceptance and resource consumption in change management will be reported. This chapter includes two sections.

Section 1

Review of terminology and key background literature on risk management models –the extracted article is published in proceeding of PEM 2017 international conference (Aghazadeh Ardebili et al., 2017)-, risk response strategies, risk acceptance, resource consumption, similar methods, and how this leads into the Ph.D. project. Section **2)** The attributes of resilient and sustainable decision making in the presence of the risk. This section is published in Sustainability Journal (Aghazadeh Ardebili & Padoano, 2020).

2.1 Terminology and Important Definitions

This section provides a detailed definition of important terms that are used with the same meaning in the literature. In some cases, there are different meanings for a term in different articles - none of them are accepted with all – or in some cases, it needs more explanations to clarify how the term is associated with this study, and last but not least, there are important acronyms which we will use in next sections of the dissertation, which are explained in this section. Besides, this section does not aim to define common terms (such as 'University') or where the term is self-evident. Moreover, some new and original terms are introduced in this study, but they will be explained in detail in the methodology chapter of this document.

Alternatives (alternative ways):

Alternatives are the different measures that are feasible to be taken in order to accept the risk. In this study, alternative ways are different ways to tackle the problem of the threats and gain only the opportunities of RO by making some changes in the company.

Analytic Hierarchy Process (AHP):

The Analytic Hierarchy Process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms (Thomas L. Saaty, 2008).

Analytic Network Process (ANP):

The Analytic Network Process (ANP) is a new theory that extends the Analytic Hierarchy Process (AHP) to cases of dependence and feedback and generalizes the super-matrix approach introduced by Saaty (Thomas L. Saaty & Vargas, 2013).

BOCR:

Analysis of decision making which potential alternatives are evaluated through four factors includes Benefits, Risks, Opportunities, and Costs (Wijnmalen, 2007). This framework considers both positive attributes (Benefits and Opportunities) and negative attributes (Costs and Risks) to support decision-making.

Combined risk response (CR) [Novel term]:

In the existing literature, response strategies are limited to 4 different types including avoiding, mitigate, transfer, accept, share, exploit, enhance and contingency; but, in the most practical references of project management includes ISO 31000 and PMBOK, four main risk response strategies are accepting, mitigation, transfer and avoid.

This study aims to design a method for accepting the risks in which the opportunities behind it surpass the threats. In this study, an opportunity of this kind is called Risky-Opportunity. For this aim, it is necessary to make some changes to limit the negative effects of the risk and exploit the opportunity. The changes that should be done are called Alternative ways in this study. To find the best alternative way, different scenarios are considered to increase the risk-taking capability of the project, then, the risk should be broken down through the risk of smaller activities in alternative ways and scenarios. The final selected alternative way is going to make some changes in the project and address the threats of the risk with a single or a group of activities. When the alternative way includes different activities, it could be named as a sub-project inside the main project work breakdown system (WBS). This sub-project has its own WBS and RBS aim to make some changes to exploit the pure opportunities of the risk. Therefore, this new subproject is defined as a combined risk response (CRR) strategy.

Pure opportunity:

In this study, pure opportunity refers to a chance of improvement.

Pure threat:

In this study, the pure threat is a probable event, which causes deviation from the objectives of the company. It could be trouble, danger, ruin, natural disaster, terroristic attack, etc.

Real options:

Real options, includes two main phases. These two phases are different activities aim to screen and then structure a simulation model. In this method, the definition of the "options in" is "a way to define the basic element of flexibility" and designers are going to find the best solution for increasing flexibility in a specific field to accept specific risks (Wang & Neufville, 2006). The similarities and differences between this tool and the new method introduced in this study will be elucidated in the next chapter.

Resilience:

In general, resilience is understood to mean the capacity to adapt to changing conditions without catastrophic loss of form or function. In the

Resource:

In this study, resource refers to available stock or supply of money, materials, tools, staff, and assets besides raw data, information, and knowledge.

Resource allocation:

In this thesis resource allocation refers to the plan and effort of assigning a specific amount of one or more kinds of resources to an activity.

Risk:

Etymologically the word "Risk" derived from one of the words "Resicum" with Latin root, "Rhizikon" with Greek root (sandoval, 2016) or "Risque" with French root within the meanings are related with threats or avoiding threats(M.-W. Dictionary, 2003; Harper, 2014). In addition, a literature review on the traditional concept of risk clarifies that in the traditional horizon, the risk was in liaison with a threat in an uncertain event. However, over the past decade, risk implied an event that could produce two or more outcomes and could be defined as a probable loss or gain. Different perspectives are illustrated in Table 1 within two categories include traditional definitions and comprehensive definitions.

Table 1 Risk definitions in scholars

	Definition
Traditional prospect	the word 'risk' is usually used in the context of a potential hazard or the possibility of an unfortunate outcome resulting from a given action. (Correia, 2000)
	Probability of undesirable events. (Royal Society, 1983)

	The study group views risk as the probability that a particular adverse event occurs during a stated period. (Hietala et al., 2011)
	Risk is a probable frequency and probable magnitude of future loss. (Merriam-Webster, Inc, 2014)
	possibility of loss or injury. (McLean & McMillan, 2009)
	hazard, the chance of bad consequences, loss, exposure to the chance of injury or loss ''.(BSI Group, n.d.)
	Risk is the chance, probability that a person will be harmed, or experience an adverse health effect if exposed to a hazard. It may also apply to situations with property or equipment loss. (Pmi, 2008)
comprehensive prospects	an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective. (Simon et al., 1997)
	an uncertain event or set of circumstances that, should it occur, will affect the achievement of the project's objectives. (D. Hillson, 2003)
	Thus "risk" strictly refers to an unknown event drawn from a known set of possible outcomes. (Standards Australia International Limited & Standards New Zealand, 2004)
	Risk is the chance of something happening that will have an impact on objectives. Activities involving risk can have positive as well as negative outcomes. (Lyneis et al., 2001)

In this document, risk refers to an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective.

Risk acceptance:

This strategy is an effort to adopt the risk. The decision-maker agrees to address the risk by accepting it in case that the risk impact or probability is neglectable, the positive impacts of the uncertain events in the future are significant or when there is no other feasible response to deal with risk.

When the positive impact of the risk outweighs the negative impacts, it is fruitful to accept the risk in a way that the deviation from the objectives minimizes and the positive impacts maximize during risk response. This study aims to design a quantitative method for this strategy.

Risk Assessment:

Risk assessment is a work package consisting of joint activities of risk analyses and risk evaluation (Rausand, 2013). It could be defined as the overall process of hazard identification, risk analysis, and risk evaluation (Canadian Centre for Occupational Health and Safety, 2020; Popov et al., 2016).

Risk analyses:

A process for comprehending the nature of hazards and determining the level of risk(Canadian Centre for Occupational Health and Safety, 2020).

Risk avoidance:

This strategy includes an effort to eliminate the negative impact of the risk or decrease the probability of occurrence.

Risk capacity:

Risk capacity, unlike tolerance, is the amount of risk that the stakeholder "must" take in order to reach goals (Palmer, n.d.).

Risk evaluation:

The process of comparing an estimated risk against given risk criteria to determine the significance of the risk (Canadian Centre for Occupational Health and Safety, 2020).

Risk management (RM):

RM is the identification, evaluation, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events (Hubbard, 2020).

Risk Management includes all the processes involved in risk identification, regulation, and mitigation on a project. The objective is to increase the likelihood of positive risks (opportunities) and decrease the likelihood of negative risks (threats).

Risk management planning (RMP):

Describing how to approach and plan for risk management in a project (Larson & Gray, 2015).

Risk mitigation:

If the risk leads to negative impacts in case of happening, the risk mitigation strategy is considered to reduce the impact of the risk or probability of the occurrence.

Risk response:

Risk response is the process of developing strategic options, and determining actions, to enhance opportunities and reduce threats to the project's objectives (Larson & Gray, 2015). Risk response strategies consist of avoiding, mitigate, transfer, accept, share, exploit, enhance.

Risk-taking capability:

This is a dynamic index, which shows the changes in the stress, and strain of the company in accepting a specific RO with different alternatives.

Risk transfer:

This strategy is an effort to transfer risk to the third party, which is responsible to tackle the management of the risk effectively.

Risk tolerance:

Risk tolerance is the level of the risk that an organization or project, is able to accept without any loss (Grable et al., 2019; Kwak & LaPlace, 2005; Lyons & Skitmore, 2004; Williams & Baláž, 2013).

Risky-Opportunity (RO) - [Novel term]:

On the contrary of "Pure Opportunities", which only cause positive subsequence, Risky Opportunity (RO) is not contain only opportunities, but they are associated with some threats besides the positive subsequences. If the threatening aspects of the RO are defined and eliminated, it will be possible to gain the opportunity without deviations from the project goals; to this aim, some measures should be adopted to introduce changes and make the project risk-tolerant. These measures are alternative ways which will be explained in next headline. However, any change needs to consume a part of resources; on the other hand, this resource consumption allows the project manager to accept the risk of RO.

Stress:

Stress is an indicator represented by the ratio of the positive aspects of an alternative (Opportunity and Benefit) to its negative aspects (Threat and Cost).

Strain:

The strain is an indicator represented by the ratio of the amount of resource consumption of an alternative that needs the least resource consumption to get the tasks done.

Calculation of Stress and Strain will be explained in the methodology section.

Sub-project objectives:

In this new method, It is necessary to take some measures to accept the RO and avoid the threats. The measures are listed as alternatives, which are a group of activities to accept one RO - and one of these alternatives will be selected according to the results of the method. These new activities which are aimed to make a change in the company, are considered as a sub-project. The objectives of the sub-project could contain some specific objectives but all of the sub-project objectives should follow the main project objectives. In short, it consists of the objectives of making a new decision, that was not normally a part of the main project plan, but it is going to be done for achieving some opportunities.

context of engineering systems, this has sometimes been interpreted as the probability that system conditions might exceed an irrevocable tipping point (Park et al., 2013). Resilience is a multi-disciplinary concept, which is already used in ecosystem stability, behavioral sciences, disaster risk, and psychology (Mitchell & Harris, 2012); but also in last decade scholars use the concept in engineering (Kammouh et al., 2020; McDonald, 2017; Steed, 2000; Tierney & Bruneau, 2007).

Uncertainty:

Uncertainty is the outcome of an event when two or more possibilities exist.(Head, 1967)

2.2 Existing Risk Management Frameworks

Risk management has a long story during the last century. The word "Risk" used in different concepts; simultaneously, according to the needs, the risk management plans transformed, and the qualitative tools give the position to quantitative tools (still in some cases qualitative tools are suitable). Gradually, some of these tools are abolished, some accepted as they were, some tools are modified to improve the performance and in some cases, new tools are introduced to fulfill new needs. Figure 1 illustrates the evolution of risk analyses and risk management.

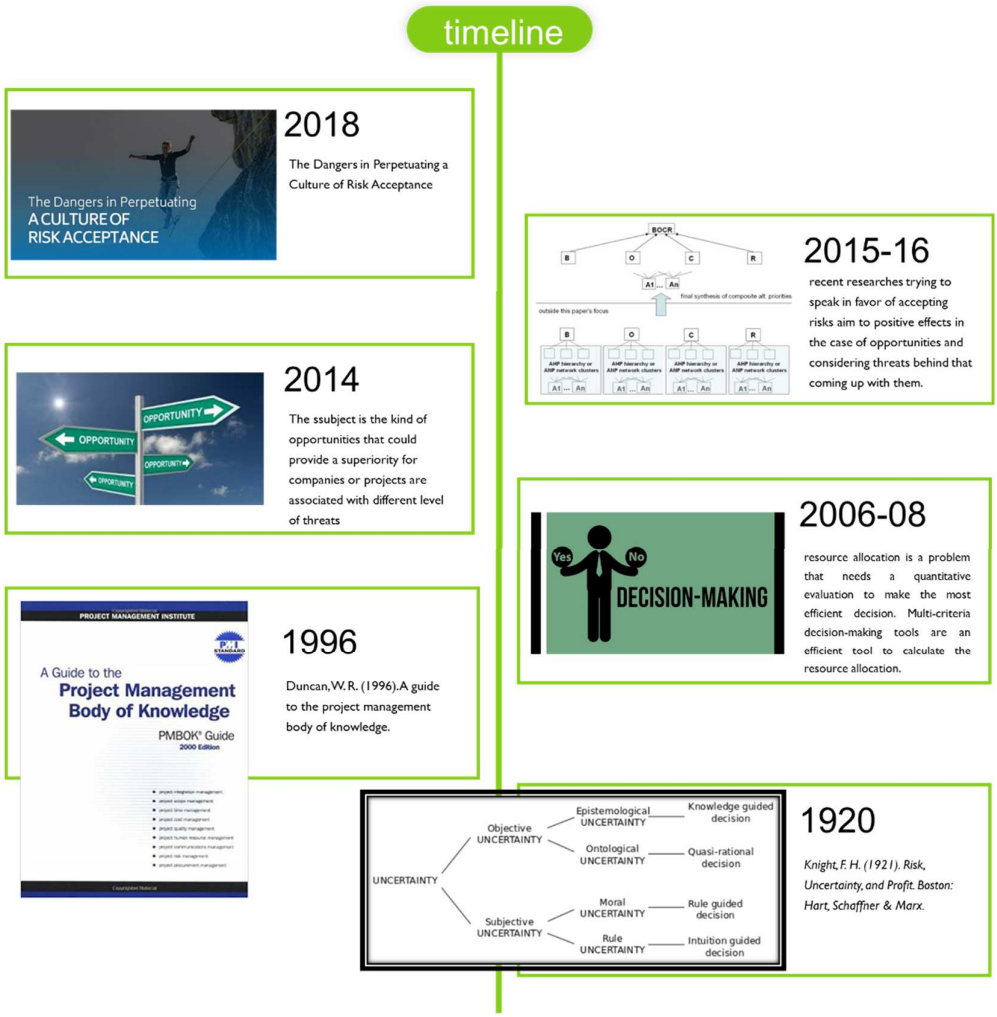

Figure 1 Risk management frameworks

According to the transition of the concept of Risk from a threat to an uncertain event that could include gain or loss, general risk management procedures should be altered regarding the new horizon, which emphasizes the opportunities in any uncertain event instead of focusing on threats. Also

with respect to the plausible opportunities, risk management plans could be counted as a competitive tool for project managers. Considering this objective, risk management plans and strategies must underscore obtaining opportunities from uncertainty in the projects. The study here presented takes into account the recent perspectives and counts risk as a source of opportunity.

Researchers suggested different risk management models and each one has its own pros and cons. The bibliographic research identified 20 frameworks that have been introduced by scholars and practitioners in risk management. Table 2 depicts the frameworks over time up to now – these are frameworks that are already suggested by researchers, standard models or customized models implementing in projects -. These frameworks are used as a foundation to redesign and improve different risk management models. All these models have 4 steps in common, namely Risk Identification, Risk Evaluation, Risk Response, and Risk Monitoring. Some of these models include the basic steps and some of them are more detailed. Still, most of the frameworks are not immediately applicable as practical procedures, so organizations should use these basic models to create a customized model for their own use. Case studies depict that risk management plans improve resource allocation (Dale et al., 2013; Kerzner, 2017), quality of operation (Ayyub, 2014; Gido et al., 2014; Potts & Ankrah, 2014), cost deduction (Edwards & Bowen, 2013), shortening schedule (ARMIC, 2009; Walker & Shen, 2002), improve flexibility (ARMIC, 2009), and improve monitoring of projects (ARMIC, 2009; Edwards & Bowen, 2013). All of these accomplishments are opportunities that were seized in risk management plans. On the other hand, most organizations are using frameworks to avoid loss as a consequence of risks. So accepting the risks could be an opportunity to open up new lines and exploit the uncertainty. Notwithstanding, others prohibit the same risks because they want to avoid any kind of threat even if it associated with some benefits. According to this aspect, acceptance strategy would be a competitive advantage besides the other benefits of risk management strategies, deciding between possible responses for a risk. In this thesis, we suggest an efficient way to prepare organizations to accept risks by redesigning a feasible risk management framework, which is more suitable for project managers who are inclined to accept the risks.

Table 2 Risk management frameworks

	Model	*Description*
1	SHAMPU (Chapman & Ward, 1996)	Shape, Harness, And Manage Project Uncertainty
2	COSO ERM 2004 (Opgenorth, 2017)	Committee of Sponsoring Organizations of the Treadway Commission (COSO) introduced a new version of original Internal Control (1992) as Integrated Framework.

3	ALARM (FERMA, 2003)	This model following EFQM framework and exploit it to risk management procedure, count as risk maturity model (Spikin, 2013) include 5 levels of maturity resemble Hillson (D. A. Hillson, 1997)
4	NIST Special Publication 800(Force & Initiative, 2010)	"Guide for Applying the Risk Management Framework to Federal Information Systems"
5	G. Smith (Smith, 2002)	P.G. Smith suggests this model for a proactive risk management plan for implementation in product development plans.
6	Leach (Leach, 2014)	This framework heading to avoid and mitigate the risk by recognizing potential risk triggers and monitoring these factors.
7	Boehm (Boehm, 1991)	Identification, analysis, prioritizing, risk management control, risk resolution, risk monitoring planning, tracking, corrective action
8	Fairley (Fairley, 1994)	Implement Analyzing the important factors of risk and Paying attention to crises management and recovery plan if the risk happened and resulted in a crisis.
9	SEI (Dorofee et al., 1996)	Include basic steps: Identification, analysis, response planning, tracking, control
10	RBS (D. Hillson, 2002)	The Risk Breakdown Structure (RBS) suggested as a tool for risk management
11	The Orange Book risk management model (Treasury, 2004)	developed from the model in the Strategy Unit's November 2002 report: "Risk – improving government's capability to handle risk and uncertainty"
12	Kliem & Ludin (Kliem & Ludin, 1997)	Include basic steps: Identification, analysis, control, reporting
13	PMBOK (PMI, 2004)	Risk management planning, risk identification, qualitative & quantitative, risk response planning, risk monitoring & control
14	PRMA (Bartlett, 2004)	The last step in this model communicates with consultants that make it unique in terms of outsourcing a part of risk management.
15	PRITCHARD (Pritchard, 2014)	Include 4 basic steps: risk planning, risk evaluation, risk response, and risk control
16	ISO 31000 - Risk management (Luko, 2013; Purdy, 2010)	Provides a set of principles, a framework and a process for managing risk.
17	360-degree RISK management model	This model tries to empower managers to have a better response instead of avoiding the risks.

	(Subramanian & Srividhya, 2008)	
18	Nicoms Risk Management Framework (Dia Global, n.d.)	The key to this model is establishing an effective risk management regime
19	IIRM Risk Management Framework (Investors in Risk Management, 2016)	Develop a risk management framework, Implement a risk management framework, Review and enhance a risk management framework
20	SRA's Regulatory Risk Framework (Solicitors Regulation Authority, 2013)	Risk-based regulatory framework

2.3 RISK RESPONSE STRATEGIES

Literature Review

This study focused on the risk acceptance strategy; the pillars of designing a new tool are to review the studies on response strategies and then focused literature review on the accept response strategy. To avoid rework and exploit the existing experiences and case studies during this study, it is fundamental to get familiar with previous works in both academia and practice. For this aim, a bibliographic search is performed.

Two databases are suitable for this search. Web of Science and Scopus are excellent sources to consult for information on the topic. Both of these databases are multidisciplinary and include a wide range of scientific articles on different disciplines, which help to find the risk response related articles from engineering and management to medicine and social sciences and even humanities.

SCOPUS is selected because it has rigorous evaluation criteria for their content of journals and is the world's largest abstract and citation database of peer-reviewed literature, including scientific journals, books, and conference proceedings, covering research topics across all scientific and technical disciplines. More than 150 leading research organizations rely on Scopus data. Delivering a comprehensive overview of the world's research output in different fields. These characteristics make SCOPUS outstanding for our research aim (Elsevier, n.d.; Oliveira et al., 2018).

In this study, a literature review has been done regarding a customized approach designed for this thesis based on the two standard procedures

suggested by MDJ Peters et al. (Al-Zubidy & Carver, 2019) and Peters et al (Peters et al., 2015).

First and the most important step of the literature review is keyword selection. In this research, we used a novel 5-step process to find the best keywords for the literature review search. In the following, the steps are described in detail.

The keyword selection process for literature research

Step 1:

The scope of the literature review is defined.

1. Background on risk response strategies
2. Background on risk acceptance
3. Databases selection (SCOPUS)

Step 2:

Table 3 shows the primary keyword selection and grouping according to the main concept of research. Group A, B, and C will be used inside the search string and world.

Table 3 Search keywords

GROUP A	GROUP B	GROUP C
RISK	RESPONSE	PROCESS
UNCERTAINTY		STRATEGY
		PROCEDURE
		TOOL
		METHOD

Step 3:

Scopus is selected to carry out a two-trial search string to choose the most proper keywords combination for the main search. 1st Trial includes using separated words and 2nd trial include the combination of the groups to make noun phrase for search. The 50 first results of the trial searches were sorted by relevance, Group A, B, and C will be combined to use combined noun phrases. This was a decision, based on author preferences regarding the two trial search results in lists of papers.

Step 4:

This step includes the 2nd phase of Keyword selection. This phase is a conceptually related word investigation. In this phase, the goal is to find other keywords that could be effective to put in the 2nd search query string to find the most related papers with the main objectives of the study. In this step, four types of words are studied. Table 4 shows the different types. The most related words are selected and then a study on 50 selected papers in pilot search in step no. 3 repeated to look for finding the words. The strategy is that if a related word used in pilot search papers, it will be added to the search string. Final keyword table is shown in Table 5.

Table 4 Conceptual keywords search

	SYNONYMS	ANTONYMS	RELATIONSHIP WORDS	JUDGMENTAL WORDS
REFERENCES	Meriam Webster Dictionary Thesaurus.com	Meriam Webster Dictionary Thesaurus.com	Scientific Background	Scientific Literature
SEARCH RESULTS	Ambiguity is the synonym of uncertainty	--	Threat	*dilemma* results in *Risk Encounter* result in a *response*
SELECTED WORDS TO PUT IN SEARCH STRING	Ambiguity	--	--	Encounter

Table 5 Search keywords

GROUP A	GROUP B	GROUP C
RISK	RESPONSE	PROCESS
UNCERTAINTY	ENCOUNTER	STRATEGY
AMBIGUITY		PROCEDURE
		TOOL
		METHOD

Step 5:

This step is the 3rd phase of keyword selection include search in Abbreviations since abbreviations are another category that is useful to find and include keywords in the systematic literature review. Three references used to perform a search on abbreviations include Google.com, Oxford abbreviation dictionary, and Abbreviations.com. The results show that there is no significant academic abbreviation to add in keywords group. Table 6 shows the results of the search.

Table 6 Search keywords

	Reference	*Most Related Abbreviations*	*Result to add in the keywords*
Keywords in All groups separately.	Google search for an abbreviation	No proper result	--

For example Risk.	Oxford abbreviation dictionary	No proper result	
	Abbreviations.com	No proper result	--
Combination of words in Group A, B, and C	Google search for an abbreviation	RM (Risk Management)	--
	Oxford abbreviation dictionary	No Proper result	--
	Abbreviations.com	RM (Risk Management)	--

In the following the process and results of the literature review on Risk Response Strategies in SCOPUS and WOS will be discussed.

Scopus search and results:

After identifying the keywords, we could perform a search in databases. SCOPUS database is available from the following the link provided by the University of Trieste:

https://www.biblio.units.it/BD

Advanced search by "query string" was selected to control the search factors. In this study, the implemented search language for Scopus included the following characteristics:

1. The search is limited to peer-reviewed papers.
2. The language is limited to English.
3. The search excludes the scholars on Math, Arts, Physics, and Chemistry to stay focused on practical risk responses hypothesizes and case studies in applied science.
4. Boolean operators AND and OR are used to combine the keywords.
5. TITLE-ABS-KEY("XXX") returns documents with "XXX" in their abstracts, article titles, or keyword fields.
6. DOCTYPE(ar) returns documents classified as articles.
7. SRCTYPE(j) returns documents from journal sources

The string of the search in the database is as follows:

TITLE-ABS-KEY (("risk response" OR "risk encounter") OR ("Ambiguity response" OR "ambiguity encounter") OR ("uncertainty response" OR "uncertainty encounter")) AND ("process" OR "strategy" OR "procedure" OR "tool" OR "method") AND (EXCLUDE (SUBJAREA," MATH") OR

EXCLUDE (SUBJAREA,"ARTS") OR EXCLUDE (SUBJAREA,"PHYS") OR EXCLUDE (SUBJAREA,"CHEM")) AND (SRCTYPE (j)) AND (DOCTYPE (ar)) AND (LIMIT-TO (LANGUAGE , "English"))

The result of the search string includes 339 documents. Figure 2 shows the results regarding the subject area. Major articles are investigate engineering, business, medicine, and social science. Figure 3 shows a significant increase in studies after 2000. The result includes papers, which are published from 1972 until 2019. The results exported with RIS format include Citation information, Abstract, and Keywords and references. Mendeley Desktop is used to find the duplicates, just one duplication found between whole results.

The first step is to search in the references of the papers in the result list of the Scopus search to find articles that maybe are not listed in the Scopus search results but they are strongly related with the "risk response" argument. Table 7 shows the list of 4 papers which is identified from the references study and added to the main file.

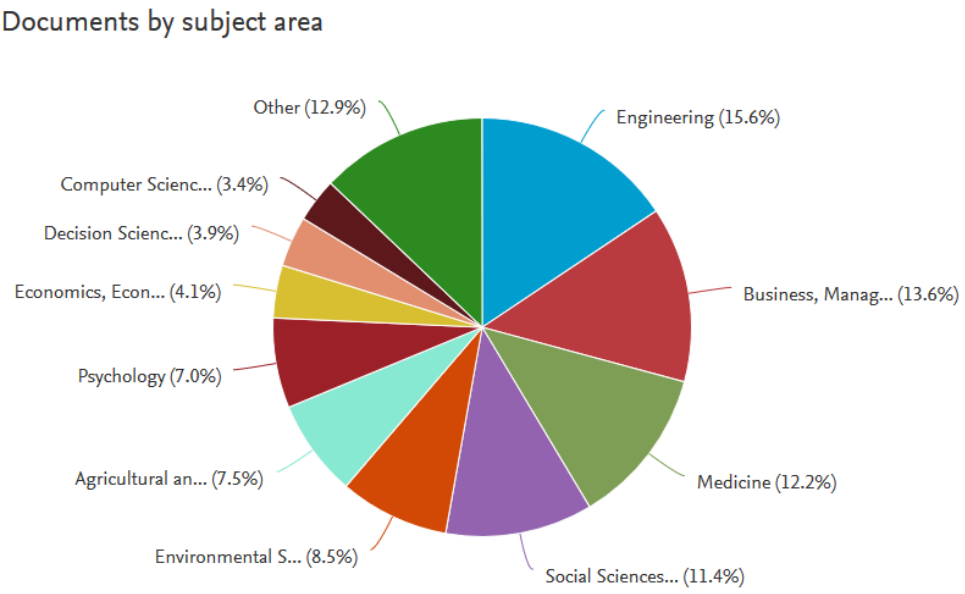

Figure 2 Result of the published papers in Scopus by the subject

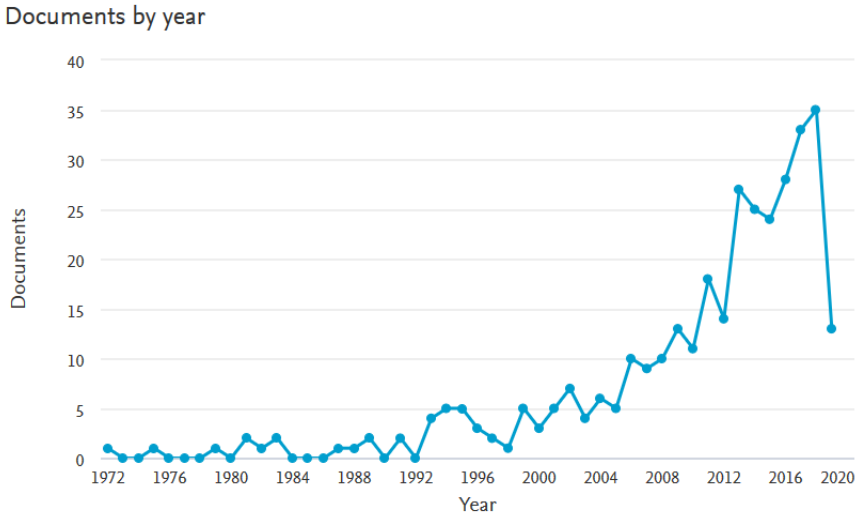

Figure 3 The trend of the published papers in Scopus by the year

Table 7 Three papers extracted from references investigation of the papers

Num.	*New references*
1	Huang, L., Ban, J., Sun, K., Han, Y., Yuan, Z., & Bi, J. (2013). The influence of public perception on risk acceptance of the chemical industry and the assistance for risk communication. *Safety Science*, *51*(1), 232-240.
2	Huang, L., Duan, B., Bi, J., Yuan, Z., & Ban, J. (2010). Analysis of determining factors of the public's risk acceptance level in China. *Human and Ecological Risk Assessment: An International Journal*, *16*(2), 365-379.
3	Lamm, H. (1988). A review of our research on group polarization: Eleven experiments on the effects of group discussion on risk acceptance, probability estimation, and negotiation positions. *Psychological Reports*, *62*(3), 807-813.

In this phase, the first screening of the list starts. The elimination criteria include:

1. Health care studies are focused on the risk of special disease and biological responses of the patients.
2. Health care studies associated with preventive measures.
3. Health care studies associated with the emotional, mental, and behavioral response of the patients in the face with a threat.
4. Psychological studies on pure psychologic risks and patients response.
5. Environmental studies focused on crisis management and disasters risk response (These responses are practical activities aim to save people and exit from the crises).

6. Environmental studies focused on wildlife and animal's biological response to changes (like climate change) and threats (like pollution).
7. Economic studies focused on enterprise, marketing, and financial risk responses.
8. Social studies on victimization risk, crimes, and race/ethnicity risk response.
9. Laboratory and experimental approaches to study risk response of phenomena (for instance hurricane dynamic simulation in the laboratory).
10. Engineering studies on technical risks and responses.

After the first screening, 171 out of 342 articles remain in the list after this phase. Figure 4 shows different categories of the papers in the remaining list after the first screening.

In the second phase, the study will focus on extracting related articles with the methodological theme on risk response strategies (the subject of the thesis) and finding the studies with common conceptual objectives. The second screening phase is done regarding the conceptual and methodological relation with the articles and risk response strategies. The abstracts are studied and General response surveys include cause and effects of risk responses, and strategies other than acceptance will be eliminated from the list.

The remaining articles are the final list of this step. The paper's methodologies and conclusions sections are skimmed to find out the similarities or methodological cases that could help us to improve this thesis's basic proposal. Table 8 represents the characteristics of the final list of articles. The list of the papers listed in Appendix A. In the next section, the full paper study will focus on risk acceptance and resource consumption papers – the full paper study will be employed on the selected articles in the final list -.

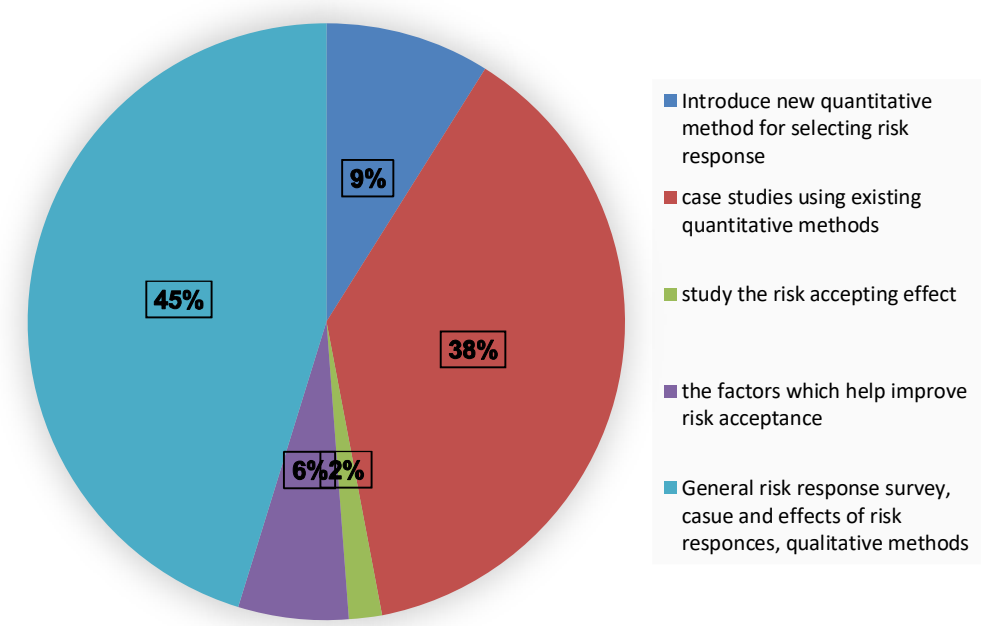

Figure 4 categorized pie chart of the papers after the first screening

Table 8 Characteristics of the final list articles methods

	New Methods	Num.	Existing Methods	Num.
1	Particle Swarm Optimization (PSO) algorithm aim to keeping the total budget at the lowest amount	unique	Protection motivation theory (PMT) for risk reduction	1
2	A new method to manage risks for ICLS based on ERM. integrating the management of risks and aligning risk management with strategic objectives.	unique	Risk Identification and ranking	8
3	Computerized Method for Delay Risk Assessment Based on Fuzzy Set Theory using MS Project	unique	Different fuzzy methods	5
4	The optimization model aims to minimize the total risk costs with time constraint	unique	qualitative methods, brainstorming, benchmarking	6
5	Applying importance measures to risk analysis	unique	risk quantification, Pairwise Elicitation for a DSS	2

6	A hybrid model comprising both fuzzy logic (FL) and hierarchical holographic modeling (HHM) techniques where risk is first identified by the HHM method and then assessed using both qualitative risk assessment model (named risk filtering, ranking, and management Framework) and fuzzy-based risk assessment method (named FL approach).	unique	Monte Carlo Simulation	2
7	Multiobjective Harmony Search (MOHS)	unique	KNIME combine with WEKA	1
8	Innovation risk in digital business model	unique	project management maturity model (PMMM) 2	2
9	Bring together two seemingly disparate bodies of literature – ambidexterity (the ability both to exploit and explore) and mindfulness – to take a fresh perspective on the management of uncertainty	unique	probabilistic approach	5
10	The multimethod research approach is adopted	unique	probability-impact	2
11	The optimization model is developed, which integrates three critical elements that are the project cost, project schedule, and project quality	unique	AHP and ANP	7
12	A computerized risk evaluation model	unique	SYSTEM DYNAMICS	2
13	A novel numerical procedure, which realizes the stochastic analysis with dimensional reduction integration (DRI), C-type Gram-Charlier (CGC) series, and finite element (FE) model	unique	Risk Critical Point (RCP)	1
14	Fuzzy preference relation and consistency induced ordered weighted averaging (C-IOWA) operator	unique	risk-based project value (RPV)	1
15	The present paper introduces a Decision Support System (DSS) including a modeling approach with the objective of selecting a set of RAs that minimizes the undesirable deviation from achieving the project scope	unique	MCDM, MADM, and MODM	6
16	**Total number of novel Methods**	**15**	FMEA	4

	1
Delphi analysis	1
fault tree analysis	2
judgmental risk analysis process (JRAP)	1
The model, Hierarchical Exposure Tree & Alternative Risk Responses (HETARR), defines risk as an exposure attributable to the failure of reaching the project's aims	1
Total number of existing methods	**61**

The methods are listed in Table 8. Multi-criteria decision-making methods, especially AHP and ANP, are the most popular quantitative method to analyses regarding the existing methods. At the end of this chapter, a focused review will be performed on ANP and BOCR methods.

2.4 Risk Acceptance and Resource Consumption

Three of the papers are highlighted As new approaches in Table 8. These papers have similar objectives to minimize resource consumption in risk acceptance strategy.

Particle Swarm Optimization (PSO) algorithm aims to keep the total budget at the lowest amount. Besides minimizing risk contingency while keeping the total budget at the lowest amount, the proposed model could also provide recommendations for appropriate risk response strategy (Kuo et al., 2019).

Zuo et al. in 2018 introduced a new optimization approach focused on secondary risks. In case of risk acceptance, due to the risk response actions, new risks arise as a direct result of response activities. The optimization model in this study aims to minimize the total risk costs with time constraints being placed on the project make span. By solving the model, an optimal set of RRAs along with the earliest start time for each activity can both be obtained (Zuo & Zhang, 2018).

Zhang Y. and Fan Z.-P in 2014 designed a new optimization model, which integrates three critical elements that are the project cost, project schedule, and project quality. The optimization is based on an iterative process that involves making trade-offs between the project budget, time, and quality according to objective requirements and managers' judgments and the iterations stops when the objectives mater (Zhang & Fan, 2014).

All three papers are fruitful tools for project risk management, but the difference between the methods designed in this thesis with all the above-mentioned papers are as follow:

1. In this method, we consider a combination of the risk response strategies and the concept of risky-opportunity during the analyses.
2. In this method 'risk-taking capability' of an organization is assessed according to each RO.
3. A new method which is proposed in the current study Identify the most efficient resource and the amount of resource consumption to make the project ready to accept risk.
4. A new method which is proposed in the current study does not necessarily minimize the resource consumption but compares the two indexes (Stress and Strain) to illustrate the resource consumption besides the situation of the company after accepting an alternative.

In the next chapter, three methods will be explained in detail. Real options have some aspects in common with the proposed method in this thesis, ANP based BOCR is used in this thesis as a quantitative method to calculate Stress, and Strain indicators, and SWOT is a qualitative approach which could be beneficial to RO and alternatives identification.

2.5 Discussion and Conclusion on the results of the literature review

The Highlights

Regarding the results of the literature study, the following highlights are associated with the two main concepts including risk acceptance and resource allocation:

- The definition of the risk changes over time by revealing the importance of the positive aspects of the risk.
- The last risk management framework which is introduced in 2018 aims to introduce risk acceptance culture.
- 20 different risk management frameworks are founded in literature, which are mostly customized versions of the basic 4 step risk management model of risk identification, risk assessment, risk response, and monitor.

- Only 2 percent of the studies mentioned the risk acceptance Figure 2. Nevertheless, considering the positive effects of the risks are an important part of the uncertainty management, risk acceptance as a response strategy, was not investigated enough in literature.
- Regarding the existing and fully defined methods in Table 8, the quantitative methods are mostly based on MCDM methods, weighting, and ranking the risks and probabilistic approaches.
- New methods are mostly focused on improving the preciseness of the tool in calculations. For example by using fuzzy logic to consider the fact that decision making by human is employed to handle the concept of partial truth, which the quantified truth value may range between completely true which is 1 and completely false which is 0. Or the other example is focusing on the computerized problem solving or digitalization to design a new method.
- The majority of the new methods are quantitative methods.
- All of the methods are based on minimizing costs.
- Most of the methods in risk assessment tools are aiming to avoid the threats and consequently use reject, transfer, and mitigation response strategies.

Patterns

- The evolution of risk management framework started by highlighting the importance of hazards but end up in risk acceptance culture.
- The evolution of risk assessment tools shows that implementing the risk assessment tools started by qualitative assessment but gradually changed to quantitative evaluation of the risks.
- The trend of increasing the published papers illustrate the need to use decision support tools for choosing risk response strategies.
- The majority of the papers are in engineering, business, and management subject area which shows the popularity of assessing the risks and using risk management plans in projects.

Themes

Regarding the diversity of the subject areas, case studies, literature reviews, and theoretical and methodological approaches on the risk management tools are widely employed in diverse research and practical themes.

Conflicts

The main conflict between the existing methods and the definition of the risk is neglecting the risk acceptance strategy to exploit the positive effects of the risks.

Gaps

- There is a big gap of combined risk response strategies instead of selecting four strategies including accept, reject, transfer, mitigate.

- None of the quantitative methods does consider the effect of changes and different amounts of resource consumption on the whole project.
- The quantitative methods consider each risk with a single solution and response and compare it with all other risks. But it is possible to compare different solutions for a risk that could incur different costs and different results in case of accepting the risk.
- All of the existing methods consider the same weight for different response strategies. Therefore, most of the methods neglect the opportunities behind accepting the risk and reject the risk by simple comparison.
- The existing methods are not considering the capability of change in the company to accept risk.
- Minimizing the costs is neglecting the different ways of resource consumption to increase the productivity of the risk response strategy.

State Of Current Knowledge Concerning A Central Research Question

1. How could the risk-taking capability be assessed?

A risk-taking capability, in the current study, is defined as the capability of change in the company to accept risk is different from the risk tolerance and risk resistance. Therefore this study is going to introduce a method to support this concept.

2. How could the risk-taking capability be increased?

Regarding the gap in the literature on combined risk-taking responses, it is possible to implement a risk break down the system to investigate the risk from micro risks perspective and make some changes in the company aim to accept the risk without any deviation from objectives.

3. Is it possible to use quantitative tools to support decision-making with the aim to accept the risk without negatively affecting the company's sustainable strategy?

The sustainability strategies become a competitive advantage and considering this strategy in the objectives of risk acceptance decision support tool can conserve the company from deviation from strategic objectives.

4. How to select the kind and quantity of resources that should be employed to accept the risk?

In the existing methods of quantitative risk evaluation, the cost is defined as the expense of recovery or losses in case of happening a risk. But in the

method that is designed in this current study, resource consumption is considered as a fundamental element for making a change in the company to be able to accept risk. It means that the type and quantity of the resource which allocates for each alternative way of the change will be calculated separately.

In the remaining of this section, there is a closer review of the other risk assessment tools that had some aspects in common with the new method that is designed in this study and their differences with a new method.

2.5.6 OTHER METHODS AND DIFFERENCES

"Real Options" and "Risk Management"

Both the concepts of risk management and real options are associated with financial aspects. But risk management is focused on the protection of individuals and companies as an insurance strategy in the face with different probable losses (Dionne, 2013) and then extended to all fields that uncertainty prevails and probable losses are likely. On the other hand, the idea of real options are suggested for financial context and later implemented in engineering and design flexibility in an uncertain environment (Wang & Neufville, 2006).

In this study, we suppose that all of the operations include production and services, could be identified as a project. Therefore, risk management is applicable in all of the aspects of uncertainty associated with projects. However, the real options mostly concerned with the alternatives which are most contingent to prepare the best flexibility besides the highest value. (Wang & Neufville, 2006). More importantly, the risk is the possibility of something dangerous happening (C. Dictionary, 2015), and risk is not defined as a real event and this category predictable just probabilistically (Slovic & Weber, 2013).

There are two types of Real options "on" and "in". First type projects are financial options taken on technical things, treating technology itself as a "black box" and Real options "in" projects are created by changing the actual design of the technical system (Wang & Neufville, 2006). Nevertheless, risk management is not limited in the primary designation of a technical system.

Another eminent difference between real options and risk management is that in real options, parameters of the formulation could be certain or uncertain or mixed but in risk management, all of the parameters are uncertain.

To sum up, once plausible options are identified in the real options model, a detailed simulation can validate the options. Here it is the point that the

procedure of RO finishes if it can find the best option. Quite the contrary, in the new risk management method, the whole process is not finished when risky-opportunities identified, but, the action of evaluation of the stress and strain system will be performed and it will continue the performing during all of the projects untill it finishes. Therefore, RO method finds the best real option and suggests it but the stress-strain system continuously assesses the situation to keep exploiting the uncertainty.

SWOT

SWOT analysis (or SWOT matrix) is a qualitative technique at the strategic level. This method identifies strengths, weaknesses, opportunities, and threats related to business competition or project planning (Reihanian et al., 2012).

In qualitative form, SWOT is a present state of the company about a decision or an uncertain event. Nevertheless, in the last decade, many case studies show that SWOT could be combined with other methods to provide a decision support system. For instance, combined SWOT with BSC, AHP, TOPSIS, FANP, and ANP analyses implemented in case studies of manufacturing, mining and sustainable development (Arsić et al., 2017; Azimi et al., 2011; Görener et al., 2012; Korableva & Kalimullina, 2016; Yüksel & Dagˇdeviren, 2007).

BOCR:

BOCR (benefit, opportunity, cost, and risk) is a multi-criteria decision-making method that uses four indicators to solve decision problems. Bayesian network and/or AHP (analytic hierarchy process) or ANP (analytic network process) analysis can be implemented to calculate the values of each indicator. BOCR analyses are similar to SWOT matrix in some way but in this method (B∗O)/(C∗R) ratio provides a quantitative index which is used to support the final decision (Thomas L. Saaty, 1990, 2000; Thomas L. Saaty et al., 2005; Tchangani & Pérès, 2010; Wedley, W.C. et al., 2003).

In this thesis, we use the BOCR framework to calculate the parameters to assess the value of the Stress Indicator.

2.5.7 Conclusion

In summary, the risk management tools are evolving continuously and the trend is toward establishing the culture of risk acceptance and using positive effects of the risk as a competitive advantage. Therefore, regarding the gaps revealed during the literature review and on the other hand, the main research questions of this study, a new quantitative method is required to accept the risky opportunities considering the resource consumption and risk-taking capability of the company.

Section 2

The attributes of resilient and sustainable decision making in the presence of the risk. This Ph.D. project aims to design a decision support tool based on risk acceptance. This method will analyze different ways to make a change in the company, increase the risk-taking capability, and identify the type and the amount of resources to make the changes. Regarding the main objective no. 4 of the current document, the decision tool should support and increase the resilience and sustainability of the decision and the company. All of the decision group members should follow specific attributes to reach the resilient and sustainable decision, so, the literature review focused on a group decision. Therefore, besides the method and its analytical approach, we should identify the attributes of such a decision making process. For this aim, a literature review conducted to identify the attributes of the decision making that should be considered during the implementation of the new method. This section is published in Sustainability Journal (Aghazadeh Ardebili & Padoano, 2020).

ABSTRACT:

The most critical decisions usually involve several decision-makers with different roles and opportunities to commit key resources. Several group decision-making (GDM) approaches can support the identification of a joint or compromise decision in less conflicting settings, where there is a group of subjects (e.g', partners) who pursue a common overall objective. However, considering the uncertainty in future events and complexity of modern-day systems, decision processes do not always produce beneficial results or give the participants a positive perception of their role in the process. Group decision-making should then take into consideration some aspects that might insure future resilience and sustainability, particularly the achievement of the objectives in view of future risks and the transparency and participation that are needed to limit problems in the implementation phase of the decision. The literature survey presented in this study identified a research gap regarding GDM. Differently from traditional GDM, which was first discussed in the early 1980s and whose body of knowledge is pretty defined, resilient and sustainable GDM (R&S GDM) is fairly new. The main objective of this study is then identifying the main attributes for supporting sustainable and resilient group decisions. To this aim, a preliminary focused systematic review was conducted to study the existing group decision-making methods in the literature and how the

concepts of sustainability and resilience have been employed. After defining the search keywords and exclusion criteria for the individuation of the articles, the first screening process was carried out and the most relevant articles were selected. The last steps of the systematic review were the classification of the articles and the full paper examination to extract the main factors of R&S GDM. Seven attributes were listed as the key factors of R&S GDM. In light of those factors, a group decision process concerning an injection moulding line in Tajikistan was investigated. The case study highlighted that over self-confidence, information flow and transparency were the main reasons for faulty decisions, thus suggesting that information system and information fluidity play an important role in R&S GDM. Finally, the most important managerial implications of R&S GDM are reported.

Keywords: Sustainable supply chain; green service; payment service provider; thermal paper; waste reduction; multi criteria decision making; TOPSIS; sustainable consumption

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2.2.1. INTRODUCTION

Different multi-criteria decision-making methods are available to support complex decisions, which usually employ the decision maker's (DM) preferences to weight the criteria and prioritize the alternative courses of action (solutions). These methods are mostly designed to rank solutions and select the best one for a single DM. However, in the case of several decision makers or stakeholders with decision power, the situation can be different. Making joint decisions is, for instance, an important part of any business run by a group of partners. In such cases, even in the presence of an overall common goal, finding the best choice that is compatible with all requirements and concurrently relevant to all DMs' preferences is a challenge. For instance, it can be required that some subjects represent other key partners' goals, even if they do not actually participate in the decision process. Further, the uncertainty of future events and the complexity of the system in which the decisions are made must be taken into consideration. It is therefore important to identify analysis and evaluation methods that can provide "resilient decisions", which are able to ensure dynamic equilibrium of the system by correcting, minimizing or avoiding the effects of unforeseen events. As highlighted in the following sections, "resilient" and "sustainable" are here interpreted as attributes of the decision-making process and results, while, in many other studies, they are used as criteria in the evaluation model. Then, after identifying the main factors, the second step was to appraise the outcome list to evaluate the role of each factor in a real case group decision

The core of this study was a systematic review of the literature in order to individuate a set of the main factors that influence the resilience and

sustainability of decision-making. The identified factors were then analyzed with specific reference to a real case of group decision. Consequently, the research objectives were refined across two stages. In the first stage we developed a systematic review to answer broad research questions (RQs) and the second stage is the case study concerning group decisions in a production line in Tajikistan, in which the actual influence of the identified factors on decisions is investigated.

To sum up, this article aims to achieve two types of objectives. The general objectives are finding research subjects, themes and gaps in the published research on group decision-making (GDM) where resilience and sustainability are considered. To this aim, 38 papers were identified by means of a four step focused systematic review and subjected to a detailed analysis to extract the important factors of resilient and sustainable group decision-making (R&S GDM) (Supplementary Materials). The factors will need further investigation in the future to confirm their role; therefore, in this respect, the present study can be considered as a first step of a deeper and wider research. The particular objective is to investigate the identified factors connected with resilient and sustainable GDM in an industrial case. Accordingly, two groups of research questions are considered: G1RQ and G2RQ, general and specific, in turn:

G1RQ

G1RQ1: Are there any factors that make a group decision more resilient and sustainable?

G1RQ2: Do published studies consider resilience and sustainability just as criteria to be used in the evaluation models, or they also interpret them as attributes of the decision process and results, giving thus a meaning to the concept of resilient and sustainable group decision-making (R&S GDM)?

G2RQ

G2RQ1: To what extent did the investigated company consider the identified factors in the group decisions?

G2RQ2: What was the impact of either considering or ignoring each factor in the decisions of the company?

In the next section a general methodology of the article and the detailed methodology of the systematic review and case study are explained. Then in Section 3 the results of the literature review and in Section 4 the results of the case study are reported. Section 5 provides a discussion on the findings. Section 6 highlights the managerial implications of this study and Section 7 wraps up the results and sets out the conclusions.

2.2.2. MATERIALS AND METHODS

General Methodology

This paper presents a literature review on resilience and sustainability in the context of group decision-making (GDM) and includes two stages. In the first stage, we are going to survey the literature on GDM. The second stage of the study investigates the failure of group decision-making in a real company. In the first stage, the main goal is to explore in a systematic way the GDM methods that take into consideration the concepts of resilience and sustainability; we consider two different search strings including risks and important metrics. The string "metric" is chosen because it is important to find how the main factors that influence the effectiveness of group decisions have been structured and used. "Risk" is chosen because it is a key aspect that is discussed in resilient engineering and is often associated with group decision-making. Therefore, the survey will synthesize two different focuses including resilience and sustainability and discuss the practical group decision-making factor aim to have a resilient and sustainable decision.

In the second stage the main goal is to investigate the reasons behind failure through the concepts obtained in the previous stage and understand them. This discussion on the failures of the case study could lead us to the evaluation of the impact of the identified factors, related to resilience and sustainability in a real group decision.

Methodology—Literature Review

The first stage of the current investigation is the literature review that includes two phases. The first phase is a general study of the published research on GDM which shows connections with the concepts of sustainability and resilience, which we used for the focused literature study as inclusion criteria in the abstract examination phase and for the definition of the concept of "resilient decision". The results of the first phase are reported in Sections 3.1 and 3.2. The second phase is a systematic review focused on risks and metrics of GDM in the context of resilience and sustainability, performed by means of a novel approach. Figure 5 shows the focused systematic review process. This process is an original way to conduct a systematic review followed by the investigation of a case study to find confirmation of the key points highlighted in the literature. As Figure 5 illustrates, this process has four steps: Definitions, data collection, paper examination and analysis and discussion of the results.

The main theme of GDM in this paper is resilient and sustainable decision-making. Figure 6 illustrates the scope and limitations of the survey regarding the keywords. In Figure 6 the process of narrowing the scope is shown by the quantity of published documents in each of the subject areas. In the first step of the focused systematic review, Scopus was selected to review the state of art and existing knowledge. Two software were selected

to work on the dataset: Mendeley and MicROsoft Excel. Mendeley is a free reference manager provided by a company based in London, UK. Mendeley was selected because of its interconnection with Scopus; it is possible to import the results of advanced search in Scopus directly to the reference manager (see Annex A). MicROsoft Excel was used as a spreadsheet to work with keywords, summarize the abstracts, cluster the articles regarding different criteria to find patterns and trends and as a feature calculation and graphing tool. The dataset produced by Mendeley was exported in CSV format to be used in MicROsoft Excel. It was then possible to analyze the selected articles as they were retrieved and stored by Mendeley.

The second step of the systematic review is data collection (Figure 5). The strategy is to combine keywords to narrow the scope of the search. Therefore, the first step is to identify the keywords. This step is the most crucial part of the survey because the review is limited by the narrowed scope and the results depend on the focused selected papers (Figure 6).

Keyword selection has been done in the second step. First the important keywords are listed. The list includes a representative index of the main objectives. These keywords are group decision, method, resilience, sustainability, risk and metrics. The second step is implementing trial searches in Scopus while only limiting the search scope by keywords, sorting the results list according to relevance and checking the keywords in the first 100 papers to find the similar keywords that are used in scientific papers for the same context. The search query for Scopus advance search is as follows:

> TITLE-ABS-KEY ("group decision" AND "method") AND (KEY (“Keyword * ”))
>
> * the keyword seat in this position

The snowball strategy was used to collect other similar keywords from the published literature. Table 9 shows the results of snowball keyword selection.

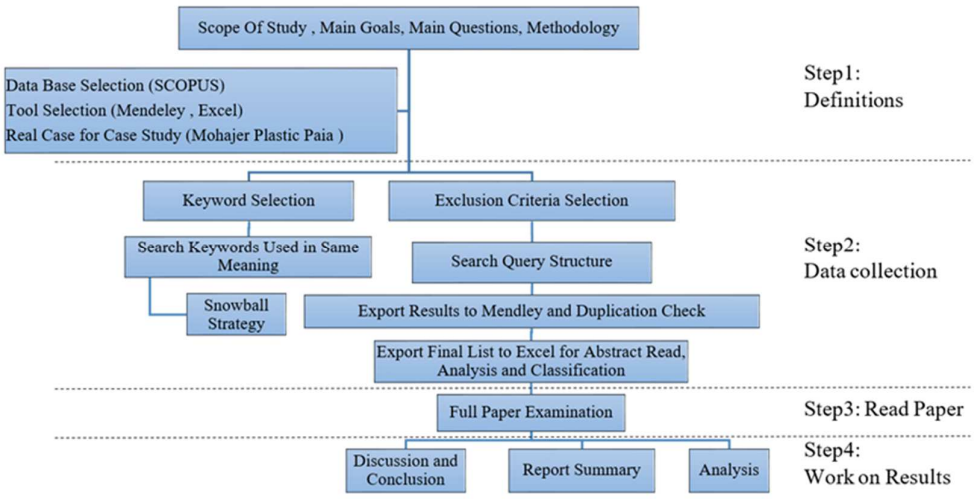


Figure 5 Systematic literature review process.

The advanced search query is used in Scopus search page; Scopus Search API supports a Boolean syntax, Boolean operators are implemented to combine the keywords. Scholarly sources in Scopus cover many document types such as reports, editorials, books, journal articles, conference papers and theses, but in this paper the query considers indexed journal articles especially because of the double blind review of the before publication and it a decision of the authors. Exclusion criteria of the search results include mathematics, art, physics and chemistry and the results are limited to English papers. Table 10 shows the two focused query strings. The results of the search are exported in Mendeley to undergo a duplication check. Thirty-one duplications were found in the results and eliminated from the list. Then the final list was exported in Excel to identify and classify the metrics and risks of R&S GDM.

Table 9 Query Strings.

Selection Steps	*Keywords*			
Primary Keywords	Sustainability	Resilience	Risk	Metric
Snowballed List	sustainable	resilient	threat, uncertainty	index, measure, indicator
Final Decision for Search String	"sustainab*"	"resilien*"	"risk" OR "uncertainty" OR "threat"	"metric" OR "measure" OR "index" OR "indicator"

In the next step the abstracts were examined. The aim of this part is to find patterns, themes, conflicts and gaps. To do so, we made a list of questions (G3RQ) that were used in the abstract examination:

G3RQ1: Scope of the articles

What is the subject area of the article?

What problem is the article addressing?

G3RQ2: Methodology

What are the metrics for sustainability or resilience concepts and how are they defined?

What are the risks of ending up with an ineffective group decision?

What are the key objectives and methods? Does the method need a prerequisite?

G3RQ3: Findings

What are the main findings, key insights and gaps of the study?

What are the limits, strengths and weaknesses of the research and the future challenges?

If the abstract did not give enough information to answer the above-mentioned questions or if the last of the above questions was raised after reading the abstract, the full paper was examined after the abstract. After reading the collected abstracts and full papers, we summarized the results of the analysis, classified the papers regarding the philosophical background and extracted the methods and important factors that impact on GDM. The results are reported in Section 4. Finally, all of the references were imported into the Zotero database to organize the reference list.

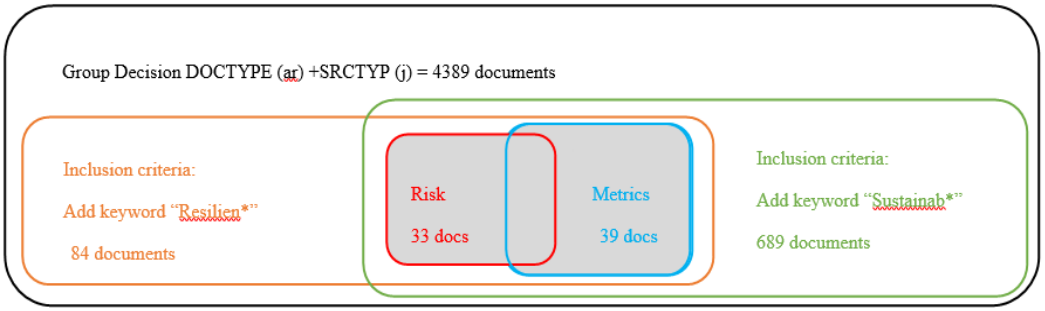


Figure 6 Scope and limitations of Survey

Table 10 Query Strings

Focus	*Query String*	*Result (papers)*
Risk	TITLE-ABS-KEY ("Group decision" AND "method") AND ("risk " OR "uncertainty" OR "threat") AND ("resilien*") AND ("sustainab*") AND (SRCTYPE (j)) AND (DOCTYPE (ar)) AND (EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "CHEM")) AND (LIMIT-TO (LANGUAGE , "English"))	39
Metrics	TITLE-ABS-KEY ("Group decision") AND ("metric" OR "measure" OR "index" OR "indicator") AND ("resilien*") AND ("sustainab*") AND (SRCTYPE (j)) AND (DOCTYPE (ar)) AND (EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "CHEM")) AND (LIMIT-TO (LANGUAGE , "English"))	33

Methodology—Case Study

The selected case is a company that suffered the impacts of ineffective decisions and failed. The following data collection method was used in order to investigate the main factors of resilient decision-making, which are already identified in the systematic review stage of the current study. Firstly, general information about the company (Section 2.4) was collected through an interview with open questions. Then, the study focused on the reasons of the failure and the factors that affected group decisions in the company. Two online Skype interviews were conducted. The first online Skype interview was administered to collect data about the key decisions, their causes and the results. Open-end questions were asked to the executives, the members of the decision group, to identify the most problematic issues and the perceived reasons of ineffective decisions. The second online Skype interview was semi-structured and aimed to rank the ineffective decisions and then collect information about the causes and the effects of this ineffectiveness. The interviewees were asked to assign a level of impact to the causes of failure on a 1–10 scale (10: Maximum impact); the arithmetic mean was then used to rank such causes: Table 13 in the "Results" section shows in the last row the obtained rankings. The results are illustrated in Section 4.2.

Case Company—Injection Molding Line In Tajikistan

Mohajer Plastic Paia is an injection moulding company in Tajikistan, which faced bankruptcy mainly caused by poor decision-making. The company started production in 2007. The factory had six plastic injection moulding

machines with different capacities (PA 100/250, PA 200/620, PA 300/100 and PA 500/2800). The company were using Parsian plastic injection moulding machines, which is an Iranian brand. The moulding production line had 14 different moulds to produce 11 sizes of plastic containers for agricultural productions transportation and four different sizes of bucket of paint.

2.2.3. LITERATURE REVIEW RESULTS

Resilient and sustainable decision-making

Resilience is a recent concept which is popular in ecology, social science, technology and engineering. The bond between ecological concerns and planning was established in 1971 (Holling & Goldberg, 1971) and in 1975 Haber presented the difference between resiliency and stability and proposed a methodological approach in which ecological resiliency information provides a decision-making support resource (Haber et al., 1975). That was the trigger for considering a combination of concepts including logistic evolution, resilience, stability, risks of disruption or crisis, socioeconomic risks, energy security, etc., in decision-making (Ursu et al., 1985). More specifically, Vertinsky introduced an ecological model of resilient decision-making in 1987. He used the same term "resilience" that ecologists use as a property of a system for the persisting ability of a system dealing with discontinuities in their environment (Vertinsky, 1987). A resilient decision can be defined as follows: "Well succeeded decisions adopted to guarantee a system's dynamic equilibrium, so as to correct, minimize or even avoid the effects of an unforeseen event" (Reis et al., 2008). In the beginning, the implementation of the resilience concept in decision-making was more popular in water management, aquaculture and ocean science (Beck, 1997; Hall & Davis, 2001; Hanna, 1995; *Scopus - Ocean and Coastal Management*, n.d.); however, later on, researchers started to investigate organizational resilience (Knops et al., 2004; Mallak, 1997) and sustainability.

The primary integrations of sustainability in decision-making were proposed in the early 1990s (Allen et al., 1991; Labonté, 1991), where the concept was considered as an evaluation dimension. Sustainable decision-making tries to assess the outcomes of a decision against the three pillars of sustainability (environment, social and economic). The interest for sustainability-based decisions increased substantially after 2006 and now there are more than 26 thousands documents which are related to both the sustainability and decision-making subject areas. However, in a 2018 study, Dong et al. highlighted that environmental impacts are still scarcely considered in decision-making (Yan Dong et al., 2018). On such accounts, it can be remarked that both aspects (resilience and sustainability) play a key role in strategic decision-making. Studying multiple economic,

environmental and social indices increased recently (Ruiz & Guevara, 2020) and, in the most recent years, researchers have started to consider combinations of political, socio-economic and environmental aspects in decision-making (Beiragh et al., 2020) in both the production and service sectors (Aghazadeh Ardebili et al., 2020). Implementing this new concept of decision-making could be fruitful in parallel with the sustainability agenda. In April 2019, the American Geophysical Union proposed the topic "Resilient Decision-Making for a Riskier World" in a special issue regarding a case study of drought in Nicaragua (AGU100) and different metrics introduced in the published case studies for resilience (Béné & Doyen, 2018; McPhail et al., 2018).

In the last two decades, the new concept, "resilient engineering", became a pivot point in sustainable development (Hunt, 2009; Malkina-Pykh, 2002; Merad & Marcel, 2012) and infrastructure planning (Hansen & Neale, 2014; Nelson, 2018) related decisions. It is a crucial necessity to create and sustain a resilient infrastructure. For instance, in the pathway toward sustainability and resiliency, Sinha and Graf presented an open source database which includes basic information for water and wastewater pipeline infrastructure (Sinha & Graf, 2012). This database provides information on pipeline condition assessment, renewal, technologies and management practices and cost information. It shows the different information that has already been used in infrastructure design and management and the complexity of infrastructural systems. This fact stressed the importance of resiliency of infrastructure and related decisions. There are other examples that investigate the risk, resilience and sustainability of infrastructure lifecycle contexts (Y. Dong & Frangopol, 2015; Frangopol & Soliman, 2016); and in other cases the researchers took into account geotechnical information (Nikolaou et al., 2017), resilient structural material (MacKie et al., 2016), safety (Timashev, 2019) and even climate change for future infrastructural resilience (Espinet et al., 2017). These examples show the interdisciplinary and complexity of these decisions and the investigations reveal the importance of implementing resilient engineering and its prerequisites such as resilient decision-making. However, sustainable development and infrastructure related decisions are usually made by a group of decision makers, thus requiring further investigation on group decision-making processes.

Figure 6 shows that there are more than 4000 published articles associated with group decision, the largest part of which was issued in the last two decades. This testifies to the recent strong interest in this topic. More specifically, 84 articles regarded resilience and almost 700 articles considered sustainability. Notwithstanding these numbers, investigations on resilience and sustainability in the context of group decision are scarce. The next section provides a literature review on group decision-making and

in Section 3.3 attention is focused specifically on published research related to R&S GDM.

Group Decision-Making

The first studies on GDM were published in the late 1950s in psychology. Torrance addressed the importance of harmony, congeniality and agreement in group work and the effect of willingness of some members to disagree with other members of a group in decision-making (Paul Torrance, 1957). Then Ziller emphasized the characteristics of group decisions under uncertainty; for instance some members' reactions to the alternatives could be in contrast to the condition in which the leader alone makes the decision (Ziller, 1957). Group decision-making became a more popular topic in the 1960s (Moscovici & Zavalloni, 1969); researchers studied group decision-making under conditions of realistic complexity (Shure et al., 1963), combining statistical tools with GDM (Stone, 1963), GDM in the presence of risk (Bem et al., 1965) and the factors that impact the speed of GDM (Joslyn & Banta, 1966). Then in the early 1970s different methods were implemented in GDM, such as a modified version of the Delphi process (Rutherford et al., 1973), a Q-sorting psychometric method for classifying items (Helin & Souder, 1974) and Coleman's linear model (Blin, 1973).

The late 1980s and early 1990s were a transitional period in which the adoption of multi-criteria decision-making methods was investigated (Dyer & Forman, 1992; W. W.-L. Lee, 1982; Rao et al., 1988). From this point forward, many GDM studies were mainly focused on Multi-Criteria Decision-Making (MCDM) methods. Some authors have suggested extensions of existing methods like TOPSIS (C.-T. Chen, 2000; Shih et al., 2007), FMEA (Boral et al., 2020) and DEMATEL (Abdullah et al., 2019). More recently, an increasing inclination to use fuzzy MCDM is evident (Amin et al., 2019; Demircioğlu & Ulukan, 2020; Fahmi et al., 2019; Fahmi & Amin, 2019; Uztürk et al., 2020). The fuzzy approach takes into account the inherent ambiguity of human judgment and perception (Capuano et al., 2017; Kacprzyk, 1986). For instance, Uztürk et al. used multi-granular linguistic information because of the different degrees of knowledge between stakeholders who are the members of a decision-making group (Uztürk et al., 2020).

GDM requires discussion, negotiation and deliberation between the members of the group. Therefore, to reach an acceptable decision that reflects the sometimes conflicting opinions within the group, all members should ideally declare their preferences (Pérez et al., 2018). In several actual situations, some of the partners do not participate in the decision-making process directly. This could affect decision-making because some information could be crucial but the active participants could be unaware of it. Bourgeois defines Management Information System (MIS) as an information system used to support decision-making and coordinate,

control, analyze and visualize information in an organization, especially in a company (Bourgeois, 2018).

The potentials of information systems in aiding problem solving have already been studied and introduced under the concept of Group Decision Support Systems (GDSS) (McLeod & Schell, 2007). More recent studies have investigated the usage of MIS as an intelligent decision system that can support group decision-making (Turban et al., 2010). In general, research underlines the fact that information flow and storage is an important factor in decision-making. Nevertheless, it would be important to investigate more profoundly the role played by information in GDM and verify if it is one of the main factors that influence the resilience of group decisions.

Resilient and Sustainable Group Decision-Making (R&S GDM)

The selected 38 papers are here surveyed. The literature review presents the trend of publications, the subject areas of the published paper in R&S GDM, the methods that take into consideration the sustainability issues in GDM and the risks in the GDM process; finally, it identifies the main factors of effective GDM. An organized pattern will be discussed, which gives a new interpretation of existing GDM methods in light of sustainability and resilience.

General View on the Selected Articles

Putting the selected articles in chronological order discloses the sharp raise of the importance of the issue and the need of investigating GDM from multidisciplinary perspectives. Figure 7 shows the published articles by year. The first paper published in 2004 (Wilson, 2004) shows that GDM plays a role in improving the social pillar of sustainability. The subject area of this article is bio-cultural conservation and proposes some approaches that are useful for improving the efficacy of consultative processes within conservation programmes. Wilson focused on four main themes, "1) the purpose of the consultative group; 2) the nature and types of group membership; 3) the decision-making procedures within the group; and 4) the impact of location on group decisions" (Turban et al., 2010). He maintained that as long as consultation is approached in a philosophically honest way, producing ecological integrity and social justice will be possible. This was a reason behind considering group decision-making as a means of participation, in which the members of the group and the process of decision-making becomes a method to improve social factors of sustainability. Figure 7 depicts a slight increase from 2004 to 2017; however, the steep rise of the number of publications started in 2017 and, after that year, the quantity of publications doubled each year. This sharp increase shows the interest of researchers in GDM considering resilience and sustainability in the last decade.

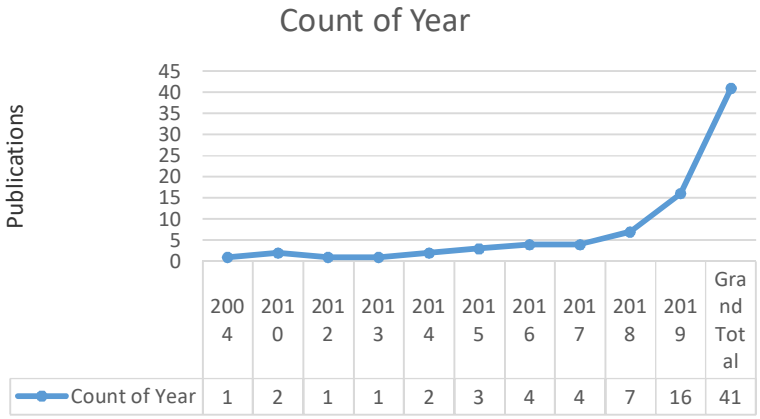


Figure 7 Selected publications in chronological order

In this study, we consider sustainability and resilience as two main categories and then classify the articles regarding the risk management methods and metrics that are associated with the sustainability pillars and resilience. Figure 7 shows the scope of the articles.

Table 11Scope of the articles.

Subject area	*Environment*	*Social*	*Economic*	*Resilience*	*Total*
Bio-cultural conservation		1			1
Building material selection	1				1
City planning	3	1	1	2	3
Consensus level in a group			1	1	2
Cost line	2	1	1	1	2
Culture		1		1	1
Development studies			1		1
Disaster management	2	2	1	1	3
E-commerce			2		2
Energy sector	1	1			1
Facility location	2		1		2
Information, data, cyber security		1		2	2
Infrastructure			1		1
Land use management		1			1
Organizational resilience				1	1
Partner selection			1	1	1
Resilient strategies	1			2	2
Safety	1		1		1
Satisfaction maximization of group members	1				1
Self confidence	1			1	1
Settlement resilience	2	2	1	2	2
Supply chain	2	4	3		4
Water supply and waste management	1	1			2
Grand total	20	16	15	15	38

Table 11 shows that the majority of the published work is associated with environmental issues (20 papers). The values in the last line of Table 11 show that the sustainability pillars and resilience concept have been

considered in supply chain, city planning and disaster management more than in other topics. In city planning, researchers mostly focused on sustainability of transportation in cities and emergency management including seismic risk mitigation and resilience in coastal cities. Moreover, Table 11 illustrates that in 48% of cases, the authors considered both the sustainability pillars and resilience in GDM.

Methods and Metrics

In 2019, Chen claimed that environment, natural resources, health and comfort of inhabitants are important criteria in the selection of building material (Z.-S. Chen et al., 2019); he developed a novel hybrid multi-criteria group decision-making model based on Quality Function Deployment (QFD) and ELECTRE III. The business simulation game is another method, employed by Phadoongsitthi et al. in 2017 in GDM, that discloses the effects of national culture on GDM (Phadoongsitthi et al., 2017). In this study, the authors remarked the existence of differences in the approach to cooperation among teams from Japan, China, Hong Kong and Thailand.

In 2019, Setiyowati et al. aimed to develop a Group Decision Support System (GDSS) to identify development priorities in six regions (Setiyowati et al., 2019). They combined two important factors that usually influence the regional development priorities and used a combination of GDM concepts: MVHAC cluster technique and the item-based cluster hybrid method. In the economic development sector, focused on E-commerce, two processes were introduced in 2019. First, Satisfaction maximization of group negotiation and deviation minimization of system coordination utilized by Yong et al. (Yong Liu et al., 2019) and second a "novel fuzzy group decision method, which not only integrates QFD and an improved version of technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) but also combines the qualitative analysis and quantitative analysis," introduced by Liu (A. Liu et al., 2019). However, Chen et al. used satisfaction maximization of group members in a different sector (Z. Chen et al., 2019). Looking for environmental benefits and competitive advantages, they proposed a hybrid model for evaluating the sustainable value requirement. The proposal is a combination of the fuzzy set, rough set, decision-making trial and evaluation laboratory and analytical network process methods.

Wu (2016) used traditional ELECTRE-III under an intuitionistic fuzzy environment to an offshore wind power station site selection in the energy sector (Wu et al., 2016). Qin et al. proposed TODIM, which handles information in the form of crisp numbers (Qin et al., 2017). Two years after TODIM, Tadić et al. (Tadić et al., 2019) conducted the most recent study on the selection of the most appropriate locations by a two-objective genetic algorithm (GA) and they claimed this is the most suitable method for the same routing issues. GA is a fruitful method to find the optimal solution;

and Arsovski et al. (Arsovski et al., 2015) also used a combination of the fuzzy group decision-making problem and GA. In this case, the authors calculated organizational resilience potential factors (ORPFs) relative importance first and then they used GA to find the near optimal enhancement of ORPFs' values. Arsovski et al. studied enhancement of organizational resilience towards 120 Small and Medium Enterprises (SMEs). The importance of resilient strategy selection is here crucial.

Besides Arsovski, three other articles used fuzzy multiple criteria decision-making for complex decision systems in strategy selection:

1. Fuzzy analytical hierarchy process (FAHP) with the aim to select the appropriate resilient strategy for seaport operations (John et al., 2014);
2. Triangular and trapezoidal linguistic data and fuzzy multiple criteria decision-making in strategic supplier selection (Haldar et al., 2014);
3. Combination of Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) and Ideal Solution (IF-TOPSIS) in order to partner selection (Büyüközkan & Güleryüz, 2016).

Another implication of TOPSIS is used for wastewater treatment plan selection by applying an intuitionistic fuzzy set and then ranking various plans (Zhou et al., 2018). Another more complex method, employed in the decision-making process to balance water supply–demand strategies used a novel three phase approach (Cambrainha & Fontana, 2018). The first phase is data collection; the second phase is problem structuring. They used the SODA method for problem structuring which includes surveying alternatives (supply and demand) and criteria; and then structured a model regarding the results of the survey. The third phase is the decision-making process using PROMETHEE II, integer linear programming (LIP) and sensitivity analysis.

The Analytical Hierarchy Process (AHP) is another popular method to support GDM. Mostofi Camare and Lane implemented AHP in a comprehensive resilience study (Mostofi Camare & Lane, 2015). They considered all pillars of sustainability including environmental, economic, social and cultural dimensions, aiming to estimate vulnerability, resilience and adaptive capacity measures associated with adaptation strategies in coastal communities.

Janssen is the only researcher that used an agent-based model in 2010 (ABM) in a population aggregation study (Janssen, 2010). He focused on an ancient settlement to study the long-term vulnerability of small-scale human societies. In this study, ABM was used to evaluate small-group decision-making on movements.

Risk Management

The project management body of knowledge (PMBOK) defines "risk" as an uncertain event which could have a positive or negative effect on the objectives (Rose, 2013). The importance of risk management in sustainability studies has been particularly highlighted in decisions associated with the transition to sustainability, where the effects of accepting some risks in this transition have been investigated (Ali Aghazadeh Ardebili et al., 2017). Martins and colleagues used MCDM in a group decision model in 2012 (Martins et al., 2012). They presented a model based on a geographic information system (GIS) to evaluate the social vulnerability to seismic risk. In their investigation, they recommend the integration of social vulnerability indexes into seismic risk mitigation policies. This integration of social indexes into risk mitigation policies was a novel approach.

Two papers investigated GDM in cost line area resilience. Levy in 2010 focused on cost line resilience and used Drama Theory II (DT II) (J. K. Levy, 2010). Levy upheld important characteristics of this method. He used this method because "DT II emphasizes that decision-makers engage in a rational-emotional process". Chen et al. introduced the new concept of group decision support systems as an emergency management support tool (Y. Chen et al., 2018). Licuanan et al. studied two issues in coastlines: Climate change and human activities (Licuanan et al., 2015). The main objective was to identify the consequences of these issues such as marine flooding and eROsion, besides identifying measures to minimize the impacts of these two issues on coastline areas. The tool introduced by this group in 2015 suggests engaging more stakeholders in participatory planning and group decision-making as this provides opportunities for learning about the issues. There are three articles on other subjects associated with disaster management (H. Li, 2018; Loos & Rogers, 2016; Nguyen et al., 2019).

The subjects are evacuation decision-making in wild fire, a risk-based emergency group decision method for haze disaster and flood adaption. Nguyen et al. in 2019 studied individual and group evacuation decision-making separately (Nguyen et al., 2019). On the other hand, Loos and Rogers in 2016 showed that utility functions can demonstrate the role of individual decision-maker values in decision outcomes (Loos & Rogers, 2016); however, they conclude that MCDM ensures that decision makers consider multiple benefit qualities of natural capital projects.

Another example of decisions made by individuals in joint objectives is decision-making in joint infrastructures. For example, development of joint irrigation as an infrastructure in agriculture industry increasingly depends on individual investment decisions of farmers. The "make" decision is

based on their current knowledge and understanding. However, researchers claim that it is ultimately a group decision (Nikkels et al., 2019).

Wilmer et al. in 2018 used a data oriented group decision in the land use management sector (Wilmer et al., 2018). They analyzed meeting transcripts, interviews and focus group data related to stakeholder group decision-making. However, in data oriented decision-making, data security is defined as a risk. To manage the risk of mis/disinformation, which influences the final decision, Nielsen et al. in 2019 suggested providing a mapping of how information affects the decision-making context (Nielsen et al., 2019). Another problem in group decision-making is information security. Regarding the study by Bharathi in 2017, data brokering, global exposure to personal data and lack of governance-based security design are the top three risk factors in this case (Bharathi, 2017).

In the supply chain sector, two articles have completely different focuses on sustainable supply chain management considering social and economic aspects. Both articles, published in 2019, show an increase of research interest in this sector regarding resilience and sustainability. Samani et al. studied a completely different supply chain network (Samani et al., 2019). This paper is focused on the blood supply chain network which is a crucial network associated with healthcare systems in society. This supply chain network has a great social impact and also its economic effect on society is important. In the proposed model the authors considered risk mitigation and used quantitative factors aiming to minimize the loss of product freshness and total cost of the network.

On the other hand, in a well-known topic of supply chain management, Bai et al. considered economic, environmental and social sustainability dimensions in supplier selection (Bai et al., 2019). The authors claim that social sustainability issues have received relatively minor investigations compared to the economic and environmental sustainability dimensions. They proposed a social sustainability decision framework in this article and provided a case study on the novel group decision-making approach, a grey-based multi-criteria decision-support tool composed of the 'best-worst method' (BWM) and TODIM.

Main factors

It is worth remarking that, in the reviewed literature, different authors name the key factors taken into consideration for evaluation or analysis purposes differently. The terms "index," "measure," "metric," "factor" or "indicator" are used and, in many cases, a clear distinction of meaning is not made in the paper. This fact required using the different terms as keywords in the systematic literature review.

Wilson in 2004 studied bio-cultural conservation and concluded that it is crucial to carry out a consultation in a philosophically honest and rigorous

fashion (Wilson, 2004). This means that "honesty" is an important factor in assessing the performance of decision-making. Honesty is a human moral characteristic and a social factor that plays an important role in a decision's success. Classical decision-making models do not incorporate the role and influence of honesty; in fact, only three papers were found in SCOPUS that study the effect of honesty in group decision-making: A significant gap in the research on this topic remains (Khalid & Beg, 2020; Tanford & Cox, 1988).

Marleau Donais in 2019 focused on the popular advocate "streets for everyone" in a workshop and introduced novel support decision-making (Marleau Donais et al., 2019); he also emphasized being transparent and improving communication of the outcome. The body of knowledge on the impact of human psychological behaviors in decision-making is not completely structured yet. The positive effects of "transparency" in environmental impact assessment, with the establishment of explicit goals in decision-making in committees, the effectiveness of dialogues and communications at all levels and the increasing capabilities for communicative actions have been already discussed (G. Levy, 2007; Morrison-Saunders & Bailey, 2000; Wene & Espejo, 1999). Thus, transparency can be considered another meaningful factor of R&S GDM.

Liu et al. in 2019 considered "self-confidence" as a component of human psychological behavior (X. Liu et al., 2019). They applies this new index to the environmental pollution emergency management decision-making. They implemented self-confident fuzzy preference relations to express the experts' evaluations and, in a case study, they designed a self-confidence score function. The case study aimed to identify the best solution for environmental pollution emergency management; but the authors concluded that the proposed method is feasible and effective in general. In general, self-confidence is an individual's subjective evaluation of their own worth (C. R. Snyder & Lopez, 2009). This positive or negative evaluation of the self is interrelated with concepts of self-efficacy and an individual's beliefs about their capacity to influence the events (Bandura, 1977). This concept is also crucial between group decision members because it affects the final decision of each member (Hoffman & Elwin, 2004).

Two articles in 2019 studied the behavioural characteristics that exist in group decision-making. Tang et al. (Tang et al., 2019) and Liu et al. (Yong Liu et al., 2019) considered the consensus level of the group members as an important index in GDM. The five-step process for decision-making that Tang et al. presented is as follows:

Obtaining ordinal preferences;

Classifying all decision-makers into several subgroups using the ordinal k-means clustering algorithm;

Measuring consensus levels of subgroups and the global group using novel ordinal consensus indexes;

Providing suggestions for decision-makers to revise preferences using feedback strategies;

Obtaining final decision results.

Altogether, having a shared opinion, among the members of a decision group, about the problems at stake enables the group to reach their goals; consensus level can then be considered another key factor of R&S GDM.

Tadic et al. in 2017 studied environmental protection and seaport safety considering competitive advantage and long-term sustainability (Tadic et al., 2017). They proposed a modified fuzzy extended analytic hierarchy process and finally concluded future improvement lay on benchmark and knowledge sharing. Knowledge sharing could be defined as an index that measures the information flow between the decision makers in a group and its influence on the decision-making performance. There are two important aspect regarding this factor. The first aspect is the sensation of the group members; in a group of decision makers, DMs' sense of group identity and personal responsibility lead the members to share their knowledge and experience (Cabrera & Cabrera, 2002). The second aspect is the channel of knowledge exchange. Modern information and telecommunication technology is available to support such exchanges acROss time and distance barriers (McNurlin & Sprague, 2001). In short, the exchange of information among decision makers is a vital component of the knowledge-management process in group decisions and knowledge sharing is an important factor of R&S GDM.

Supply chain sustainability management is rather new but very popular among researchers and there are still many gaps in the literature and methods. Osiro et al. in 2018 implemented a new metric to fill the gap of considering the degree of difficulty of collecting data in supply chain studies (Osiro et al., 2018). They proposed a combination of techniques—Hesitant Fuzzy Linguistic Term Sets (HFLTS) and QFD—with the aim of providing a group decision model in supply chain sustainability management for selecting metrics. In brief, the evaluation based on a range of linguistic expressions regarding data collection and its difficulties (information availability, human resource, time required and other resources) led to a better representation of judgments. Therefore, degree of difficulty of data collection is another factor of the R&S GDM.

In a different sector, Pishdar et al. studied the Internet of things and its challenges in supply chain management in 2015 (Pishdar et al., 2018). They used rough group decision-making and trial evaluation laboratory (DEMATEL) and finally provided a group of suggestions for managers.

This paper suggests security policies and emphasizes the importance of security risk assessment. This result is significant and shows that data security level could be an index in group decision-making. Data security means safeguarding digital data from destructive forces, unwanted actions of unauthorized users and unauthorized disclosure of confidential information (Summers & Koehne, 2004). In effect, data security considerations including data storage location, access and modifications regarding the information that is used in the group decision processes of a company influence the performance of final decisions.

In conclusion, a closer look at the identified factors shows that they are attributes of the group decision-making activity, not criteria hat are used in the decision process. The seven key factors, identified in the literature as the main attributes of R&S GDM, are honesty, proper self-confidence level, transparency, communication and knowledge sharing, degree of difficulty of collecting data, data security and consensus. In the next section the results of the case study are reported.

2.2.4. CASE STUDY

Case Study Foundation

This case was selected as it well represents a situation where the main decisions should have been made in a joint decision-making process involving all partners. A group was responsible for administering and managing the company, but there was no management information system to share the information between the decision makers. The decisions, which had the highest impacts on the bankruptcy of the company, were taken in absence of one of the partners.

The main goal of the case study here is to investigate the potential reasons of the failure of the group decision-making and the effect of the identified factors, discussed in the previous section, on group decisions in a small company and the issues which caused the failure in this production company. Often, senior managers are responsible for high impact decisions, which sometimes should be taken even if one of the key decision makers is not available, as in the case study.

Ineffective Decisions

The analysis of the key decisions taken by the company suggests a classification of the ineffective decisions into three main categories: Poor decisions in procurement, human resource management (HRM) and contracts with third parties (Table 12). The reasons of ineffective decisions are ranked according to the respondents and illustrated in Table 13.

Table 12 Ineffective decisions.

Categories	*Decisions*
procurement	1. Purchase of inappropriate injection moulds
	2. Purchase of low-quality raw material
HRM	1. Poor HRM
contracts	1. Presell contracts
	2. Rental contracts (rent the machines to the other companies)
	3. Provide and sign poor contracts in terms of the text of the contract, content, and concept (from the professional and legal point of view)

Table 13 Reasons for ineffective decisions and ranking.

Ineffective Decisions.	Reasons													
	Mental Shortcuts	Being Too	Poor Comparison	Information Flow	Attentional Bias	Unintentional	Bandwagon Effect	Gambler's Fallacy	IKEA Effect On	Hindsight Bias	Uncertainty	External Influence	Decision-Making	Ranking Of The
Procurement		√		√	√		√	√	≺	√			√	2
HRM	√		√	√										3
Contract		√		√	√		√	√	≺	√			√	1
Ranking Of The Reasons	6	1	#	2	3	#	7	8	9	4	#	#	5	

* The bandwagon effect is a psychological phenomenon in which people do something primarily because other people are doing it. ** If something happens more frequently than normal during a given period, it will happen less frequently in the future. *** The IKEA effect is a cognitive bias. **** DMs overestimate their ability to have predicted an outcome that could not possibly have been predicted. # Regarding the respondents, these reasons had no effect (or neglectable) on the Ineffectiveness of the GD in the case company.

2.2.5. DISCUSSION

The technical details in procurement are very important because a wrong purchase could impose dramatically negative outcomes. In small companies, quality control is more under the responsibility of an individual than a department, and the role of the technical experts is crucial in decision-making both before purchase, to ensure a complete list of requirements, and also after the purchase, to control the quality of the purchased items. In the specific case, wrong procurement of the moulds not only caused extra cost in terms of the price of the moulds, which was above the market price, but also some indirect costs, in particular related to the replacement of wrong moulds and double logistic operations.

Supply chain management is another key point and could affect the efficiency of the company during production and costs. In this company, just one of the partners (a member of the decision group) was familiar with the reliable channels of the supply of the raw material. In fact, wrong purchases were one of the principal mistakes, made in the absence of the other partners.

In small companies, human resources are possibly the most important factor for reaching efficiency in production. Poor HR management is irrecoverable. Not only all physical activities in production lines depend on human resources, but human resource management also affects production planning because decision makers consider the available manpower and skills before making decisions about increasing or decreasing the production in a specific period. Especially when technical skills are important, the absence of an expert or poor task assignment to the workers could decrease efficiency. In this company, one of the managers was not familiar with the skills and potential of the personnel. Consequently, when other partners were not in the company for long periods, he made poor decisions about task assignment to the available human resources.

Presell contracts need production planning. In small companies, production capacity is limited and usually difficult to increase in the short-term. Since the main products of the company are plastic containers for agricultural produce (fruits and vegetables), the demand is subject to seasonality. One of the poor decisions was to presell contracts in high seasons and overload the production line to produce more and compensate the production amount and contracts. However, over-production could damage the machines and moulds. This could result in extra costs for the overhaul of moulds and maintenance of machines. Because of this, presell contracts put the production under pressure and ended in serious damage to the machinery and equipment of the production line. This overload resulted in discontinuous production and, after a while, the company lost customers and long-term contracts. Meanwhile, renting the injection-moulding machines or moulds to other production companies could have the same impact with overloading the production line. To sum up, making wrong contracts and overloading the production lines call forth unforeseen major overhaul, extra maintenance cost and loss of market share. Last but yet important, writing and signing a contract raise legal responsibility. Therefore, they need special skills to provide a proper contract in terms of the text of the contract, content and concept (both from a professional and legal point of view).

Table 13 shows that cognitive bias is the most important reason of decision failures. Moreover, Bandwagon Effect has high rank, which means that also the rate of uptake personal beliefs and ideas increases the more in individuals that they have already been adopted by other members of the

group. Some members made decisions primarily because other companies were doing it without considering the differences between the companies. On the other hand, high rank of Gambler's Fallacy and Decision-Making Methods depict the members made decisions without considering future uncertainty. As for the case study, beside Attentional Bias, a major cause of inadequate decisions was "over self-confidence:" one of the decision group members based his decisions only on personal inference from the past events; indeed, he did not communicate with the others to collect the information that would have been useful to support the final decisions.

In small companies, each member of the decision-making group plays a crucial role. Serious problems could ascend if one of the members take a day off or take break for a period for emergency reasons, unless the other members of decision group have clear information about his/her role and how they can fill the gap when he/she is not present. Especially in decision-making, all members of the management group have significant experience, information or skills, and their absence in the decision-making process could cause fundamental problems in production, planning and management. In this situation, an integrated management information system seems necessary to avoid any problematic decision in absence of one of the members. The main goal of using a management information system in this case is to avoid mistakes and subsequently to increase the value and profits of the business. Table 12 illustrates the reasons of the poor decisions which had been made by one of the members of the decision group. Grey boxes show the reasons that are associated with each poor decision in first column. Being too optimistic is a personal characteristics of the decision maker, which affects only two of the poor decision categories. In summary, the most important reason is possibly the information flow between decision makers, which influences all categories of poor decisions. This fact emphasizes the necessity of an information system in this situation to avoid them.

2.2.6. MANAGERIAL IMPLICATION

Group decision-making presents some specific features that must be considered; in particular, the decision cannot be attributable to any single individual but it is a result of the knowledge produced by and opinions of all the participants. In order to acquire information, useful to support decision-making, process it and, finally, take a decision, the participants may use MCDM methods to evaluate options against a set of evaluation criteria. It is worth remarking that the identified seven factors, highlighted in Section 3.3.4 (Honesty, Proper self-Confidence level, Transparency, Communication and Knowledge sharing, Degree of difficulty of collecting data, Data security and Consensus), are reported in the examined literature as indexes, metrics, measures or indicators of successful group decision-making, not as criteria to be employed in MCDM methods. Therefore, they

can be interpreted as attributes of R&S GDM: a R&S GDM process is then a GDM process that embodies them. In summary, R&S GDM is a specific type of GDM whereall the members of the decision group, by considering the seven factors, aim to make GDM sustainable and resilient. a:.

All of the members of the decision group should contribute to the above mentioned seven factors and, in this respect, the figure of a group leader plays a crucial role. It has been observed that people management skills and team work are two key managerial competences (Rajadhyaksha, 2005). As a result, providing the appropriate milieu for the members of the decision group is an important role of leaders. Specifically, those who emerge as being very good leaders often have important qualities in preparing the prerequisites of team work and also group decision. In addition, the leader should possess a strong understanding of the company's products/services, processes, goals and the group decision members to be able to put into practice the attributes of R&S GDM. This fact introduces a new role of the leader: To inspire, motivate, mentor and direct the decision group members to enable the seven factors of R&S GDM.

Another measure enabling R&S GDM is empowerment. It has been already proven that employee empowerment enhances employee performance (Fernandez & Moldogaziev, 2011; Meyerson & Dewettinck, 2012). Menon developed an integrative psychological approach for employee improvement (Menon, 2001); on the other hand, individual empowerment increases team performance (Fernandez & Moldogaziev, 2011; Mathieu et al., 2006; Menon, 2001; Yang & Choi, 2009). Current study highlights that decision-making group member empowerment would be a necessity to reach resilience in group decisions. As a result, sustainable and effective group decisions need a novel empowerment context, which is "Decision Makers Empowerment," aiming to increase the group decision effectiveness by improving the seven factors in decision group members.

General consensus among all members of a decision group is often unachievable in practice; however, various methods have been introduced in order to arrive at consensus in a group. The traditional method is removing the outliers: The group members with very different opinions are removed. This might possibly result in the loss of some precious ideas and in an impact on the sense of belonging in the organization. The results of the present study specifically suggest that the traditional method inversely affects the resilience of the group decision: Removing a member from a group in a specific decision can cut the information flow, weaken the knowledge sharing factor and influence the self-esteem of the member. A different method to reach consensus, without negatively affecting R&S GDM, is eliminating the outlier opinions, instead of the member of the decision-making group, in three steps: The consistency checking process, the consensus reaching process and the selection process (Liao et al., 2016).

Other authors suggest that considering the decision-making group as a social network could enhance the consensus level (Herrera-Viedma et al., 2017). Some consensus degree models have been introduced that could be fruitful to monitor and measure the consensus level and reach the maximum consensus (Fedrizzi & Kacprzyk, 1988; Herrera et al., 1996; Kaeprzzyk, 1988).

Finally, it must be noted that the factor "communication and knowledge sharing" includes two concepts that are related with information flow between the group members. The information system and information fluidity then play an important role in R&S GDM. In this respect, the measurement of the MIS effectiveness and level of information fluidity could be indicators of the resilience and sustainability of GDM in the organization and help a possible transition of actual GDM processes towards R&S GDM.

The empirical analysis of the role played by the seven factors in actual decision-making processes is an avenue of research that is required to confirm their benefits for producing more sustainable and resilient decisions. This would also suggest improvements in the organizational management of the operational and functional levels of the companies.

2.2.7. FUTURE SCOPE OF STUDY AND LIMITATION

The present study was conducted in two stages. In the first stage, a systematic review was implemented to identify the most effective factors of the R&S GDM . Evidently this is a significant gap in this subject area; however, the related studies are increasing sharply and another systematic review could be a future work to investigate "if new factors will be appended to the results of this list in future". The second stage was a case study. The main limit of this stage was the size of the company and the location of the case company. This company was a small enterprise production company located in a developing country. The general validity of the outcomes of the study is therefore debatable. Confirmations of the results could only come from further case studies, particularly concerning larger decision groups, bigger companies and other countries.

2.2.8. CONCLUSION

The systematic review of the scientific literature shows a lack in the resilience and/or sustainability of GDM with only 38 published papers. On the other hand, the body of knowledge on resilient decision-making is also still ambiguous. The main factors that have significant impact on sustainable and resilient GDM are as follow:

1. Honesty

2. Self-confidence
3. Transparency
4. Communication and knowledge sharing.
5. Degree of difficulty of collecting data
6. Data security
7. Consensus

The systematic process for the literature survey, introduced and implemented in this paper, could be a systematic model for similar studies aiming to extract information from the literature and structure it by defining the key aspects.

A closer look at Tables 12 and 13 and the results shows that over self-confidence in the members of a group leads the decisions to failure. The case study (Table 13) points out that communication problems and knowledge sharing were obvious in all three classes of problematic decisions (Table 11). Weak information flow raised the lack of resilience in group decision-making; as a result, misaligned decisions in the partnership situation in that company were the main reason for the failure. Regarding this failure, weak information flow causes misaligned decisions. Information flow plays a crucial rule on R&S GDM and the level of fluidity of information could be a performance index for a group decision. However, information flow was not the only problem of the communication between the members, the interviews unveiled that lack of transparency in the existing communications was another significant problem in the decision-making process of this company. Lack of transparency is a problem, but in some decisions, this issue can compound the problem of information flow too.

Last but yet important, in the case study we could not find any evidence of the R&S GDM factors in the principal decision-making activity of the company: Ignoring the attributes of resilience and sustainability in group decision-making could result in ineffective decisions and consequently in the failure of the enterprise.

3 Methodology

This section is a systematic explanation of the novel ROs analysis method (ROAM). The method is already presented in three doctoral workshops (Aghazadeh Ardebili, 2018a, 2018b, 2019). The contents of this section and is going to be submitted as an article to IJAHP as an extracted article from the Ph.D. research and final thesis. The examples that are used to elaborate on the new terms are adopted from the case study that is published in the proceeding of the 7th international conference of production engineering and management (Ali Aghazadeh Ardebili et al., 2017).

3.1 INTRODUCTION

A "project" may be considered as an organized network of activities aimed at achieving a set of goals. Projects are common in the industrial and service sectors. During the lifecycle of projects, some unanticipated events could happen because of internal and external changes in the projects. Therefore, important deviations from the objectives may derive from uncertain future events, which can have positive or negative effects concerning the objectives during the project life-cycle (C. Snyder, 2013). Usually, those events with pure negative effects are anticipated, where possible, in order to avoid, mitigate, or transfer their outcomes. On the other hand, some uncertain events can be associated with threats, but they might concurrently include some opportunities and benefits for the project; As already reported, these events will be called 'risky-opportunities' (ROs) in this paper. Finding a way to take maximum advantage of future uncertainty and risky opportunities is the main motive of this study. In this respect, the question is: "is it possible to take advantage of the positive effects of a RO, but at the same time avoid the negative effects of that event?" Stakeholders aim to take any existing opportunity that a project opens up. Nevertheless, there is a gap in the existing quantitative methods of risk management to consider the threats, the available resources, and gain the positive effects of risky opportunities.

In this research, a feasible method, supported by a specific procedure, has been designed with the aim to accept ROs. The new method could help the

project managers to select which are the best ROs to accept. Then, according to their positive and negative effects, it specifies the necessary actions that must be taken, spending a specific amount of the available resources, to avoid the existing threats in the chosen ROs. The new method is based on the concept of 'risk acceptance' in order to gain opportunities, which makes it different from traditional methods of risk management. The concept of risk acceptance requires a new metric: this is called 'risk-taking capability.' it is obviously different from the existing comprehensive terms 'risk tolerance' and 'risk resilience.' Traditionally, the concept of risk tolerance is used to analyze the capability of a company or project to take the risk according to the existing resources (Fredman, 1996) and investigations have been done to identify the impacts of variables and individual characteristics on risk tolerance (Sung & Hanna, 1997). Conversely, risk-taking capability evaluates the opportunities according to their risks. This study concerning the risk management within project level and the project level RO. In the next section, the literature review discusses the existing risk management models.

3.2 Risk and resource consumption evolution in decision science

In the introduction section, risky-opportunities were defined and the new method was suggested as a solution to have a different view on opportunity management and resource allocation. The survey in chapter 2 proves the importance of carrying out a study on risky opportunities and resource allocation which are lacking. Hetrick Stressed the need for a screening definition of an opportunity and he used the Monte Carlo method and the balancing of risk on different projects (Hetrick, 1969). Some studies emphasize the need of using the positive effects of uncertainty and there are case studies that focused on opportunity management besides the risks (Peker et al., 2016; Thomas L. Saaty, 2015; Wiratanaya et al., 2015). In particular, Hillson, Olsson, and Ivascu et al. Investigated a kind of opportunity that could provide superiority for companies or projects and are associated with different levels of threats. Therefore, it seems that academics are inclined to illustrate the importance of both threats and opportunities(D. Hillson, 2003; Ivascu & Cioca, 2014; Olsson, 2007).

Nevertheless, risk-taking is not a new concept. Research on risk-taking has been started in 1944 by a study on proportional income taxation (Domar & Musgrave, 1944) then in 1965 individual risk-taking (Lefcourt, 1965) and in the 1970 group risk-taking studied by researchers (Teger et al., 1970). In a personal level, who believes in his competence in decision making, sees more opportunities in future uncertainty (Krueger & Dickson, 1994) however in management level, it is a necessity to see both sides, so, a strong project manager should involve the effective management of risk considering both threat and opportunity (Steed, 2000), and in general

uncertainty management in projects should include risk management and opportunity management (Chapman & Ward, 1996).

The existing literature unveils the importance of resource consumption along with risk-taking. From decision-making lens, in a structured management decision environment, resource allocation is very important. The first research on resource allocation decision in a risky environment, was conducted at Victoria hospital in 1975 and published in 1979(Kirudja, 1978). But nowadays, resource allocation is an inseparable analysis that comes along with uncertainty studies and risk management such as risk-based surveillance (Alban et al., 2020), resilience-based studies (Lenjani et al., 2020), safety (Vamvakas et al., 2019), healthcare (Grant et al., 2019), etc. Even the two highest cited articles which considered resource consumption in a risky environment are in the cloud-computing subject area (Buyya et al., 2009, 2008). This is a significant clue that illustrates the importance of resource consumption management in risk management.

From the risk management methodological point of view, one of the most important methods, which is supporting the analysis of opportunity and threat, is the BOCR approach (Thomas L. Saaty, 2001). BOCR allows to consider all aspects of the projects including the risks, opportunities, costs, and benefits, which are evaluated through the analytic network process (ANP) to identify the best project or portfolio (Mohammadi et al., 2015; Tchangani, 2015; Wijnmalen, 2007) However, this approach has been criticized by some scholars. For instance, B/(C∗R) is criticized because some researchers believe "the product of costs and risks is not meaningful" (Millet & Wedley, 2002)or "opportunity and risk priorities could be regarded as probabilities" (Wijnmalen, 2007).

On the other hand, resource allocation is a problem that needs a quantitative evaluation to make the most effective decision. Several multi-criteria decision-making (MCDM) tools have been employed to this end (Y. Li et al., 2016; Ramanathan & Ganesh, 1995; Thomas L. Saaty, 2008; Thomas L. Saaty & Vargas, 2013; Tulasi & Rao, 2015). In the same avenue, the method proposed here is based on MCDM to evaluate the risk-taking capability of a company, with the aim of risk acceptance to seize the opportunity and specify the quantity of resources needed to take any RO at a project level. In the following sections, the methodology will be explained. The highlights and the practical aspects of the method will be explained by utilizing a case study concerning the subcontract for the construction of a reheating furnace in a project of a Hot Rolling Mill Plant. This case study was published in 2017 and explains the risks of an outsourced job in a project, which includes the engineering, procurement, and construction phases (EPC Project) (Aghazadeh Ardebili et al., 2017). In that project, the installation of the furnace was outsourced, nevertheless, because of the sub-contractor incompetence, the erection of the furnace stopped and the project failed to

continue. It was necessary to take new measures done to solve the problems. It was necessary to make a risky decision because the existing options came along with uncertainty. All of the alternative solutions to finish the project erection was associated with some threats, however, there was a necessity of taking some risks. In the next section, a novel quantitative method to support such risky decisions will be explained in detail.

3.3 MATERIALS AND METHODS

3.3.1 ICT Tools

The software and ICT tools that are used to create the material in the current article are as follows:

- Micrsoft Excel is used as the spreadsheet to calculate the Strain in Table 15.
- The graphical material and the figures are made by Microsoft Word.
- Zotero is an open-source reference management software which in the current article is used to manage the citations and create bibliographic data in this article (George Mason University & George Mason University, n.d.).
- SuperDecisions that is a decision support software, are used for create and analyzing the network. This software implements AHP and ANP for combining judgment and data to effectively rank options and predict outcomes (Adams et al., n.d.).

3.3.2 Terminology and definitions in the new method

This section aims to clarify the key terminology and understandings. First of all, it should be reaffirmed that some terms are used based on accepted definitions in previous literature including project, risk management, risk management plan, and its 4 steps. However, RO is in no way meant to an uncertain event with pure threats or an uncertain event with pure opportunities. In this study, this descriptor is a novel concept for this kind of uncertain events, and it was selected as it is necessary to have a clear and different definition for this group of future events in this method to high light the risk acceptance chance for this group. ROs are future uncertain events that can have both positive and negative effects on the project objectives at the same time. It depends on the nature of the event and the project that they may have positive effects on some goals and negative effects on others, or they may have positive or negative effects in different times during the project lifecycle.

The term "goals" throughout this study, are categorized into two types. There are two kinds of goals within the new risk management plan. In a Project, a group of activities are planned and undertaken aim to achieve the main goals; therefore, main goals are are associated with the outcomes of

the main project and they are related to the primary objectives. In general, the risk management plan is followed to control future uncertain events in order to avoid any deviation from the main goals. The secondary goals include the objectives that decision-maker wants to achieve by accepting the risks of a RO within the main project. This group of objectives should be in parallel with the main project objectives. To be brief, it consists of the objectives of the necessity of making a new decision, that was not normally a part of the main project plan, but it is going to be done for achieving some opportunities. For instance, considering the reheating furnace construction project, the existing contractor company failed to accomplish the project and fulfill its responsibilities. The objectives, in this case, could continue the blocked and failed project with existing contractor. The first option is to continue with that company and find some ways to restart again. Since the contractor cannot meet the primary objectives of the project and failed, the client needed a failure strategies to restart the project and finish it. However, there are other options also that they are a bit riskier but if the client can tackle the threats, new options could be more effective than continue the job with the existing company. One of the new objectives could be "repairing the mistakes that the last contractor made during their activities". Repairing the faults were not included the main project objectives.

Risk response is used to refer to the strategy whereby decision-makers plan to deal with each risk. There are four kinds of risk responses avoid, mitigate, transfer, and accept. However in this study, (shown in Figure 9/step 3) two of the risk response strategies were considered in general because of two reasons. First, the risks that could be transferred to third-party are already delivered and the activities that can be done without risk by a specific contractor are already outsourced. Second, the mitigation and measures to increase the project resilience regarding the pure threats are already taken.

By using the term pure threats of an RO, we take the position of the disadvantages of the RO, which cause the possible deviations from the objectives associated with each alternative way of accepting the RO. Although, pure opportunities of an RO are the pure benefits of accepting the risk of RO. The main secondary goal in this method is taking advantage of RO by achieving these opportunities.

Alternatives are the different measures that are feasible approaches to be taken in order to accept the risk. For each alternative, the weights of RO is calculated employing the ANP. Weights of the elements inside a cluster are local weights that resulted from pairwise comparing such elements inside the cluster.

We define Stress as a concept that is an index to show the relative importance of opportunities and benefits of an alternative to accepting an RO to the threats and cost of it. Mathematically stress compares the sum of the values of the weight of all threats and costs, belong an alternative with

the sum of the weight of opportunities and benefits of that. These weights will be calculated by ANP in Figure 9/step 5. The major differences of this term with risk, threat and hazard is that Stress is based on the concept of risk acceptance.

Stress changes if any change happens in one of the tasks during the project lifecycle. This makes the index dynamic and, as it is a parameter dependent on other elements, it is different from the traditional static concept of risk. Stress will also change if the amount of resource consumption for the alternatives changes.

Resources are the available sources that are employed to make the changes, following the alternatives to take advantage of ROs. Resources may include human resources, budget, assets, material resources and consumables, and time.

Basic consumption stands for the sum of the values of all different resources, which are required to be used to take the measures of the cheapest alternative with the aim to make a change in the project and accept the RO.

Strain is a ratio of the amount of resource consumption to Basic consumption. The strain will be calculated using formula 2 -which will be explained in detail in section 3.4-.

3.3.3 General methodology and the novelty

In this section, in addition to generally introducing this method, the differences in this method with the other approaches will be included. To briefly introduce this method, at first, it aims to accept a risk to take the embedded advantage of uncertainty behind a specific future RO which is already different from all of the existing risk management tools (RMT). There are different RMT used by practitioners and researchers. A class of the traditional RMT, -for instance risk register (Patterson & Neailey, 2002), or MCDM with considering the risk as a negative criterion (Amirshenava & Osanloo, 2018; Chatterjee et al., 2018; Kabak & Dağdeviren, 2014)- try to prioritize the risk response strategies to avoid the risks and suffer less from the negative impact but gain more, however, this method aims to analysis alternative ways to make a change and just benefit the positive impacts. Another class of the RMT just helps the decision-maker to get the idea of the probability of occurrence, accuracy, and severity of impact, and quality of the risk; for instance probability-impact matrix (Aghazadeh Ardebili et al., 2018), and risk data quality assessment(H. Chen et al., 2014); however, this group is not quantitative approach to support the decision maker. The last group of RMT are qualitative methods like brainstorming (Masár et al., 2019), root cause analysis (Cerniglia-Lowensen, 2015), and SWOT (Rauch, 2017) that try to draw an image of the risk and company itself in case of facing the risk; this group could be useful also during this method and could be integrated with the new method.

Therefore, first the ROs are identified and then different ways to eliminate the negative effects while keeping opportunities will be listed. The primary step is to see what the alternative ways to accept an RO. Then, calculate the amount of resource consumption for different ways of accepting an RO. And illustrate both the negative and positive impact of each alternative way using the stress index. Finally the outcome of the method will show how the stress changes with resource consumption that are used by different alternatives of an RO. The result provide a decision making tools that decision maker can compare the sensitivity of the resource consumption on decreasing the stress. Regarding the complexity of the process, this method is a suitable decision support tool in project management level and not for the shop level risk management.

3.3.4 Characteristics of the new method

A project includes a group of activities aim to achieve a particular goal. It could be carried out individually or collaboratively. However, carrying any activity, rely on consuming some resources. These include the project budget and the stock or limited supply of materials, equipment, staff, and other assets that can be used to execute the works during the project. The available resources of a project are limited and controlling the amount of resource consumption is a crucial part of project management. Planning could foresee the development of the activities; nevertheless, future events during the project lifecycle are uncertain, and consequently, uncertain future causes risks. The uncertainty could rise threats in achieving the goals or positive effects on it; so, the project managers take decisions regarding such events to avoid any deviation from predefined goals in the project. The most known risk in projects is natural disasters and if it happens, even if there are no damages, it may impact the schedule and the end of the project. This delay is a pure threat and a deviation from one of the main objectives. Conversely, there are many opportunities in any project associated with some threats and, to get the opportunity, some changes should be considered to become tolerant in front of risks. These opportunities are also uncertain and may have positive effects on achieving the primary goals of the project. An example is using new technology or equipment to perform a work package of the project, which was originally planned to be executed by traditional means. Using the new equipment could increase the accuracy and speed but acquiring the tool would increase the project costs. Moreover, using the new tool in a project could raise some new risks regarding utilizing the new tool by personnel, human error, maintenance of the tool, etc. It could be concluded that this kind of opportunity is connected to some threats.

The new concept of risky-opportunity is referring to this class of risks: risky opportunities (ROs) are not pure opportunities, but opportunities associated with some threats. If the threatening aspects of the RO are

defined and eliminated, it will be possible to gain the opportunity without deviations from the project goals; to this aim, some measures should be adopted to introduce changes and make the project, risk-tolerant. However, any change in a project needs to consume resources; this resource consumption allows the project manager to accept the risk of ROs. Due to the limitation of available resources, there is a need to identify the relations between the positive outcomes produced by 'risk acceptance' and resource consumption. The present study aims to quantify the relation between risk acceptance and resource consumption to design a dynamic method that is usable during the whole project life cycle.

Figure 8 depicts the aim of the changes is to move the boundaries of acceptance and avoiding the risks and bring the position of a risky opportunity inside the acceptance area. To this aim two new parameters will be used including stress and strain which will be explained in detail in section 3.3.

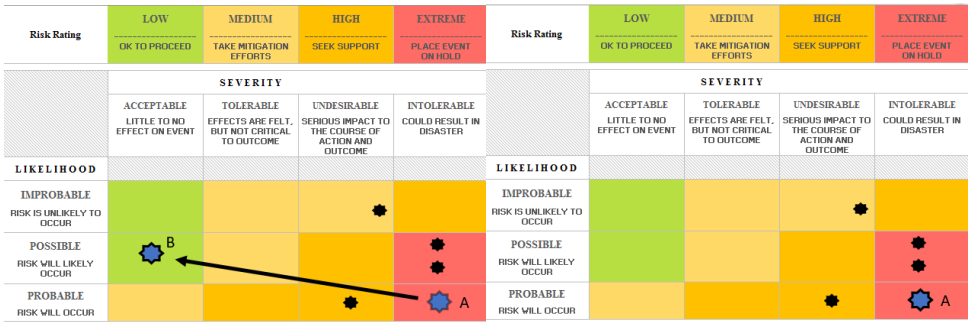


Figure 8 position of different RO regarding the probability of occurrence and the severity of impact [1]

The probability-impact scheme was imported from the risk identification phase. This matrix is a significant qualitative illustration and an important part of the risk management plan. After finding the ROs, it is necessary to analyze the existing probability and impact. This step helps to compare them. For instance, RO_a in the right scheme in Figure 8, has a high impact and high probability of occurrence. If the important pure threats of RO_a are eliminated, the new position of the event will be RO_b. Even RO_b may need some small changes to eliminate all of the threats; however, the matrix shows that the impact of threats is acceptable and their probability is low, therefore it is ok to proceed and accept the risk because RO is in a green position. In the green position, more resource consumption seems unnecessary.

In some cases, small changes in a project make a big effect and this matrix does not show the result. it means that the probability-impact matrix is not

[1] https://www.smartsheet.com/all-risk-assessment-matrix-templates-you-need

an effective tool to make the final decision about the ROs. take some measures can change the resilience of the project and acceptance borders in the probability-impact matrix for the specific RO; nevertheless, these mesures do not influence the condition of the other ROs. The left matrix in Figure 8 image the situation after making changes and moving the border. In this case, the company becomes tolerant in the face of threats associated with RO. It will take only advantages of the opportunities that come along with accepting new RO. Another weakness of the probability-impact matrix in the risk acceptance process is unveiled here: when a specific RO is changed, the other ROs stay in the same position, and this can be confusing.

The existing risk management methods are static and limited to evaluate the situation after taking a specific measure. Conversely, in the proposed method, there are many alternatives and the aim is to define the most effective alternative in terms of resource consumption to take the risk so a dynamic approach is employed to show the result of making different changes in the project.

3.3.5 Integrating new method with 4 step risk management plan

Risk management is a process that typically includes 4 main steps Identification, Assessment, Response and Monitor in which, the steps pursued continuously as a cycle during the project lifecycle (Conroy & Soltan, 1998). However, most of the scholars and practitioners prefer to customize the general "4-step risk management plan" to initiate and plan the risk management approach with further detailed steps(Burnaby & Hass, 2009; Mazăreanu, 2011; Ward & Chapman, 2008).

The flowchart in Figure 9 is an illustration of the cutting edge logical flow of the new method within the general 4 step model of risk management. This flowchart shows methodically brocken the action plan of complex processes down into manageable steps. In the new approach that contains the ROAM steps, the project starts with identifying the scope and then project planning the classic risk management model, which is shown inside the green box. The new method begins from the first step of the classical risk management plan after risk identification. Defining risky-opportunities is triggered by the opportunities that are identified according to project scope and objectives. Then, different alternative ways to tackle the problem of the threats and gain only the opportunities of RO is identified. Another significant difference of this method with other risk management methods is that they do not consider changes and resource consumption for changes.

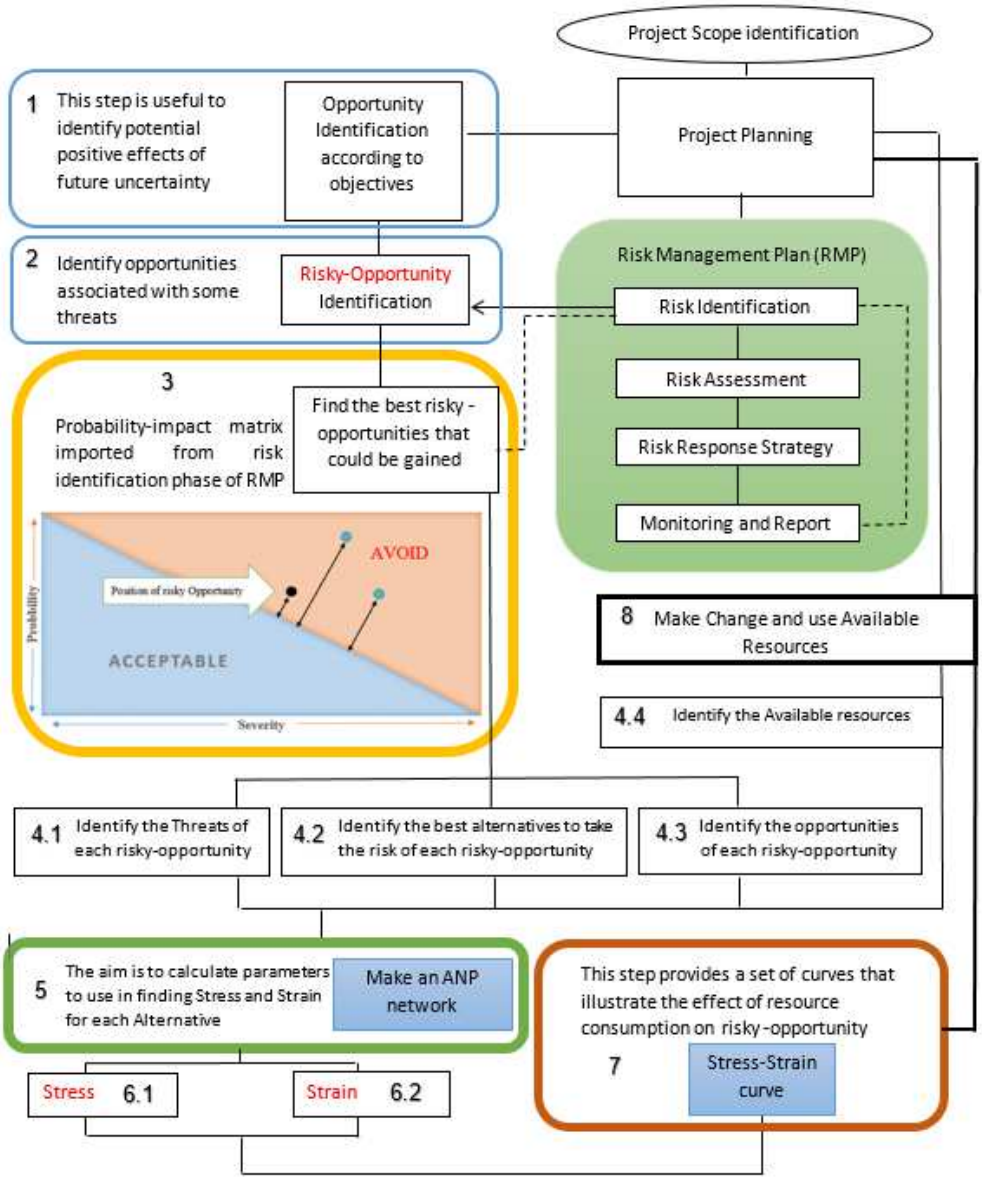


Figure 9 The general procedure of the method

3.3.6 Outline of the steps of the method

1. The planning stage of a project starts with the definition of the project objectives and scope, followed by clarifying the project sub-objectives, requirements, and resources. Implementation of the method in Figure 9 at project level could start after defining the work breakdown structure (WBS) when the work packages and execution stages are already identified. When the project and work packages are fully defined, risk management model starts with risk identification phase. The new method also starts at this point. The aim is to accept risky-opportunities (ROs) to exploit the uncertainty; therefore, the result of the method could affect the project planning

and change the WBS. If the RO is accepted through the implementation of an alternative, it means that one or more goals of the project will be obtained by the new alternative way. Consequently, the old defined work in WBS will be replaced by the alternative. Moreover, the risks of that alternative will be added in the identified risks list because still all risks should be monitored even if they are mitigated or eliminated by the new alternative. In the following, the steps involved in the process are explained in more detail (the numbering of the steps is that used in Figure 9): Identify the opportunities in future uncertain events that if the event happens, the result of its positive effect on the project main objective will bring new benefits on. However, as Peter Drucker necessitated, it is crucial to focus on important tasks and take the right risks to gain the highest return (Drucker, 1995). Therefore, prioritizing these opportunities aim to decide on the most fruitful ones, take pride of place in the risk and opportunity management measures. The goals are key to business success and selecting criteria to take the opportunities is also critical, so in the current study, we propose selecting 4 criteria according to what Drucker noted about being goal-oriented and focus on the results. These are evaluation criteria to identify, judge and select the opportunities that may be the result of a specific uncertain event.

   i. The control must be economical. "the less effort required to gain control, the better" (Cohen, 2009). We name this criteria "economic"
   ii. There should be significant symptoms or significant achievement. We name this criteria "impact"
   iii. Feasibility of the measure. The control measures of the risk should be feasible. We name this criteria "feasibility"
   iv. Congruent results of if the risk happens and opportunity is taken. The measures and control actions must have no conflict with the other goals and works. We name this criteria "congruency"

2. Identify the threats associated with the selected opportunities and define the ROs and construct secondary goals –secondary goals are described in section 3.1- regarding existing WBS and goals. This step needs a brainstorming session to identify all alternative ways of doing the existing works even if they are associated with risks. To do so, the project manager leads the brainstorming session which includes a group of technical experts, project control experts, project coordinator, and project management. The participants of the session and their skills depend on the organizational chart in the project and project management and execution structure. In some projects the works are going to be outsourced, therefore, in this case, the contracting officer should take part in the brainstorming session. For instance, ROs in the furnace construction project include finding

another subcontractor to continue the job, splitting the job and outsourcing just a part of the job, and doing the job with existing personnel of the company and avoid outsourcing. All of these options are risky according to their essence but each one has some hidden opportunities (Aghazadeh Ardebili et al., 2017).

3. When the risky substitutes that have some evident advantages are fully identified and prioritised, the comparison of the severity and the probability of occurrence of the defined ROs could be useful to draw an image of all of the RO and select the most efficient RO in case of risk acceptance. Probability-impact scheme for the threats and impacts of each RO should be generated and the closest ROs to the border of acceptance will be chosen to take to going-on. The values of probability and impact is collected by means of historical data or interview with experts.
4. This step includes four sub-actions in the RO method:
   4.1. In this step, first, the alternative ways of carrying out necessary tasks to be able to accept each RO will be identified. Then each alternative way will be brocken down into the smaller task and their activities. In project management and systems engineering, this is called work breakdown structure (WBS). In this study, we call it an alternative breakdown structure (ABS). ABS is providing more details about the deliverables of the alternative with a hierarchical structure of the smaller components, which facilitate two different analyses of step 4.2 the risk identification of each alternative, and 4.3 estimations of the required resources for each alternative. The following example illustrates two different alternatives of the RO, in the furnace construction example:

      RO1 continue with the existing sub-contractor.

         RO1A1 close the old contract, impose a penalty, and restart a new contract with a heavier penalty of failure.

         RO1A2 impose a penalty for the delay and continue the project with the existing schedule.

      RO2 outsource the remaining works to another contractor.

         RO2A1 split the job and find 3 different subcontractors for piping, steel structure, and refractory.

            RO2A1.1 prepare a call regarding remaining works of the furnace erection and set a date for the auction.

            RO2A1.2 publishe a call for the auction.

RO2A1.3 organize and hold the auction.

RO2A1.4 evaluate the suggestions of the subcontractors regarding the price, schedule, and technical potentials.

RO2A1.5 start the work with a new subcontractor -the WBS of erection activities is the same as the old contract-.

RO2A2 organize an auction to find another contractor for the whole work package.

RO3 carry out the job by the company personnel

RO3A1 hire new personnel.

RO3A2 train the existing personnel and carry out the task with The company's existing personnel.

4.2. This step is devoted to identifying the pure threats of each alternative way. Concidering ABS, it is possible to organize a brainstorming session to identify the pure threats of each alternative. The final task is classifying the pure threats to make a network. After identifying the pure threats, we suggest to structure cause-and-effect diagram and root-cause analysis to track down the reasons for each pure threat. In this step, it will help to identify new threats besides drawing a clear image of the threat. The result of this step will be employed to support performing pair-wise analysis and ranking the pure threats. Finally, this step ends with ranking the pure threats employing pairwise analysis.

4.3. This step is devoted to listing the pure opportunities of each alternative. The opportunities are already identified and in this step, the main task is to identify if any new opportunity raises in case of picking each alternative and then classify the opportunities to make a network. Finally, this step ends with ranking pure opportunities employing pairwise analysis.

4.4. Carrying out any task in a project requires some resources. These resources could be personnel, equipment, facilities, funding, assets, and any element that is considered essential to complete the activities of an alternative. There is always a constraint about the available resources of a project at any point in its schedule. In this step the maximum available resources that could be allocated to the remaining project activities from the present point onward -this is a milestone on the project schedule when the project manager starts to use the RO method-, are listed. Allocation of a specific amount of one or a combination of particular resources is needed to carry out the tasks of each alternative. After identifying

the tasks that each alternative includes, it is possible to list the resource types that are required for each alternative option together with the amount of each resource for that alternative.

5. Feasible ROs will be selected according to the most effective opportunities behind them, the least hazardous pure threats, and probability impact matrix of step 3. To analyze these ROs, stress and strain of each alternative should be calculated. Analytic network process (ANP) has been selected to calculate the required parameters because it is a general form of the analytic hierarchy process, which models the interdependencies between all clusters. ANP starts with clustering the opportunities, threats, ROs and their alternatives, and resources; then it is possible to consider all effects between criteria, objectives, and alternatives on each other besides "local" pairwise comparison (among elements in the same cluster). To this aim, a network should be constructed. This network includes 6 clusters. The general network is depicted in Figure 10. In this method, the comparisons are made in the BOCR model by aggregating all the criteria of each into their merit. Therefore, we break the network to four smaller networks to solve in terms of benefits, opportunities, costs, and risks networks separately. It is a worthwhile use of Table 9 to list all of the elements of the network and some technical attributes including the probability-impact of the pure threat and pure opportunity, and the relation between the elements before constructing the network.

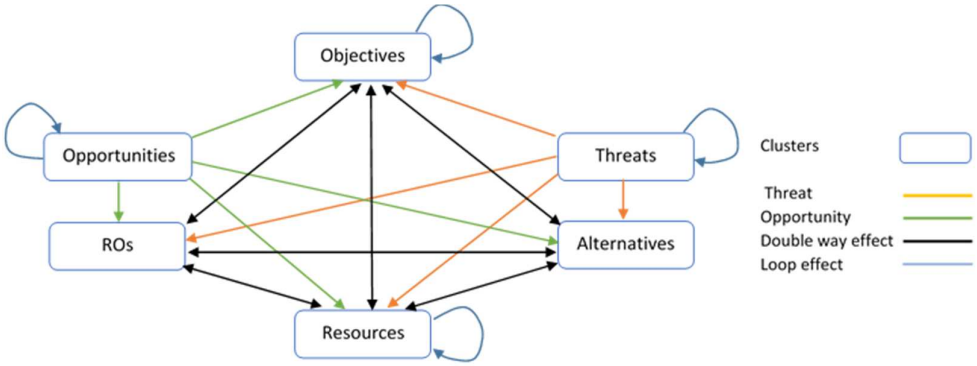


Figure 10 the general network includes all clusters

The BOCR model derived from the general network is shown in Figure 11. The alternative cluster includes the different ways of making a change in a company to tackle the threats of each RO to gain pure opportunities. Opportunities cluster includes pure opportunities for each alternative. Threats cluster includes pure threats of each alternative. Resource cluster includes all of the available resources for carrying out one of the alternatives.

Table 14 Sample table for listing the relations/probability and impact of the elements

Tr/Op/Be/ Co[1]	Description			Objective No.[5]	Alternatives			
	How it influences[2]	Prob. [3]	Impact [4]		A1	A 2	A 3	…
Tr1				O_{m2}, O_{s1} [6]		*	*	
Tr2								
OP1								
OP2								
Be1								
Co1								

[1] This column is the reference of the row and the abbreviations are as follow, Tr: Threat, Op: Opportunity, Be: Benefit, Co: Cost

[2] In this column the elements are explained in a brief way. For instance the main root of the threat, the type of the cost etc.

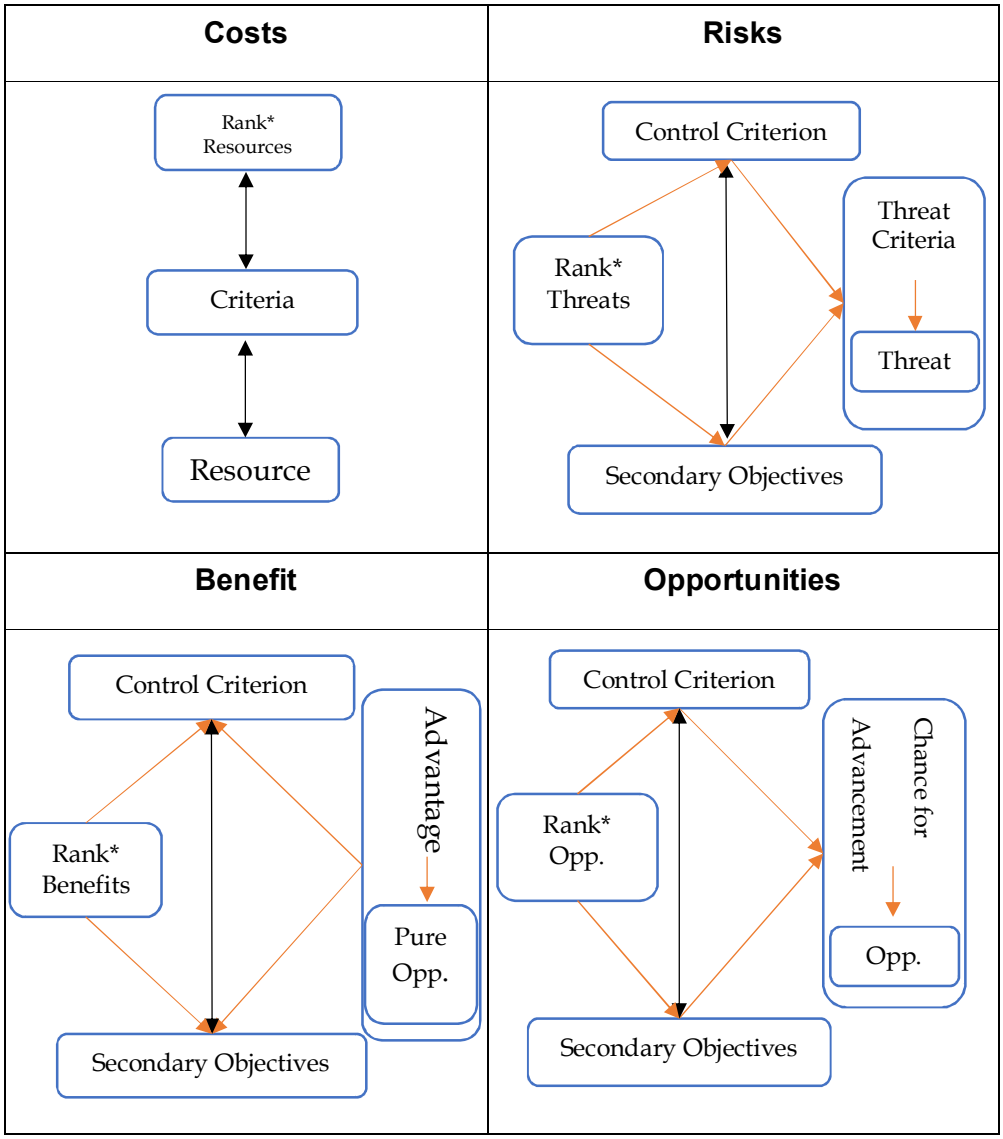
[3] This Column shows the probability of the pure threat and the chance for the advancement of opportunities. -The chance of advancement of a pure opportunity is 100%. This group is called benefit in BOCR model which raises a certain advantage in case of accepting the related RO-

[4] This column shows the severity of the impact of Threats, Benefits and Opportunities, Costs

[5] This column list the Objectives that Threats, Benefits and Opportunities are associated with

[6] O_{m2}: Main Objective No. 2, O_{s1}: Secondary Objective No. 1

** The colored boxes are the alternatives that are related with the Reference of the row. For instance, the first row shows that threat number 1 is associated with alternative no. 2 and 3*



* Ranking is the elements to calculate the weight of the elements is the main reason that ANP is employed, therefore, it counts as an objective beside Secondary objectives.

Figure 11 The BOCR model

After configuring the network structure, clusters, and all of their elements, for each network in the BOCR framework, the weight of the threats, opportunities, and benefits and, the resources should be calculated by ANP. In this model, Opportunities of BOCR Model stands for expectations about the desired spin-off, the chance for advantage, and future profit in case of potential revenue, whereas Benefits sit in for certain positive achievements and advantages. Cost represents the cost of each alternative and Risk signifies the threat network. However, in the current study, we don't use the whole

BOCR analysis and the formula bB+cC+rR+oO (T.L. Saaty & Ozdemir, 2003), but just the framework of the BOCR model adapted in current method. The framework is used to split the main network of Figure 10 to four smaller network aim to make the calculations easier and work with less confusing matrix construction and operations. Deployment of less complicated quantitative decision-making methods will raise less confusion during the steps of the analysis and less problem of communication and information flow in group decisions (Peniwati, 2017; Thomas L. Saaty & Peniwati, 2013). This is a significant reason to use the BOCR framework to simplify the calculations and avoid the unique and extensively big matrix for ANP calculation; this increases the resilience and sustainability of group decisions (R&S.GDM) by improving the communication attribute of R&S.GDM (Aghazadeh Ardebili & Padoano, 2020).

Each alternative is a group of activities to accept one RO and one of these alternatives will be selected according to the results of the method. These new groups of activities are called Alternatives in this study. They will be carried out to make a change in the company, so an alternative could be considered as a sub-project whitin the main project. The objectives cluster in the network includes secondary objectives that are the objectives of the sub-project as shown in Figure 12. The intersection between the sub-project B objectives and main objectives shows that a part of this sub-project aims to satisfy a part of the main project objectives by taking advantage through accepting the RO.

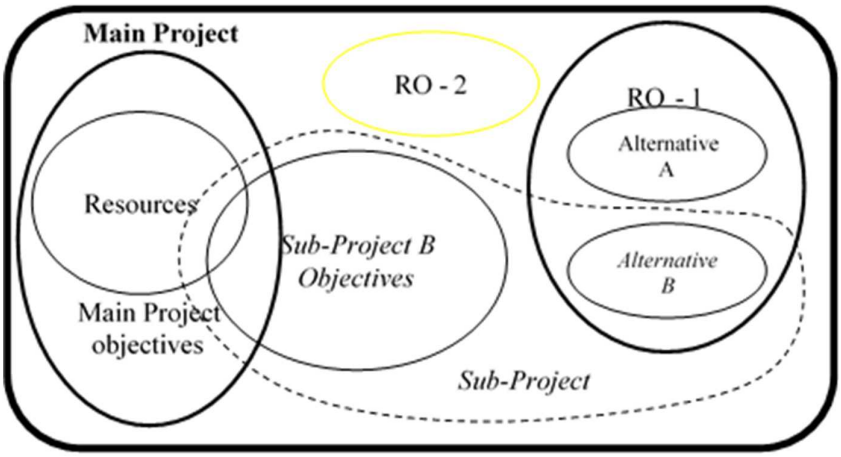


Figure 12 Relation between main project, RO and subproject objectives

Also in this step, the four networks are solved to find the priority of each parameter to calculate the Stress of the alternatives. We suggest analyzing the ANP employing Super Decision software, which is introduced in Sub-section 3.3.1 of the current document. Nevertheless, the general steps of ANP is provided hereafter (Altay

et al., 2009; Dikshit & Rhoades, 1992; Hosseini et al., 2013; T. L. Saaty, 2010; Thomas L. Saaty et al., 2005):

i. *Define the control criteria, sub-criteria in the four networks or hierarchy, alternatives, and clusters and structure the network drawn on the secondary goals.* Since this method is the decision-maker (DM) oriented, DM classifies the components to group them and make the clusters. (C: the set of clusters; N_i: the set of nodes (criteria) belonging to cluster C_i)

ii. *DM identifies the relationship between the components*. These relations define how the components affect each other. (R: criteria relationship matrix with k*k dimension, having $k = \sum_{i=1}^{N} ni$ where r_{ij}=1 if and only if n_i influences n_j node, otherwise r_{ij}=0)
Supposing that one or more criteria of a cluster are connected to one or more criteria of another cluster, then the first cluster influences the second. This is the foundation of constructing the cluster relationships matrix Q. (Q: n*n matrix, which is a square matrix of order n)
R and Q matrices describe inner and outer dependencies among the components of the network.

iii. *Constructing pairwise comparison matrices of the components to obtain the priorities.* (A_{Ci}: the clusters pairwise comparison matrix; B_{CiNj}: the nodes pairwise comparison matrix) the comparison of each component with itself is considered 1 (if k=l then a_{kl}(or b_{kl})=1). In the reciprocal matrix $a_{kl} = \frac{1}{a_{lk}}$. All comparing judgments have done by the decision-maker to construct comparison matrices.

iv. *Constructing pairwise comparison matrices of the clusters to obtain the priorities.*

v. *Consistency check for all comparison matrices.* If the ratio of the inconsistency of a matrix (C.R.) is higher than 10%, the matrix should be revised and controlled to reach an acceptable inconsistency level. $C.R. = \frac{C.I.}{R.I}$ while $C.I. = \frac{\lambda_{max} - n}{n-1}$ and R.I. stands for random consistency index is a constant depends on the matrix size and introduced by Saaty to calculate C.R. (Thomas L. Saaty, 1996).

vi. *Relative importance weights Calculation employing the Eigenvalue method* (Golany & Kress, 1993; Thomas L. Saaty & Vargas, 1984).

vii. *The derived weights are placed in the corresponding column blocks of the supermatrix.*

viii. *Supermatrix should be transformed into column stochastic* (Thomas L. Saaty, 2005) *and Weighed Supermatrix calculated.* The interrelation matrices are used to compute the weighted supermatrix (H. Lee et al., 2012).

ix. *The Weighted Supermatrix should be limited.* To find limit priorities, the weighted supermatrix is raised to a sufficiently large power aims to transform a limit supermatid. Multiplying the weighted supermatrix continues until it converges into a stable limit matrix (Thomas L. Saaty, 2005). If the supermatrix only includes interrelated clusters, additional steps should be considered for obtaining final results(Hosseini et al., 2013). In the case of using the traditional BO/CR method, limiting priorities should be synthesized (Thomas L. Saaty et al., 2005).

6. This step includes two sub-actions.

6.1. Stress should be calculated as follows:

$$Stress_{\text{alternative}} = \frac{\sum \text{threat weight} * \sum \text{cost weight}}{\sum \text{opportunity weight} * \sum \text{benefit weight}} \quad (1)$$

Given alternative A_i , the weight of threats, cost, opportunities and benefits of that alternative will be employed to calculate the numerator and denominator of the Stress of that alternative.

Opportunity weight: the benefit subnetwork is employed to calculate the weight of all of the pure opportunities; but for Stress of alternative A_i , the weights of pure opportunities of RO_jA_i will sum up together.
Alternative, pure threats, and cost weights are calculated in the same way.
Since the weights of the elements that are calculated by ANP are dimentionless, the Stress is also a dimentionless parameter.

6.2. Strain should be calculated as follow:

$$Strain_{\text{alternative}} = \frac{\text{amount of resource consumption for alternative i}}{\text{basic consumption of the resource}} \quad (2)$$

Table 15 illustrate a sample calculation of the amount of resource consumption for alternatives and finding the basic consumption and strain.

Table 15 Sample strain calculation for an outsourcing project (Yellow box shows the basic cost consumption)

Ro	*Subset*	*Alternatives*	*Cost in euro * 10^3*	*Strain*
Failure strategy	Continue with existing subcontractor	Continue and try failure strategies	92	3.36 *
Change the strategy	Outsource to another subcontractor	No. 1	70	2.56
		No. 2	80	2.93
		No. 3	92	3.17
	Split the job and outsource refractory works	Existing Hr Without Recruitment	86	3.13
		Recruitment - New Personnel - 2 Welders, 1 Inspector, 1 Fitter For Piping	102	3.75
		Recruitment - New Personnel - 2 Welders, Inspection Company, 1 Fitter For Piping	113	4.15
		Recruitment - New Personnel - 2 Welders, 2 Assistant, Inspection Company, 2 Fitter, 2 Fitter Assistant. 1 Low Pressure Threaded Joint Line Fitter And 1 Assistant For Piping	124	4.55
		Recruitment - The Full Team For Piping -1 Technical Office Engineer, 1 Foreman, 2 Welders, 2 Assistant, Inspection Company, 2 Fitter, 2 Fitter Assistant. 1 Low Pressure Threaded Joint Line Fitter And 1 Assistant For Piping	27	1.00
		Recruitment - The Full Team For Piping -1 Technical Office Engineer, 1 Foreman, 2 Welders, 2	135	4.94

	Assistant, Inspection Company, 2 Fitter, 2 Fitter Assistant. 1 Low Pressure Threaded Joint Line Fitter And 1 Assistant For Piping		
	Recruitment - A Full Team With A Technical Consultant	146	5.34

* It is worth remarking that this value means that the consumption of this alternative is 3.36 times the basic consumption.

7. In this step, the calculated stress and strain for each alternative are used to find the position of the A_i in the stress-strain coordination system. When each alternative has a specific point in the stress-strain coordination system: we connect the points that belong to the same RO (see Figure 13/point 1,2, and 3). These systems in the coordination system show the risk-taking capability of the project in terms of accepting the ROs and using the resources. The main managerial implication of this group of systems is to support the project managers to decide on accepting the RO or just ignore them. In the following the highlights of using these systems are listed:

- The positive gradient illustrates an increase in strain. In this case, the more resource consumption can cause the more stress. It could be a result of using more amount of resource than what it is reasonable or available. Another reason could be a result of high probability and high impact of new threats with which an alternative is associated.
- The negative gradient means that spending a specific amount of a resource for an alternative reduces stress. The ideal solution could be the highest negative gradient.
- Any point illustrates the characteristics of an alternative A_i. Each line is made by connecting the points that belong to the alternatives of a RO.
- This chart shows how a project reacts in front of the threats if we accept a risky-opportunity. When the gradient is negative, the stress decreases from alternative A_i to A_j, then Aj could be a way to accept the RO.
- This chart depicts how the company could change their risk tolerance if an alternative was selected and some changes happened; therefore it could be a dynamic index to show risk tolerance of a company in front of specific threats. Figure 13 is a sample of the resulting chart. As it is shown in Figure 13, the orange line is the result of connecting the alternatives of RO-1 include point 3 and the

blue line is the result of connecting alternatives of RO-2 include points 1 and 2.

- In this chart, the strain quantities are normalized.
- If the slope is steeper, a small resource consumption has a big impact on the project. Therefore, the raise and run of the line between two alternatives shows the efficiency of the resource consumption.
- The slope of the lines between two alternatives provides the risk taking capability of the project, changing from one alternative to the other.

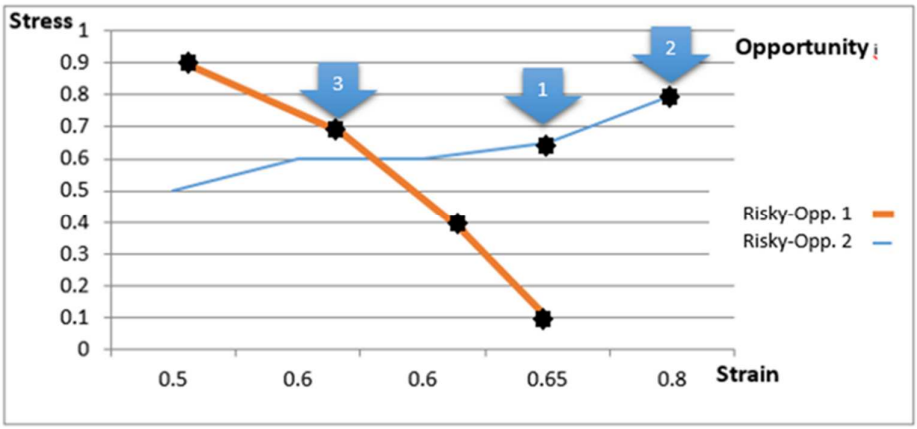


Figure 13 A sample result of the method

The final step of the method is carrying out the tasks of each alternative, monitor the changes, and reports. These reports are necessary because always there are unknown-unknown risk in the project that may appear during the project lifecycle. As a result, the process of carrying out the tasks should be controlled to see if a new threat unveiled during the project. It is plausible to face new ROs during the project, in this case, the method should be implemented again. This will illustrate the risk-taking capability of the project in face with the new RO.

3.4 Conclusion

The key results of this chapter are:

1. The novel method for evaluating (or measuring) the 'risk-taking capability' of an organization;
2. The method to support decision-making to help the sustainability strategies of a company and simultaneously accept the risks of changes and improvements;
3. the procedure to identify the most efficient resource consumption and the amount of resource consumption to make the project ready to accept risk.

In order to assess the risk-taking capabilities, three new concepts have been introduced: risky-opportunities, stress, and strain, which are different from traditional notions like risk. Stress and stain are two original concepts that will be used as indexes and designed according to the requirements of this method, to find a quantitative tool for risk acceptance evaluation and resource allocation. To calculate the parameters of these new indexes, a multi-criteria method is considered, specifically, the analytic network process (ANP) because ANP models take into explicit consideration mutual influences between elements and feedback effects. According to the ANP procedure, the pair-wise comparison matrix will define the priorities of each element in the clusters. Then for each alternative way of accepting the risks stress-strain system will be used to assess the risk-taking capability for each risky opportunity.

In summary, the methodological result of the study was a metric to assess risk-taking capability. This is represented by employing a group of systems that consider all of the opportunities and risks together in a network. Practically, with this method project managers could use an index for evaluating (or measuring) the 'risk-taking capability' of a company or project to support decision-making and adopt sustainable strategies.

4 Case Study - ROs Identification

This chapter reports an introduction to the case company. A case study of PSP company carried out aims to identify functions, issues, and solutions regarding the transition towards providing a sustainable supply chain. The primary version of this chapter is published in PEM 2019 international conference proceeding (Aghazadeh Ardebili et al., 2019) and the extended version which is in the current thesis is published in Sustainability Journal (Aghazadeh Ardebili et al., 2020). The results of this chapter (identified ROs) will be used in Chapter 5 to conduct RO Analysis Method (ROAM).

ABSTRACT:

Analyzing and designing how service is provided to the customer is crucial for sustainable supply chains in services. In this respect, there can be barriers to applying sustainable improvements due to regulations, practices and customer culture. This study is focused on finding the waste produced by the service of one of the biggest payment service provider (PSP) companies in Iran and how to meet the essential needs of the sustainable supply chain. It has been observed that using thermal papers as a biohazardous material causes environmental problems and even it is hazardous to mix them with normal paper waste in the recycling process. Moreover, preventive maintenance of the thermal printers itself causes a huge number of unnecessary shuttles between the customers and service suppliers, which represents a source of CO_2 emission, traffic—especially in the capital—and high maintenance costs for the company. Three main alternatives to the thermal paper receipt were analyzed and ranked by means of a TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) model, which employed the sustainability pillars and the technical point of view as evaluation criteria. The priorities against the set of criteria were obtained by means of surveys, which targeted a sample of customers and a pool of experts. The results highlighted that customers' habits and legislation are the most important barriers to the transition to a more sustainable service.

Keywords: Sustainable supply chain; green service; payment service provider; thermal paper; waste reduction; multi criteria decision making; TOPSIS; sustainable consumption

4.1 INTRODUCTION

A *service provider* (SP) is an organization that performs a sequence of activities to satisfy a need for a specific group of customers or for the general public. Consultancies, financial services, and telecommunication services are typical examples of SPs. The service is delivered to the users by means of a chain of activities, which may involve several partners: planning and managing the supply chain is therefore a key aspect of this business A *sustainable service supply chain* (SSSC) is a combination of a group of companies utilizing their resources to meet the end user's demand in an efficient way and at the right time. In the last decade, the concept of sustainability has been introduced in SSSCs, but the body of knowledge on green service supply chains is not sufficiently structured yet. In addition, both from the users' and the managerial perspectives the advantages of programs aimed at introducing sustainability in this field are not completely clear. Therefore, the presentation and discussion of case studies on SSSC is particularly significant.

The present study is focused on the payment service and, more specifically, investigates the case study of one of the biggest *payment service provider* (PSP) companies in Iran. PSPs offer core services (e.g., the technical processing of payments) and some complementary services that concern the same activity (e.g., the payment transaction) and are valuable to their customers. In particular, every transaction is confirmed by the production of a receipt that is usually printed on thermal paper. Previous research shows that thermal paper, being biohazardous material, causes environmental problems, and it is even hazardous to mix it with normal paper waste in the recycling process. On the other hand, using these papers and thermal printers enforce the PSP companies to provide maintenance service for the POS (Point of Sale) machines throughout the country. In a recent report (February 2019)(*The transaction receipts got smaller*, 2019), Ibena (Iranian economic and banking news channel) highlighted that thermal papers are one of the most relevant consumable costs for the banking network and payment service sector in Iran. Moreover, the *preventive maintenance* (PM) of the thermal printers itself causes a huge number of unnecessary trips that are mostly made by car or motorcycle.

It is worth remarking that payment services are widespread and a large part of their processes are based on digital technology. However, even if the payment transaction receipt can be digital, in many countries, the users still show a tendency to print it: the volumes of thermal paper used and the associated environmental costs are not negligible. For instance, a study by

Yaaguby (Yagooby, 2014) points up that the thermal paper receipts used in Iran in six months could wrap around the earth nine times. Plans of waste reduction in this sector could therefore produce considerable environmental benefits. Nevertheless, the scientific literature on the subject is still rather limited. The present paper offers a contribution to the discussion on the transition of the payment service supply chain towards sustainability, highlighting some obstacles to an otherwise technically feasible digital transformation of the whole service.

The study investigates the case of a PSP that delivers its services through a mix of "soft" activities (e.g., the digital payment) and "hard" activities (e.g., the production of the paper receipt). One of the company's strategic goals is to remove the waste from the service supply chain, making it more sustainable and efficient. On this account, the identification of technically feasible alternatives to deliver the complementary service is a first step of the study, which aims to address the question: what are the alternative ways for the thermal paper receipt, which are feasible for the target company? The analysis and evaluation of the alternatives was then carried out, in order to answer a second question: which alternative is the most effective in enabling the transition towards sustainable service, ensuring a service that is reliable and acceptable for the users? The evaluation surely depends on the main actors of the payment service, namely the PSP and the users (sellers and customers), and on the regulations in force in the specific country, which may impose requirements and limitations to the technical solutions. Furthermore, the evaluation criteria should be related to the above mentioned company's goal and to the key dimensions of sustainability. In summary, in order to address the two questions, the methodology is based on a multi-criteria model in which the feasible alternatives are assessed against a set of criteria validated by the company managers and the priorities are obtained by means of empirical surveys administered to the payment service provider and users. The present study is an attempt to provide the company with a structured method for aiding the identification and selection of the most effective solutions, and, at the same time, to individuate the barriers to improving the sustainability of the payment service supply chain.

The next section presents the results of the review of the scientific literature that points out the research gap concerning sustainability in the payment service supply chain. Section 3 illustrates the general methodology employed to address the above mentioned questions and its application to the selected case study. The results of the application are presented in Section 4 and discussed in Section 5. Some concluding remarks are included in Section 6.

4.2 LITERATURE REVIEW

The service supply chain links the service provider to other businesses or end users. The SP delivers value added services by means of a chain of activities that can be "hard" (such as the production or management of physical entities) or "soft" (such as the transmission of digital data). The nature of the service, the characteristics of the SP and their clients may influence the mix of hard and soft activities, and the features of the service supply chain. In particular, the transition to a green service depends both on the strategic objectives of the service and on the clients' behavior. Indeed, the consumers' behavior is a critical issue, which influences the cost and performance of the whole process in the service providing sector (Taghikhah et al., 2019). A recent study by Pagell and Shevchenko emphasizes several dimensions of sustainability in supply chains and highlights the importance of environmental and social issues: "Future SCM research will have to treat a supply chain's social and environmental performance as equally or more valid than economic performance."(Pagell & Shevchenko, 2014)

In order to individuate the studies related to sustainable services, a structured search on the Scopus database was carried out. The search was limited to peer-reviewed papers and the language was limited to English by click box selection in the advanced search toolbox of Scopus database.

The process of literature review included the following steps:

1. Search for relevant literature on PSP (only one paper published in Scopus);
2. Search for relevant literature on sustainability in the service sector, digital services and sustainability, MCDM in sustainability studies in the service sector;
3. Evaluate the relevance of sources;
4. Report the highlights in the literature review.

Scopus was selected since it is the largest abstract and citation database of peer-reviewed literature. The results are shown in Figure 14. The string of the search on the database is as follows:

> TITLE-ABS-KEY (("service provider" OR "service providing") AND ("sustainable" OR "sustainability" OR "Circular Economy" OR "Green") AND ("supply chain")).

Notwithstanding some studies are focused on natural systems and the influence of sustainable supply chain (see e.g., (Gruner & Power, 2017)), the research on socio-ecological integrated systems has not been carried out in

the service sector as much as in the production supply chain. In particular, most of the case studies are limited to the last five years. Papetti and colleagues suggested the web-based platform as a tool for eco-sustainable supply chain management (Papetti et al., 2019) and Hussain and colleagues studied sustainability of the health care service supply chain (Hussain et al., 2018). Figure 14 illustrates the trend in the studies on the sustainability of service supply chains. The figure reveals that only 122 peer reviewed documents including 91 journal papers and 31 conference papers have been recently published which are significantly related to the topic "sustainable service supply chain". The line graph in Figure 14 shows a sharp increase in the quantity of the publications in the last seven years; furthermore, comparing our literature review to the one by Liu et al. (W. Liu et al., 2017), we also witness a significant increase from 2017 to 2019. Nevertheless, the Scopus database does not include any studies related with sustainability of payment services, while only one paper investigates the PSP supply chain, which is focused on the internet of things and the importance of the service supply chain to achieve a positive return on investment (O'Mahony et al., 1997).

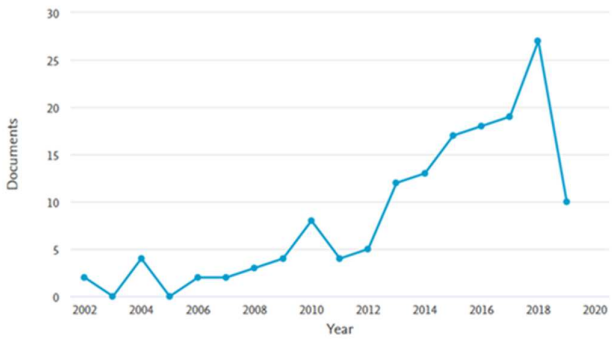


Figure 14 Recent published papers on the service supply chain (Database: Scopus).

The main activity of a payment service provider (PSP) is selling and buying for the end users. This service was studied in detail by O'Mahony in 1997 (O'Mahony et al., 1997). Payment methods include e-commerce, mobile payment, online banking, credit cards, bank transfer and others. Usually, PSP is connected to multiple banks and uses a wide range of banking networks. The largest part of the core and ancillary services offered by PSPs are digital services. The service supply chain connects online service providers, retailers and wholesalers, and the end customers that use online payment service to pay. PSPs also offer complementary services like the production and delivery of documents such as the transactions receipts. Documents can be produced in digital (soft) or physical (hard) formats, which imply different flows of activity and materials. In many contexts, the electronic payment service is traditionally enabled by POS terminals whose

management requires supplying material and other supporting services (e.g. maintenance). Other complementary services may require the management of hard activities and materials; thus, they could be subjected to close scrutiny in order to improve the service sustainability.

Since the studies that focused on PSP service are limited to one published paper, the authors decided to perform a second search on Scopus in which only two general keywords were used: "Sustainab*" and "Digital services". 71 indexed papers were found. Several of them report studies on the digitalization of services that have been usually delivered by means of hard activities. Supply chain and logistics are the most popular subject areas, where solutions of smart mobility and transportation have been evaluated considering CO_2 emission as the key environmental aspect (Johansson, 2013; Sarin, 2016; Schreieck et al., 2016; Solarte-Vasquez et al., 2016; Vinci & Musarra, 2016; Volpi et al., 2019). In a case study of YouTube as a digital service provider in 2019, Preist et al. investigated how Sustainable Interaction Design of digital services can contribute to the corporate strategies for *greenhouse gas* (GHG) reduction(Preist et al., 2019). Koukopoulos et al. in 2019 presented a prototype digital system that supports the goal of sustainability for a modern public library (Koukopoulos et al., 2019). However, the main objective of this study was attracting a wider audience of library visitors and provide new sources of revenue. Digital product-service-systems constitute another investigated subject area (Kölmel et al., 2015). In 2017, Agbozo studied the development of a digital government framework, and he considered the social aspects of sustainability and eService adoption, cybersecurity challenges, etc. (Agbozo, 2017).

In the last decade an interest in intangible offerings and service innovation has emerged, replacing the focus on tangible products and "hard" activities. In this respect, the popularity of *product-service innovation* (PSI) is increasing because of the inherent interrelation between firm performance and PSI (Sánchez□Montesinos et al., 2018). In production firms, the customer and logistics IT processes are considered the necessary basic elements of service innovation (Marić & Opazo-Basáez, 2019). A recent stream of research conducted by a group of European researchers has focused on product-service innovation (PSI) and green servitization (Bustinza et al., 2018; Kastalli & Van Looy, 2013; Marić & Opazo-Basáez, 2019; Sánchez□ Montesinos et al., 2018; Vendrell-Herrero et al., 2020). They studied different companies that implement digital solutions to support business operation. For example, they highlighted the role of "firms willing to offer green services should consider offering digital services first" (Vendrell-Herrero et al., 2020). Sectoral studies reveal that remanufacturing and recycling in the computer and electronics industry increases flexibility and sustainability of the supply chain (Bustinza et al., 2018), and implementing digital and green servitization causes significant increase of firms

productivity in the automotive industry (Vendrell-Herrero et al., 2020). Also, in food companies of the retailing sector, companies try to add new value to products by promoting digital servitization to gain competitive advantages (Kastalli & Van Looy, 2013).

Many of the analyzed papers explore means of digitalizing the activities of production, transfer and storing of information connected with the core services, which, as e.g. in logistics, often require hard activities. In the payment service, while the core service is mainly delivered through soft activities, the complementary service of documenting the transaction is traditionally based on hard activities. The receipt is printed on thermal papers using POS terminals. Thermal receipts are widely used in payment services. Most of the POS terminals, shopping receipt in selling points and shops and *automated teller machines* (ATM), which print a paper receipt, use this sort of paper. The paper is coated with different chemicals to make it printable and the reactant acid in coating material is mostly *Bisphenol A* (BPA). Several epidemiology studies disclose BPA exposures and threats of adverse health outcomes (Calafat Antonia M. et al., 2005; Heindel et al., 2015; Rochester, 2013; Vandenberg, 2011; Vandenberg et al., 2013). Because BPA is hazardous, mixing thermal paper receipts with other material to recycle them should be avoided. Indeed, BPA can contaminate other recycled paper products including paper bags or toilet paper.

On account of the diffusion of payment services, the volumes of thermal paper used and the environmental costs that it can cause, the scarcity of studies on this topic testifies a notable gap in the research on sustainable services. It is worth remarking that this complementary service is indeed a value-added service for the client and it is required by the regulations of many countries. Alternatives to the printed transaction receipts should then be identified and evaluated in order to reduce the waste and impacts produced by the service. It is therefore necessary to individuate attributes or criteria of sustainability that can be valid for the service sector and employ a method that can support the evaluation in presence of several criteria.

In sustainability studies, the criteria or indicators used by researchers in quantitative analysis and *multi-criteria decision making* (MCDM) methods are different and depend on the subject area. For instance, in agricultural studies, Balezentis et al. used four criteria (total output, total water footprint, Shannon equitability index and downside coefficient of yield variation) (Balezentis et al., 2020); while in aquaculture Martinez-Cordero and Leung tried to find the best decision regarding the employment, foreign exchange earnings, economic rent maximization, and total pollution minimization, subject to land availability and local market demand constraints (Martinez□Cordero & Leung, 2004). The emergence of new concepts such as "servitization" and product-service systems (PSS)

highlighted the need to consider socio-ecological aspects (Fargnoli et al., 2018). In this case, the interrelation between the services to enhance the production is the main objective. In 2019, Zhao et al. used customer centricity, service efficiency enhancement, reduced credit risk, and the development of scenario finance as criteria in a study to improve "Financial Service Innovation Strategies" for improving China's Banking Industry (Zhao et al., 2019); nevertheless, the main goal of the authors was creating competitive advantage. Also, Raut et al. focused on banking service and introduced 32 criteria for sustainability in the banking industry (Raut et al., 2017). However, the published studies that follows quantitative multi-criteria/attribute analysis in the context of sustainable services are rather limited.

In the sector of pure services, i.e. where services are not related to manufacturing, the studies that used MCDM approaches are very limited and they mainly include the healthcare, urban mobility and transport, and hospitality services. For example, a paper by Liu et al. in 2019 was focused on health care service and the authors used integrated *decision making trial and evaluation laboratory* (DEMATEL)-*based analytic network process* (DANP) and a modified VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) method to form a DDANPMV (DEMATEL + DANP + Modified VIKOR) model to examine consumers' adoption of mobile health care to promote the sustainable development of medical resources (Yupeng Liu et al., 2019). Moslem et al. analyzed stakeholder consensus for a sustainable transport development decision by the *Analytic Hierarchy Process* (AHP) (Moslem et al., 2019)and Ozturkoglu et al. studied the dimensions for "*sustainability-oriented hospitality service innovation* (SOHSI)" (Ozturkoglu et al., 2019). These studies were all published in 2019, showing that research on the application of decision support tools like MCDM for the evaluation of sustainable solutions in the service sector is still lacking.

4.3 MATERIALS AND METHODS

4.3.1. General Methodology

The review of the literature allowed to highlight that the payment service includes, alongside core services, a complementary service that is an important source of environmental impact, which must be mitigated for a transition to green services.

Hence, the questions that this study aims to address are:

- What are the alternatives to the thermal paper receipt, which are feasible for the specific company?

- Which alternative is the most effective in fulfilling the following goals: enable the transition towards sustainable service and ensure a service that is reliable and acceptable for the users?

A methodological framework is here proposed which aims at the identification and assessment of alternative ways to provide the transaction receipt in a specific setting. The study is mainly empirical and based on the direct observation of a selected case study, to which the framework is applied. The study follows these steps respectively: identification of the case-study, data collection to identify the alternatives to thermal paper (first data collection phase), identification of a MCDM method to evaluate the alternatives, data collection to quantify the evaluation criteria (second data collection phase), production of MCDM results.

Data were collected by means of five groups of interviews, which were conducted in two phases. In the first phase, two unstructured interviews (in-depth interview: see Legard et al. (Legard et al., 2003)) and one semi-structured interview were carried out to collect data about the mission of the company, sequence of activities, organizational information, end users, and the wastes produced in the service process and alternative methods. The company investigated in this paper (Saman Electronic Payment – SEP) is a typical example of PSP. The list of activities is published in their website and available to the public, and customers are widespread in the whole country. The semi-structured interview was focused specifically on SEP. A list of pre-defined questions was used, but, during the interviews, additional questions might have been asked to clarify specific points. In this phase, the interviewees were software engineers, who had the expertise required to explore the possibilities of software development to eliminate the paper receipts in SEP, a POS terminal maintenance technician of SEP and experts from the company. The main goal of this phase was to obtain the information useful to identify the alternatives to thermal paper.

The second phase of data collection included two stages, which were aimed to provide information to perform a MCDM analysis for prioritizing the alternatives to using the paper receipt. The first stage was the data collection from the end users and the second stage was the interview with the hardware and software development experts of SEP. Six criteria belonging to two groups were employed in the ranking model. The first group includes three pillars of sustainability, the second three criteria are associated with the company. The pillars include social aspects, environmental effects and economic issues related to sustainability. The second group of three criteria regards the company's capacity to change to a sustainable service by providing a new reporting service method, which requires software and hardware development. An important criterion of this second group is the cost of utilizing an alternative method. Figure 15 illustrate the general steps of the research conduction in a flowchart.

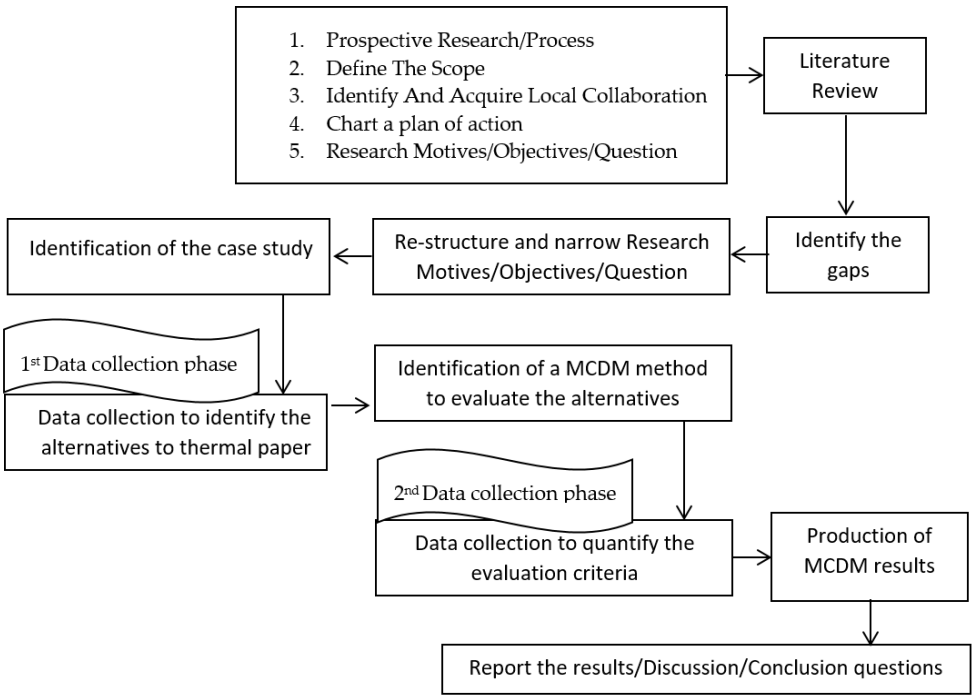


Figure 15 General methodology and research process flowchart.

4.3.2. Case Study

There are more than 900 PSP active in the world. SEP is an active PSP in Iran. In this kind of companies, profit is based on a percentage of the transaction or fixed price for each transaction. There are two main categories of costs for PSPs. The first category is related to the management of the system, including hardware, human resources and other overheads of the company. The second category includes variable costs of consumables such as thermal paper, which is used as receipt, and the maintenance service for POS machines. This second category can be reduced by means of proper planning. For instance, proactive maintenance by regular inspections could decrease the maintenance cost of POS terminals in retail stores (Roy et al., 2016; Takata et al., 2004).

SEP was selected as a case study because of three reasons. First, the managers are open to sharing their knowledge and experiences with the research team and the personnel have sufficient scientific background to clearly understand the goals and expected results of the investigation. Second, the company has strict monitoring and reporting instructions, which are followed by all departments, including the maintenance units. Particularly the database is classified and archived effectively, which makes the information extraction more reliable. Third, this company has a high rank in the world, and it supplies only services.

SEP is ranked 23 in the world and second in Iran according to the Nilson report (*Top 150 Merchant Acquirers Worldwide*, 2018), which introduced the world's top 150 Acquirers in 2017; SEP recorded 2.695 million transactions in 2017. To provide such a wide service, this company has about 800,000 POS terminals and each maintenance technician is responsible for the maintenance and service of about 900 POS terminals. As a result, each technician checks the machines in 900 different places (but in the same region) at least once a month. These trips generate high levels of CO_2 emission, traffic—especially in the capital—and high costs of maintenance for the company. The use of thermal paper is the only reason for such waste; therefore, eliminating it might not only increase the sustainability of the business but also decrease the costs and improve the reliability of the service.

The company operates in a context characterized by specific regulatory requirements. An obligatory instruction introduced by Shaparak, the branch of the central bank of the Islamic Republic of Iran, which is the responsible institution for the monitoring and control of electronic payment services in Iran—establishes to use a printed receipt in order to monitor the electronic transactions (*SHP_STD_EFTPOSRECEIPT*, 2017). This fact causes a high amount of expenditures, which include consumables, thermal printers and the maintenance of the POS terminals. PSPs have shortened the receipts by using smaller fonts and eliminating unnecessary information in order to reduce paper consumption and decrease the depreciation of the POS terminals.

4.3.3. Application of the Methodology to the Case Study

Data Collection Phase

The first phase of data collection allowed to obtain information about the technical and organizational aspects of the service provided by SEP and, eventually, to individuate the alternatives to using thermal paper receipts (see Section 4.1). As previously remarked, this phase was based on semi-structured interviews.

The data collected in the second phase were used to quantify the social criteria. Data were collected by means of a structured interview supported by a questionnaire that was distributed in a micro zone to collect data from the end users of the service. Two other structured interviews were conducted by distributing the same questionnaire in other regions in Tehran and in Mashhad to highlight differences or similarities between the micro zones, i.e. the city of Tehran and other parts of the country. The questionnaire was distributed randomly and included questions about the age, job, gender, and education to control the diversity of the sample. The questions were created with straightforward, unbiased Persian language. The questionnaire included open-ended questions, multiple-choice

questions and scaling questions; the survey was performed as an in-house questionnaire and a researcher visited the micro zone to distribute it.

Because of the availability of data, a region northeast of Tehran was selected and Raste Bazare Shomale Sharg, Haft Hoz, Sharghi was selected as a micro-zone. To find the distances and the traffic situation in the selected zone for the trips of the maintenance technicians between the POS terminals locations, Google Map was used. To focus on the active service points, the maintenance technicians were traced by the company; in this study, the service points only include the latitude and longitude of the locations that the maintenance technicians visit for the regular monthly preventive maintenance program, not all of the addresses of the owners of POS machine.

Previous questionnaires on payment service, which were already validated by experts and which are available in surveymonkey.com, survey.askform.cn, and marketest.co.uk, were used as standard templates, so that the layout and style validity is guaranteed (Uniform Resource Locators – URL – are provided as supplementary material). The sample size was calculated on the basis of the average quantity of the end users in the micro zone who performed transactions in 4 consecutive months.

The adopted parameters are:

- 95% confidence level;
- the population is 2000 (the average of transactions in 4 months in the selected zone);
- response distribution, 50% (considering the standard normal distribution without skewness, according to similar published studies conducted in the same service sector);
- sample size, 200;

$$\text{MOE (with finite population correction)} = z * \sqrt{[p * (1 - p)]} / \sqrt{[(N - 1) * n / (N - n)]} \quad (1)$$

where MOE is the margin of error (Equation 1): z is the z-score associated with a level of confidence, p is the sample proportion, expressed as a decimal, n is the sample size, N is the population size. In this case, MOE= ± 6.576%; the value is acceptable since falls in the range between four and eight.

Connelly, Hill , and Isaac and Michael (Bell, 1982; Connelly, 2008; Hill, 1998) suggest 10–30 participants for a pilot survey. Treece and Treece (Treece & Treece, 1977) suggest that in a pilot study the sample should be 10% of the sample. On such grounds, in this study, 2 pilot survey were conducted with

20 participants. The reliability and content validity were then evaluated by means of the pilot interviews. Moreover, clarity of wording was measured during the interview and all of the interviewees with different academic backgrounds and ages understood the queries easily without asking further clarifications. The Python language and three packages including NumPy, Pandas, and Matplotlib were used for data analysis of the results of the pilot survey. The code string of this section in Python is shown in Appendix B. Moreover, Figure AppendixB illustrates the comparison of the two pilot survey results in one of the questions, which was created by means of the above-mentioned code. Each pilot survey had 20 participants.

Multi-Criteria Decision Making method

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) was selected to rank the alternatives. This method considers m alternatives (options) and n criteria and the outcome of each option with respect to each criterion to find the alternative that is the closest to the ideal solution and farthest from negative ideal solution. TOPSIS is a multi-criteria decision-making (MCDM) method and in this study, it is used aim to order the preferences based on similarity to ideal solution. Among the MCDM methods, TOPSIS is appreciated by many company managers as the two abstract ideal and negative ideal solutions are clear references for the positioning of the actual alternatives (Amine et al., 2014): the ideals testify the best and worst, even if unattainable, solutions which are consistent with the decision makers' preferences (Roszkowska, 2011). In addition, the method simplifies the use summary measures (e.g. the average) obtained from judgements by many respondents. In this study, the resources and time to perform the survey and process the collected data were limited, and therefore it was decided to use the standard version of TOPSIS, which is based on crisp numbers. The classical TOPSIS analysis is popular between researchers in decision-making developed through the following steps (Dehghani Soufi et al., 2015; Wangchen Bhutia & Phipon, 2012):

Step 1:
Construct m*n matrix which have $X = (x_{ij})$ elements and x_{ij} is the performance of option i with respect to criterion j

Step 2:
Normalize the decision matrix with following equation:

$$r_{ij} = x_{ij} / \sqrt{(\sum_i x^2_{ij})} \quad \text{for } i = 1, \ldots, m; j = 1, \ldots, n$$

Step 3:
Construct the weighted matrix by assuming the weights of the criteria w_j for j = 1,…,n and multiply each column of the normalized decision matrix by its associated weight.

$v_{ij} = w_j * r_{ij}$

Step 4:
Determine the positive ideal and negative ideal solutions by following equations (where J is the sub-set of the criteria for which the maximum is best and J' is the sub-set of the criteria for which the minimum is best):

$A+ = \{ v_1+ , \ldots, v_n+\}$, where $v_j+ = \{ \max (v_{ij}) \text{ if } j \subset J ; \min (v_{ij}) \text{ if } j \subset J' \}$

$A- = \{ v_1- , \ldots, v_n-\}$, where $v_j- = \{ \min (v_{ij}) \text{ if } j \subset J ; \max (v_{ij}) \text{ if } j \subset J' \}$

Step 5:
Determine the Positive separation measures and Negative separation measures for each alternative by following equations:

$Si+ = [\sum_j (v_j+ - v_{ij})^2]^{½}$ $\quad i = 1, \ldots, m$

$Si- = [\sum_j (v_j- - v_{ij})^2]^{½}$ $i = 1, \ldots, m$

Step 6:
Calculate the relative closeness to the ideal solution Ci* and choose the Alternative with C_i^* closest to 1:

$Ci^* = S_i- / (S_i+ + S_i-) , 0 < C_i^* < 1$

The results of the ranking the alternatives are illustrated in Section 4, and a discussion and conclusion provided which is reported respectively in Sections 5 and 6.

4.4 RESULTS

4.4.1. First Data Collection Phase

Thermal Paper

SEP often purchases thermal papers for its POS terminals from the Soltanrol company. Hansol Paper and Indonesian producers presently have the highest share of thermal paper market in Iran. The characteristics of these products are the same: all of the thermal paper used by SEP contains BPA. The thermal papers are available in standard width and five colors. The average length of the receipt in Iran is 10 cm, but it can depend on the province. For example, in Fars province, the length of the receipt is 12 cm but in Kermanshah Province, the length of the receipt reaches 29 cm. Figure 16 illustrates different sizes of receipt which are offered by the same company. In all the formats, it is possible to include all the necessary information and thus decrease the length of the paper.

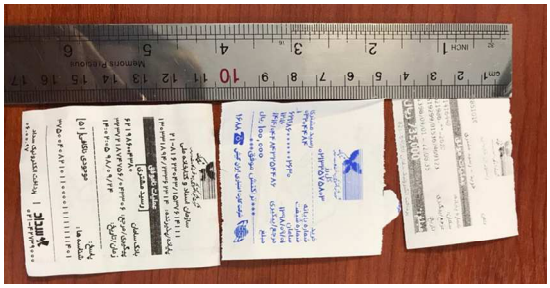


Figure 16 Thermal receipt samples of SEP in Iran with different sizes (Photo taken by the Authors).

Table 16 Transactions and paper consumption in three successive months.

Period	*Region Transactions*	*Transactions in the micro-zone*	*Consumption in the region (18-meter rolls)*	*Consumption in the micro-zone (18-meter rolls)*	*% of all companies' consumption*
97.01[1]	1,044,666	2393	601,000	1377	0.23%
97.02[1]	1,265,885	218	725,000	125	0.02%
97.03[1]	1,288,454	1128	851,400	745	0.09%

[1]The solar calendar is customary in Iran. In this study, the data belong to the first 3 months of the solar year 1397 regarding to Iranian calendar are used. In AD Calendar 01.0.1.1397 is 2018-03-21.

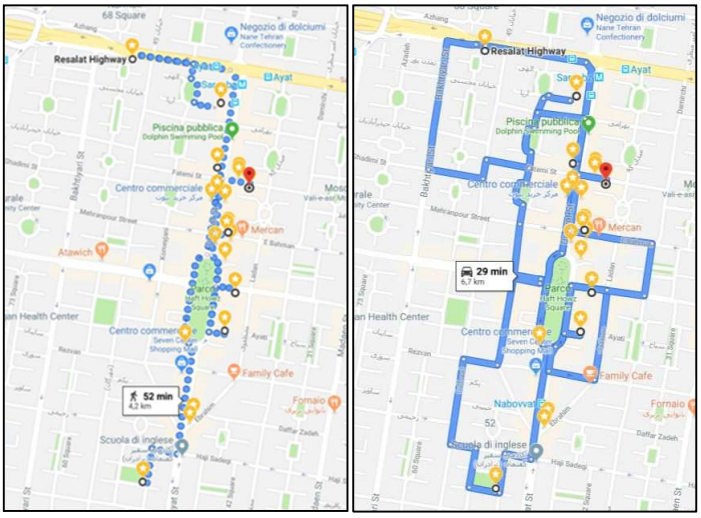
The total amount of thermal paper usage by SEP is 33,180,678 rolls (each roll is 18 meter long) during the first three months of the year. Table 16 reports the paper consumption in the selected region and micro-zone in three successive months. The paper consumption by retail sellers depends on the number of transactions. In addition, the retailer can take a report printed by the POS terminal in the shop. This report includes all of the transactions done by the same POS terminal; therefore, the length of this type of report could be even two-meter long. It is possible to retrieve a brief report or check the transactions online in the webpage of many PSPs; however, some sellers prefer to print it at the terminal.

Maintenance

POS terminals are used to record and process the information related to sales at the retail stores; therefore, they are the end points of the service supply chain. POS terminals, which SEP or any other PSP company provide for selling points, shops, and banks, need maintenance. SEP uses a range of different POS terminals with different technical characteristics. SEP uses both traditional and high-tech POS terminals.

The interviewed SEP experts remarked that malfunction of POS terminals during business hours causes great dissatisfaction among customers. Therefore, the PSPs provide maintenance services through regular inspection to minimize failures. The maintenance procedure includes two main approaches: *predictive maintenance* (PM) and *emergency maintenance* (EM). An on-site technician carries out PM through monthly inspections. This includes functionality control, software tests, and hardware control beside component replacement when necessary. In some cases, it is necessary to check the functionality after software updates. The technician also supplies new thermal paper rolls to the customers on request.

Each technician is responsible for controlling about 900 POS terminals. After an inspection, the technician should perform a special transaction to record the service that he has provided to the customer. The most important point is that the POS terminals are distributed in different locations. For instance, there are 32 POS terminals in Raste Bazare Shomale Sharg Tehran, Haft Hoz, Sharghi region. The technicians mostly use a motorbike to reach the area and walk between the selling points if they are close to each other. As it is shown in Figure 17, in the example area, the longest distance is 4.2 kilometers.



(a) (b)

Figure 17 The distribution of the selling points in Raste Bazare Shomale Sharg Tehran — Haft Hoz — Sharghi. (a) walking rout between the selling points. (b) the driving route between the points.

Customers require emergency maintenance by telephone call. When emergency service is recorded, the closest branch sends one of the technicians to solve the problem. It is worth noting that the technicians are based in the capitals of the provinces and in case of an emergency call from the other cities of the province the closest branch sends a technician there. This implies transportation and cost to the maintenance department. In

addition, the technician will not be available to carry out the assigned daily inspections; therefore, a new schedule should be identified for the technician in case EM happens. The most common problems include updating the software, changing the battery, replacing an exhausted paper roll, solving a printer paper jam and problems with the thermal printer when the print is not clear or quite absent.

The Identified Alternatives

The interviewed experts of the company suggested three alternative ways to allow a transition to green service. All the alternatives are based on the concept of electronic receipt (eReceipt) as a means to reduce the usage of thermal paper. Figure 18 shows the three alternative ways to deliver an eReceipt and their technical solutions.

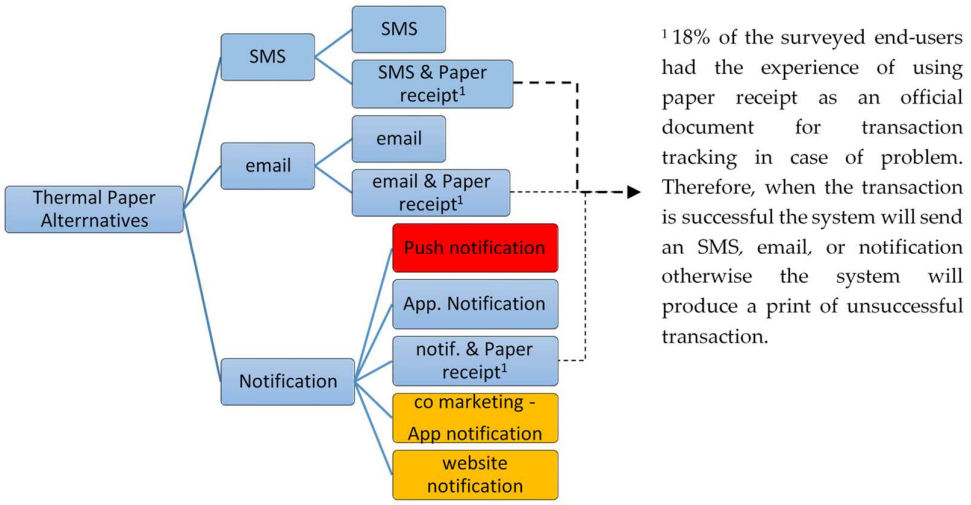


Figure 18 Thermal receipt Alternatives in Iran.

The interview with an android POS developer of the company revealed that sending a push notification needs many changes in the existing reporting system and the software of the company. On the other hand, the process of sending push notification needs a cooperation with Telecommunication Company of Iran (TCI). TCI is a governmental operator in Iran offering telecommunication services in the whole country. This external company must be a partner in the process of sending SMS, but sending a push notification is problematic for the existing infrastructure of TCI. By all accounts, sending push notification is very complicated from the technical point of view and it is presently a very expensive service. Therefore, this option was eliminated from the possible alternatives.

Co-marketing means that SEP sends the eReceipt as a notification but not through its own application; therefore, the eReceipt will be sent through the application of other partner companies. The interviewed marketing expert of the company remarked that while such event is technically possible, at

the moment and in the near future the company does not have any partner of such kind: therefore, this option was eliminated from the possible alternatives. Website notification is not applicable because the end users are not directly connected with the service provider. Co-marketing of the website notification is also not applicable because of the same reason highlighted for the application of co-marketing.

Near field communication (NFC) technology is another option, which could be fruitful to limit the paper receipts. Apple Pay, Samsung Pay, Android Pay, and others are using the same technology. However, it is possible to use NFC only if the terminal is also NFC-enabled and, as the Android POS developer expert said, "POS terminals of retail shops in Iran do not presently offer NFC for payment cards or smartphones".

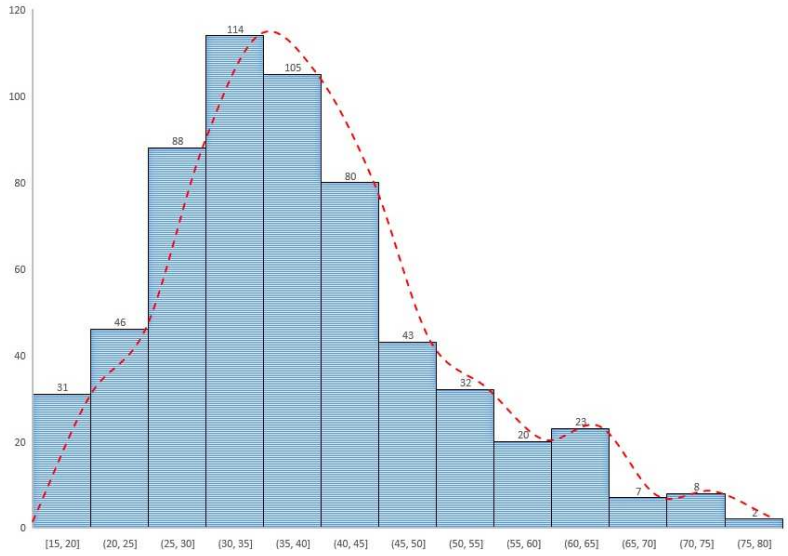


Figure 19 Age distribution of the respondents.

4.4.2. Second Data Collection Phase

The final database includes 600 respondents. The age of the respondents follows a normal distribution (Figure 19). Moreover, 43% of the respondents are female and 57% are male. They are classified in more than 60 job categories and the educational taxonomy of the respondents includes primary school, high school, high school diploma, bachelor's and master's degrees and Ph.D.. This variety confirms the diversity of the respondents. All 600 interviewees from different cities and differing by age, job, and education level use a PSP company's service in different forms.

One of the questions was aimed to assess the level of environmental concern of the end users of the payment service were aim to assess of the final users of the online payment service (Figure 20) Another question investigated the habit of "Taking the paper receipt after the electronic payment" because the POS terminal prints it, only if the customer explicitly selects this option

(Figure 21). As already mentioned, a micro-zone inside Tehran was selected for 200 random interviews, while the remaining interviews were done in other zones of Tehran and in another city. Figure 22 shows the interviewees' level of preference of using the printed receipt in the different places where the interview was conducted.

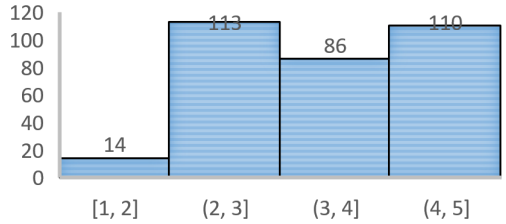


Figure 20 Concern for the environmental issues (y-axis: number of respondents, x-axis: the score in the 5-point Likert scale, 1 not concerned - 5 especially concerned).

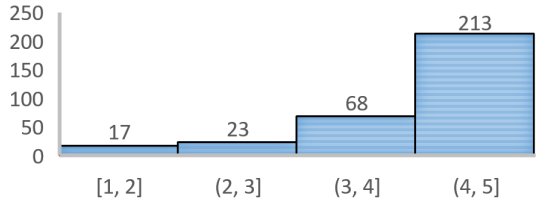


Figure 21 Taking paper receipt after electronic payment (y-axis: number of respondents, x-axis: the score in the 5-point Likert scale, 1 usually don't - 5 usually do).

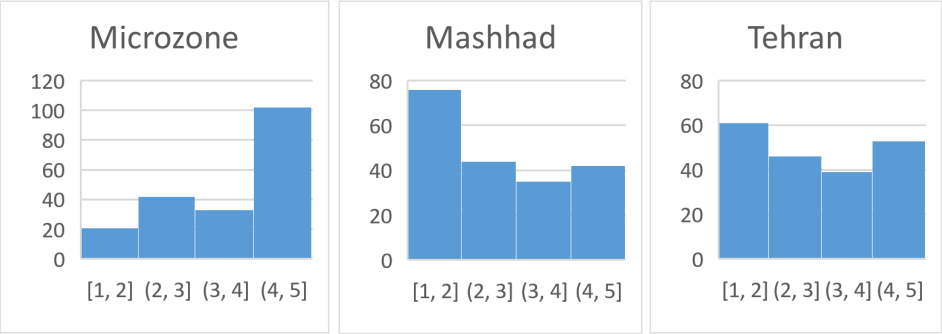


Figure 22 Comparing the end user preferences of using the printed receipt in Micro-zone (A), Tehran (B), and Mashhad (C).

4.4.3. Ranking the Alternatives by TOPSIS

This section presents the results of the application of the TOPSIS method to rank the alternatives to the printed receipts. The six alternatives (shown in blue in Figure 18) were assessed against six criteria. The criteria include

three attributes related to the company and the feasibility of the alternative to using thermal paper, and three sustainability pillars (social, economic and environmental aspects). In the first phase of data collection, the experts of the research and development department of the company suggested to combine the environmental with the economic attribute of sustainability. The criteria were weighted after the interviews with SEP experts.

SMS, email and application can be used but regulation in force establishes that a hard copy be given to the customer in case of unsuccessful transaction. According to the collected data, the percentage of unsuccessful transactions in seven successive months is roughly 10%. Therefore, the alternatives that require a print in the case of unsuccessful transactions (e.g., SMS and print) are scored 10% less than the corresponding pure electronic receipt. The successful transactions are illustrated in Figure 23. The hardware, software, and cost scoring were extracted from the interviews with the experts of the company. As the main goal of the study is to find the most sustainable alternative to thermal paper usage, the company experts agreed to give the sustainability pillars a weight of 25%. Setting up new alternative hardware and software depend on some infrastructures and third parties that are external companies. On the other hand, the cost of introducing the new reporting system to limit the use of thermal paper receipt was weighted 10% because, according to the experts, it is less important than the technical possibility of setting up the new system; this testifies the current commitment of the company's senior management to sustainable development, environmental issues, and end user safety.

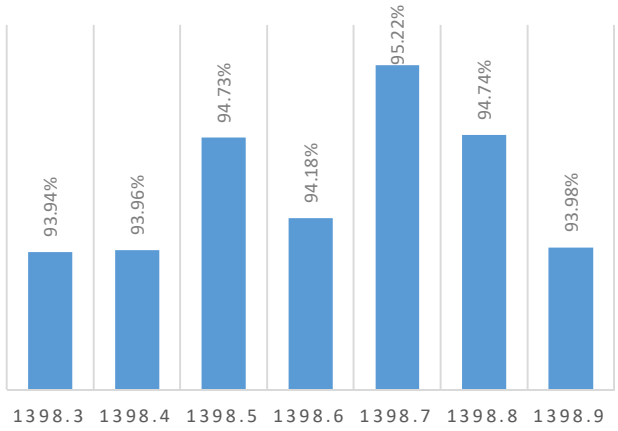


Figure 23 Successful transactions in 7 successive months.
The solar calendar is customary in Iran. In this study, the data belong 7 successive months of the solar year 1398 regarding to Iranian calendar. In AD Calendar, 01/03/1398 is 2018/05/22.

Table 17 illustrates the TOPSIS assessments. The social column reports the preferences as average scores of the interviewed end users on a five-point scale. The other columns of the table (environmental economic influence, hardware and software availability and the cost) were scored according to

the interviews with the experts of the PSP company: the scores are the averages of the experts' answers.

4.5 DISCUSSION

4.5.1. Responsible Consumption

The habit of using the printed receipts is presently very common among sellers and end customers, who usually produce and take them. Such cultural aspect is key and should be changed. For instance, the owners of the POS terminals could inspect their reports online and save a digital copy instead of printing them. As results from the interviews with the SEM experts, using thermal printers for long reports results in wear of the mechanical parts, which require maintenance before schedule and maybe emergency maintenance service and, consequently, extra transportation. On the other hand, if the transaction is successful, both seller and buyer can refute the printed receipt. In fact, the end users often check the receipt once and threw it away immediately. Moreover, since the SMS reporting of the transactions is cheap in Iran—yet more expensive than email with Iran's national internet—all of the electronic payment users can be encouraged to use the SMS reporting service for their bank account; indeed, they can receive an immediate SMS from the bank for any withdrawal from the account. This means that, the habit of printing the receipt can be considered as a "false using culture," which could be changed by providing the users with accurate information.

According to the survey results, the majority of the respondents are aware of the toxicity of thermal papers, while a 34% are not aware of the environmental impact caused by the paper receipts. The histogram in Figure 7 shows how much the respondents are concerned with environmental issues, while the histogram in Figure 8 shows the number of respondents who habitually take the receipt after electronic payments in general. In addition, 54% of the respondents declare that they suggest to others to take the paper receipt. This confirms that even if the majority of subjects are aware of the environmental and safety issues, they have a strong tendency to use the traditional form of this complementary service. In sum, the respondents' environmental awareness and practices are not aligned.

Table 17 TOPSIS calculation and ranking results.

		Max	*Max*	*Max*	*Max*	*Min*
	Weight	0.25	0.25	0.2	0.2	0.1
		Sustainability Pillars		Company		
Alt.s	Sub Alt.s	Social	Env. & Econ.	Hardwar	Software	Cost

A1	Sms	Sms	0.52	10	9	7	8
A2		Sms & Print*	0.53	9	8	7	9
A3	Email	Email	0.46	10	8	6	2
A4		Email & Print*	0.61	9	7	4	5
A5	Application	Application	0.52	10	10	7	4
A6		Application & Print*	0.54	9	9	6	5

Normalized [1]	**A1**	0.399174	0.429141	0.429547	0.45663	0.545595
	A2	0.406851	0.386227	0.381819	0.45663	0.613795
	A3	0.353116	0.429141	0.381819	0.391397	0.136399
	A4	0.468262	0.386227	0.334092	0.260931	0.340997
	A5	0.399174	0.429141	0.477274	0.45663	0.272798
	A6	0.414527	0.386227	0.429547	0.391397	0.340997
Positive Ideal Solution [2]		0.117065	0.107285	0.095455	0.091326	0.01364
Negative Ideal Solution [3]		0.088279	0.096557	0.066818	0.052186	0.061379

	S+ [4]	S- [5]	C [6]
A1	0.04543	0.046804	0.507448
A2	0.054721	0.042468	0.436962
A3	0.036924	0.056268	0.603791
A4	0.053718	0.039659	0.424719
A5	0.022008	0.061339	0.735943
A6	0.031233	0.045002	0.590308

[1] Normalized matrix constructed regarding Formula (1) in Section 2 and then the weighted matrix constructed regarding Formula (2) but not presented in this table for more simplicity.

[2] Positive Ideal solution calculated regarding Formula (3) in Section 2

[3] Negative Ideal solution calculated regarding Formula (4) in Section 2

[4] Positive separation measure calculated regarding Formula (5) in Section 2

[5] Positive separation measure calculated Formula (6) in Section 2

[6] Relative closeness to the ideal solution calculated regarding Formula (7) in Section2.

** If the transaction is successful, the system will send an eReceipt, otherwise the POS terminal will print a paper receipt for unsuccessful transaction.*

Figure 9 shows the level of preference, on a 1–5 score, for using the paper receipt in a micro-zone in Tehran, in whole Tehran and in another city. Comparing the histograms B and C unveils that the social preference is very similar in different cities; on the contrary, the answers of the micro-zone appear to be rather different. In the specific, the chosen micro-zone is a commercial area with many shops and malls. It seems that in a commercial zone, users prefer to take the paper receipt after their transactions. This might be related to the characteristics of the commercial transaction which is strongly regulated by traditional habits. To sum up, in order to decrease the use of thermal paper receipts, efforts for cultural change and public awareness are the first step.

All the interviewed experts agree on the influential role played by the regulations related to online payment in Iran. According to the instructions of the standards SHP_STD_EFTPOSRECEIPT, providing a receipt is a necessary complementary service for PSP companies. Nevertheless, this receipt could be sent by email. The paper receipt is not a requirement but just a traditional way to provide this service, which established a habit and culture that could be changed. The dematerialization of the receipt, on the other hand, is technically possible by adding a new function script in the main software of the PSP company.

According to this regulation, the POS terminal must offer the opportunity to print the receipt, but the service provider can add another option besides printing. Therefore, even if the PSP company adopts greener alternatives, the "print" option must always be available: the selection depends on the client's decision. Furthermore, if the POS terminal cannot give the paper receipt, whenever the user selects the print alternative, the transaction fails. This legal necessity calls for a culture of responsible consumption. Indeed, the whole transition to a sustainable supply chain will strongly depend on the end users' requirements and preferences. It is the end user who chooses to print the receipt or accept a green alternative. In this case, a change of habit could result from a more widespread communication of the issues connected to the hazardous material on the thermal papers and the difficulties and social costs associated with recycling this paper.

A revision of the regulation is also possible. In fact, every year representatives of the payment service sector and the authorities gather to review the obligations and rules, and survey the operations and functions of PSPs. Then, a stronger commitment to provide a greener service could be promoted within the updated regulation. On September 15, 2016, the Iranian government enacted the adoption of the agenda 2030 in all the cases where its goals are not contrary to the law. Moreover, on May 10, 2017 the Iranian foreign minister declared," We have no obligation to follow the agenda in cases that not comply with internal laws and customs". This means that the government will support the efforts to solve environmental

issues. Since the elimination of hazardous material is associated with environmental issues, the Iranian government will also promote and support the requirements for the transition to a more sustainable supply chain in the payment service.

4.5.2. Unnecessary Trips

Thermal printers in POS terminals are the source of a considerable number of trips for maintenance. Classical POS terminals have more hardware problems and high-tech sets have more software problems. The majority of the POS terminals in Iran are classical models. Therefore, the best way to decrease the maintenance operations of the POS is through the reduction of the causes of hardware wear and roll replacement, which confirm the above-mentioned conclusion. In addition, in order to decrease the transportation waste, an optimization of the route travelled for maintenance by the technicians could be useful. In the selected zone, many of the inspection locations are closer than 50 meters together (see Figure 4). Since petrol is very cheap in Iran, there is an unintentional inclination to use internal combustion engine vehicles even for short distances, which is an important source of CO_2 emission and traffic in big cities. These facts call for another cultural change to march a close distance on foot. To conclude, two kinds of improvement are required to decrease the transportation waste: first, the best route to reach all of the inspection points, and, second, the transportation means, from vehicle to foot.

4.5.3. Disposal

A robust plan for collecting the thermal paper receipts is still lacking. By all accounts, using thermal papers is not an eco-friendly way of reporting and monitoring the payments and transactions. The existing consumption of printed receipts is the source of a huge amount of thermal paper containing hazardous material. This paper waste is collected together with other solid waste and is frequently wrongly mixed with normal recyclable paper, thus contaminating the final product of the recycling activity. As previously remarked, at the end of the service supply chain there are two types of subjects, shop owners and end customers, who use the payment service and take the receipt. As for the end customers, only 17% of the respondents declared to separate the thermal paper as hazardous material, 36% of the respondents separate the paper from other kind of trash but they mix the receipts with other papers. On the other hand, there was only one of the interviewed shop owners who regularly collects the thermal receipts in a separated bin when the customer does not need to keep it anymore. To conclude, a robust plan for collecting the thermal paper waste especially in selling points and shops is necessary.

4.5.4. The Best Alternative to Paper Receipt

The TOPSIS evaluation shows that, according to the survey results, the most appropriate alternative to the thermal paper receipt in the service supply

chain of SEP Co. is the notification sent by an application (app notification). This will be a great transition toward sustainability in the service sector in Iran. Nevertheless, as remarked by an interviewed Android POS Developer of the company, some cyber-security issues will arise in case of setting up the app notification instead of the thermal paper receipt. Moreover, several end users do not use the smart phones yet, while many smart phone owners will need tutoring to be able to use the app notification.

After the internet shutdown in Iran in November 2019, many internet users distrust internet-based services. However, the proposed service can be based on the national internet, which seems to be considered more reliable after that event. Still, the cyber security of the national internet will be an issue to be settled. To sum up, implementing the app notification needs more studies on cyber security, training programs for the end users and keeping the option of printing the receipt for the group of customers who do not use smartphones.

4.5.5. Managerial Implications

The interviewed experts agree that the adoption of alternative way of reporting in the service supply chain might affect the managerial processes of the company. It has been remarked that the investigated service is complementary; therefore, a possible dependence on external providers of IT services is possibly less problematic than the case of the core service. Nevertheless, the risk of lock-in cannot be neglected: partnership administration thus becomes a core managerial activity. Particularly in the supply chain planning phase, risk management becomes a necessary administrative measure to ensure that the service is resilient and sustainable. Furthermore, as previously observed, the identified alternatives require a close collaboration with the national internet service. This cooperation might reduce the power of the company's management on strategic decisions concerning technology selection and updating, thus diminishing the company's agility.

The experts concur that the introduction of the proposed solutions will have organizational benefits too, as it will simplify some resource-consuming processes (e.g. material flow management), which, in the specific case, are presently associated only to complementary services. Moreover, the transition to the eReceipt will reduce the maintenance of the POS terminals, and the associated direct costs, but also the administration cost for managing and scheduling the maintenance service and the operators. These outcomes will eventually free up management resources that can be assigned to the core services. In addition, a partnership with the key external service suppliers could provide a competitive advantage by using IT technology to design new value-added services or open up new markets.

4.5.6. Limitations of the Study

The main limitations of the present study concern the structure of the evaluation model and the general validity of the results. The MCDM model employs a small number of criteria related to sustainability. This allowed to reduce the time required for the interviews and their complexity, which was compatible with the available resources for the survey. However, in order to carry out a more detailed evaluation, a wider set of attributes of the concept "sustainability" should be used. The attribution of weights to the criteria, which in the present study were validated by the interviewed experts, could be more accurate by means of assessment procedures like the "swing weights" or pairwise comparisons. Still, such procedures require a more demanding interaction between interviewer and respondent. As far as the results are concerned, it must be remarked that they clearly depend on the surveyed samples. In particular, the identified alternatives to the printed receipt were validated by the SEP experts and they are probably applicable to other Iranian PSPs. Nevertheless, their acceptability in other contexts should be confirmed as it depends on the technology that is economically available and the legal requirements in force.

4.6 CONCLUSIONS

The service that is investigated in this study is made up of digital core services and complementary services that can be based on soft or hard activities. The end users value the opportunity to retrieve a receipt after a payment transaction and this is often regulated by the law. Traditionally, the receipt is printed on thermal paper, which is the source of waste and environmental costs. Therefore, this study addressed the first research question, i.e., what feasible substitutions of paper receipt can be implemented, by means of interviews with the company experts. Three main alternative ways and nine sub-alternatives were identified. The second question was addressed by ranking the alternatives according to a set of criteria proposed in agreement with the company experts. In summary, a reduction of the waste produced in the traditional service offered by the investigated PSP in Iran, is possible by offering two options to the users:

1. using the app notification as a rule;
2. printing the receipt only in particular cases—as previously noted, the legislation on electronic payment sets out this requirement.

The transition to the green service needs some changes in the core managerial activity like partnership administration and the elaboration of a risk management plan. On the other hand, the new configuration of the service could provide some organizational benefits, such as a leaner service

supply chain and reduced administration costs. However, this approach has some limits that should be considered. Since the first option needs a cooperation with third parties, like Telecommunication Company of Iran, and providing some private data to the external companies, cyber security and customer privacy should be considered in the process of sending the eReceipt. In order to make the second option viable, it is necessary to raise the public awareness on the use and disposal of hazardous materials, and reinforce a responsible consumption behavior of the users of the payment service. On the other hand, the second option strongly depends on legal requirements and users' habit. In fact, the results of this study show that the public is well aware of the environmental and safety issues in general, but their declared preference for the traditional printed receipt markedly contrast with that. The complete substitution of the paper receipt with eReceipt will be possible only if public support for sustainable consumption is strong enough to influence the regulatory bodies and transform actual practices.

Each of the identified alternative ways for thermal paper receipt needs some change in the company and ancillary services that company use in service supply chain for providing the main service (electronic payment service). In addition, all of the alternatives are related with some uncertain future events and risk. In other words, the alternatives are associated with some threats beside the opportunities that they offer. In this chapter, the alternatives were prioritized according the sustainability pillars without considering future uncertainty; in the next chapter, these alternatives will be analyzed through the RO Analysis Method.

5 Implementation Example

A case study on PSP companies service is conducted to employ the Risky-Opportunity analysis Method (ROAM) in the socio-economic and socio-ecologic transition towards providing a green supply chain. The following abstract extracted from this chapter is accepted by the peer-review process on 19 March 2020 to be presented in the 2nd International Conference on Sustainable Production and Consumption and became a candidate for the Journal of Sustainable Production and Consumption - Elsevier, as a selected paper of the conference.

ABSTRACT:

The creation of a sustainable future requires a global approach, which must take into consideration the transition towards cleaner production and services. Extensive research has been focused on sustainable production, while far fewer studies have investigated the transition to sustainable services. Transformation in socio-ecological, socio-economic, and socio-technical systems is necessary to produce a systematic change towards the concept of green service. This study is focused on the payment service provider (PSP). ePayment has been considered a traditional complimentary service in financial systems. However, thermal papers that are widely used in the ePayment service are toxic because of the reactant acid in thermal paper, which is often bisphenol A (BPA). Thermal paper is thus not only a cause of health issues, but it also must be recycled separately from other papers. Therefore, making a change in the reporting system of this service is necessary to move towards green service. This study includes a multi-dimensional analysis to find the most effective way of transition towards sustainable service. Indeed, there are different solutions to eliminate, reduce, or manage the waste in the life cycle of the thermal papers. Nevertheless, different methods provide different ecological and economic benefits, but they are also associated with some risks and resource requirements to enable the change in the company's activity and processes. A Risky-Opportunity analysis method (ROAM), based on an Analytic Network Process network, was therefore conducted to compare the resource consumption and assess risks for substituting the existing

reporting system with a green one. The main goal is to find the most feasible way of introducing a change in the company for its transition towards sustainability.

Keywords: sustainable service, Green Service, Payment service providing, Consumer engagement, Toxic waste management, Change management, Service waste management, Risky-Opportunities

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5.1 INTRODUCTION

In order to enhance business sustainability, PSP companies are marching towards the digitalization of the supply chain. Printing the transaction receipt is an ancillary service of the PSP companies to provide a document for customers that confirms the transaction. The receipt is provided by POS terminal in the selling point. The POS terminals use the thermal paper to print the information about the transaction. These thermal papers are extremely dangerous and in the previous chapter, the available alternatives of paper receipt were investigated. Notwithstanding, the previous study has not taken the risks of the alternatives in account. Besides, all of the feasible alternatives that can be used to eliminate thermal paper from the service supply chain are associated with some threats. It was the main motive to conduct the study of this chapter to use the new method, consider the uncertainty of the alternatives which could come along with positive and negative effects, and finally compare the results of new method with previous analysis. The main goal of this study is to select an alternative way considering the threats and opportunities of alternatives. For this aim, we will use Risky-Opportunity (RO) analysis method (ROAM) to assess the risk-taking capability of the company in respect of the ROs. In the next section the general aspects of current study including data collection, and the methodology and tools will be reported.

5.2 MATERIAL AND METHODS

The qualitative and numerical data which will be used for the RO analysis, are collected by semistructured interview with R&D expert, Data analyst, and hardware and software developers of PSP companies. This Chapter is structured to implement ROAM in a real risky-opportunity analysis case. It is worth remarking that chapter 4, was focused on a specific PSP Provider in Iran because it was the first step of the study and we need to collect real data about the challenges and solutions. However, for this chapter, the alternatives for a PSP company in general (not a specific company) will be studied from the risk and opportunity perspectives; the interviewees are selected from the personnel of different PSP companies or other organizations, but with related skills and familiarity with electronic

payment, servitization, digitalization, cybersecurity, etc. The interviewees were selected among the experts that wanted to share their knowledge and experience; all the figures in the tables are provided by them, however, the data are reported anonymously and do not mentionthe companies and the interviewee's name. Two software, which are used in this chapter are Microsoft Excel and SuperDecisions V3.2 that is employed to create and analyse the network. The Risky-Opportunities Analysis Method (ROAM) will be implemented in this case study. The procedure of ROAM, is explained in detail in Chapter 3 of current document.

5.3 Outline of the Steps of the ROAM in Case Study and Results

In this section, ROs analysis of the PSP company employing ROAM will be explained systematically. The number of steps complies with figure 9, and the procedure of employing each step is explained in detail in section 3.3.6. The outline of the case study steps is the following:

1. *The Goal,* The main goal of this project is to analyze the ROs related to the socio-economic and socio-ecologic transition of a PSP company, towards providing a green supply chain. Regarding the recent study on the PSP supply chain, eliminating thermal paper from the supply chain acillary services contains environmental, social, and economic opportunities (Aghazadeh Ardebili et al., 2020). The opportunities associated with eliminating thermal papers are: eliminating the production of toxic waste during the service supply chain, reduce the traffic caused by EM and PM of the POS terminals, and finally eliminating delivery of the thermal paper to the end-users of PSP service to avoid its dangerous consequences on social health.
2. *All Possible Alternatives Identification*, Regarding "Section 4.4.1. First Data Collection Phase -The identified alternatives" of the current document, two kinds of alternatives are identified in this supply chain. Using eReceipt to eliminate thermal paper receipt production, and using a combination of eReceipt and paper to reduce thermal paper production. Both of these alternatives are associated with some threats, therefore they count as main ROs of this analysis.
3. *Select The Feasible Alternatives For RO Analysis,* Regarding the conducted study on the all alternative ways of these two RO –Figure 18-, three of the ROs are not feasible because of the cost, or high impact and probability of threat occurrence. Table 18 shows the probability and impact of the threats for each alternative. Alternatives 5,8,9 were already removed from the analysis; and for the next steps of the analysis 6 alternatives will be considered:

RO_1 includes the eReceipt methods:

A1. SMS

A2. Email
A3. Application notification

RO_2 includes the combination of eReceipt and paper in case of transaction failure:

A1. SMS or Print
A2. Email or Print
A3. Application notification or Print

4. *Probability-Impact,* The final suitable alternatives to investigate are already identified and ranked in Chapter 4. However, even if the alternatives are already defined, Probability-Impact of the issues are necessary to support pairwise comparison of the issues in following steps. In Table 18 all of the issues including the Threats, Opportunities, Benefits, Costs of the ROs, and their alternatives are listed. Regarding the identified costs, HRM, Assets of the company (Servers), and Budget in cash are the resources that this company needs for these alternatives. According the probability and impact of the issues in Table 18, there is no opportunity or benefit that is not likely or has a negligible impact on improving the service considering the sustainability pillars. In addition, there is no threat or cost that is highly likely and has an extreme impact on making problem in the service. Therefore, we will not eliminate any alternative regarding probability-impact of the issues.

Table 18 Future issues (Risks, Opportunities, Benefits, Costs are categorized and listed in Table 19-22)
In this table, the probability is percentage between 0 and 100%, in which 0 means the issue will not happen, and 100% means the issue will certainly happen. The impact is an integer chosen between 0 and 10, in which 0 means the issue has no impact on the project and its goals, and 10 means the issue has an extremely strong impact on the project and its goals.

Issue	*How it influences*	*Prob. %*	*Impact*	*Related RO*	*Description*
Security	Information Accuracy *	10	9	RO_1	The information about the transactions is highly likely to be correct with a very low probability of mistake.
	Cybersecurity	10	10	RO_1	The probability of the risk of failure in information security, connections security, electronic banking, and cyber fraud is very low.
Service Adoption	Purchaser	50	10	$RO_{1,2}$	It is 50% likely that the purchasers do not accept the change in ancillary service.

	Vendor	50	10	$RO_{1,2}$	It is 50% likely that the vendors and shop owners do not accept the change in ancillary service.
Availability	Purchaser	20	10	$RO_{1,2}$	It is rather unlikely that the purchasers have not access to the requirements of new ancillary services.
	Vendor	50	10	$RO_{1,2}$	It is 50% likely that the vendors and shop owners have not access to the requirements of new ancillary services.
Environment	shuttles	80	4	RO_2	It is highly likely that with the new alternative way of receipt, using vehicles for the shuttles that have moderate to strong impact on the environment will be necessary.
	Thermal paper usage	10	7	RO_2	It is unlikely that with the new alternative way of receipt, providing a thermal paper receipt is necessary.
Service Providing Issues	Data transfer speed	10	9	$RO_{1,2}$	It is unlikely that data transfer speed causes a problem in the service.
	Troubleshooting speed	60	9	$RO_{1,2}$	If the system is affected by a technical problem, the whole service will not be available. It is moderately likely that the troubleshooting takes a lot of time and causes a problem of availability. The impact of this issue is extremely high. However, the experts believe that this problem happens when all kinds of new technologies and types of equipment are employed. Nevertheless, the speed of troubleshooting increases when the operators get more experienced, and common problems are fully identified.
Infrastructure	Internal Network (national internet)	10	10	$RO_{1,2}$	It is unlikely to have a problem in the network, in case of using Internal Network (national internet). However, if a problem happens in-

					network, the impact is extremely high on the service.
	Internet connection	50	10	$RO_{1,2}$	It is 50% likely to have a problem on the internet and if a problem happens, in-network, the impact is extremely high on the service.
	Telecommunicat -ion network issues	20	10	$RO_{1,2}$	It is rather unlikely to have a problem in the Telecommunication network. However, if a problem happens with the network, the impact is extremely high on the service.
	Network data issues	10	10	$RO_{1,2}$	It is unlikely to have a problem with network data. However, if a problem happens related to network data, the impact is extremely high on the service.
	Mobile internet issues	20	10	$RO_{1,2}$	It is rather unlikely to have a problem with the mobile network. However, if a problem happens with the network, the impact is extremely high on the service.
Competition-al advantage	Information integration	15	8	$RO_{1,2}$	It is 15% likely to have common representation for information and make reusing the knowledge, easier.
	Unique and universal app.	20	9	$RO_{1,2}$	It is 20% likely that company choose a universal app. for all of the services. If it happens, it will have a strong impact on improving the service.
	Branding	30	6	$RO_{1,2}$	It is moderately likely that if the RO accepted by company, it provides a branding for company by means of advertising that they respect the sustainability pillars.
	Initial Investment decrease	40	7	$RO_{1,2}$	If the RO accepted, it is 40% likely that initial investment for entering new markets and developing new service

					needs less initial investment.
	Market share increase	80	8	$RO_{1,2}$	It is strongly likely that accepting RO increases the market share (According to the interview that has been conducted and presented in Chapter 4)
Customer Behavior	Mobile payment increase	35	9	$RO_{1,2}$	It is moderately likely that mobile payment increases.
	Internet payment increase	15	9	$RO_{1,2}$	It is 15% likely that Internet payment increases.
	Printed receipt demand decrease	60	10	RO_2	It is likely that printed receipt demand increases gradually.
Social economy	Recycling cost	10	4	RO_2	It is 10% likely that recycling costs of thermal papers decreases.
Maintenance	Maintenance	80	8	$RO_{1,2}$	It is strongly likely that maintenance and the unnecessary shuttles decrease.
Service Cost	Service cost Decrease	70	8	RO_1	It is highly likely that service cost decreases.
	Maintenance cost decrease	80	6	RO_1	It is strongly likely that maintenance cost decreases.
Usability	Service usability	50	6	RO_1	It is likely that the capacity of the company to provide a condition for its users that they enjoy using an effective and efficient service increases.
Cost	introduce new service	100	7	$RO_{1,2}$	It is certain that stablishing new ancillary service will incur a cost on company.
	advertisement	100	7	$RO_{1,2}$	It is certain that introducing new ancillary service to the users and providing a guide for the users to employ the new technology will incur a cost on company.
	maintenance	50	5	$RO_{1,2}$	It is likely that new maintenance programs will be added to the existing PM program because of new equipment.

* *Information Security is an issue related with security. It has a low probability of occurrence and has very strong impact when one of the alternatives of RO_1 is implemented.*

In the next step the clusters, relation, criteria, and network will be constructed; then the weights will be calculated through ANP using pairwise comparison.

5. *Calculating The Parameters,* This step includes different sub-steps to construct the network and solve them by ANP as per follow:

5.1. The decision criteria in the current analysis are chosen according to all three sustainability pillars because the main goal of accepting RO transforms the supply chain ecologically, economically, and socially towards a green supply chain. However, this transition is a digitalization process; therefore, the technological aspect is also included as criteria in this analysis.

5.2. The elements for each cluster are listed in Table 19-22. The criteria column in the tables illustrate how each Element is related to decision criteria.

Table 19 "Pure Threat" cluster elements

No.	*Threat Description*		*Criteria*			
	issue	Threat	Soc.	Econ.	Env.	Tec.
T1	Security	Information Accuracy	*			*
T2		Cybersecurity	*			*
T3	Service adoption	Purchaser	*			
T4		Vendor	*			
T5	Availability	Purchaser				*
T6		Vendor		*		*
T7	Environment	Unnecessary shuttles	*		*	
T8		Thermal paper usage	*	*	*	*
T9	Service providing issues	Data transfer speed				*
T10		Troubleshooting speed				*
T11	Infrastructure	Internal Network (national internet)	*	*		*
T12		Internet connection		*		*
T13		Telecommunication network issues				*
T14		Network data issues				*
T15		Mobil internet issues	*			*

Table 20 "Cost" cluster elements

No.	*Threat Description*		*Criteria*			
	issue	Threat	Soc.	Econ.	Env.	Tec.
Co1	Cost	Introduce a new service		*		*
Co2		Advertisement	*			
Co3		Maintenance				*

Table 21 "Opportunity" cluster elements

No.	*Threat Description*		*Criteria*			
	issue	Threat	Soc.	Econ.	Env.	Tec.
Op1	Customer behavior	Mobile payment method increase	*	*	*	
Op2		Internet payment increase	*	*	*	
Op3		Printed receipt demand decrease	*	*	*	
Op4	Social economy	Recycling cost		*		
Op5	Computational advantage	Information integration				*
Op6		Unique and universal app.	*			*
Op7		Branding	*			
Op8		Initial Investment decrease		*		*
Op9		Market share increase		*		*

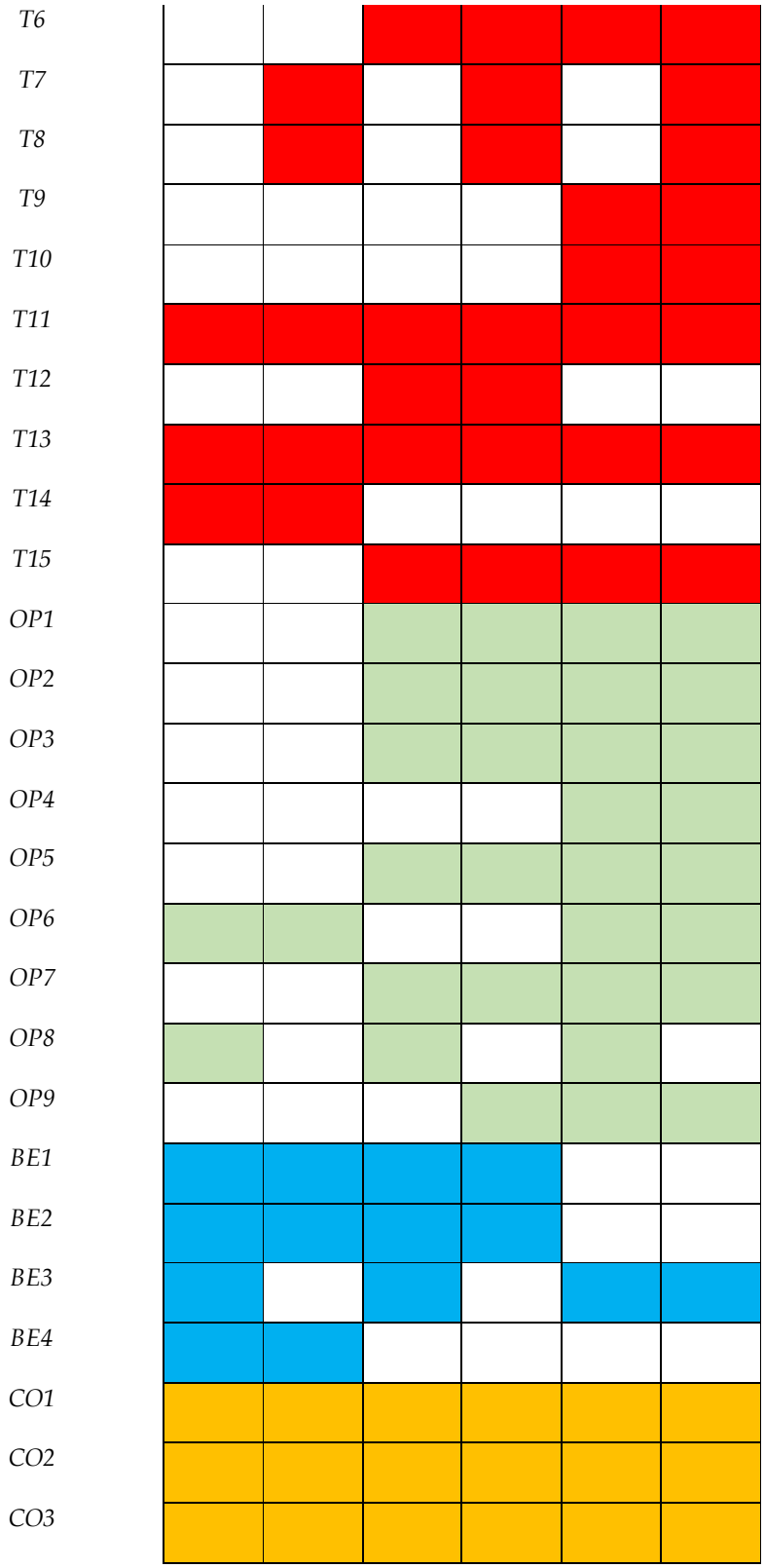
Table 22 "Benefits" cluster elements

No.	*Threat Description*		*Criteria*			
	issue	Threat	Soc.	Econ.	Env.	Tec.
Be1	Maintenance	Maintenance				*
Be2	Service cost	Service cost decrease		*		
Be3		Maintenance cost decrease		*		
Be4	Usability	Service usability	*			*

5.3. The relation between the T, Co, Be, Op, and the alternatives are shown in Table 23. The colored box emphasize a relation between the issue in the Column and the RO_iA_j in the row. For instance, T_1 is a threat that has impact on RO_2A_2, and RO_2A_3 . This relation will be used in constructing the network and pairwise analysis of the ANP analysis – Alternative no. 5,8, and 9 are already eliminated in Step 3 of the current procedure.

Table 23 The relation between T, Co, Be, Op and alternatives

Element type and no.	*Alternatives*					
	Ro1A1	Ro1A2	Ro1A3	Ro2A1	Ro2A2	Ro2A3
T1						
T2						
T3						
T4						
T5						


T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
OP1
OP2
OP3
OP4
OP5
OP6
OP7
OP8
OP9
BE1
BE2
BE3
BE4
CO1
CO2
CO3

5.4. In Figure 24, the general Risk network –refer to Risk cluster of Figure 11- and the constructed network for ranking the threats regarding the socio-economic transition problem in SuperDecision V3.2 are shown.

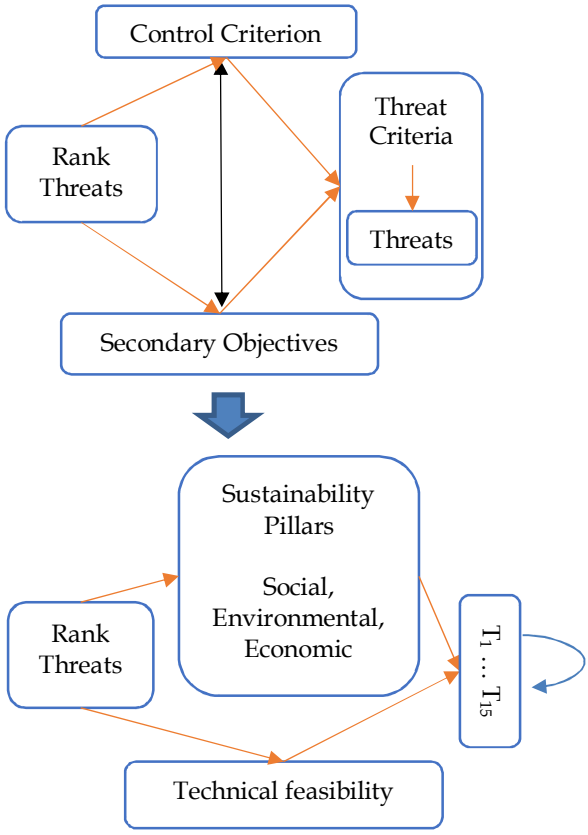


Figure 24 The "Risk" network

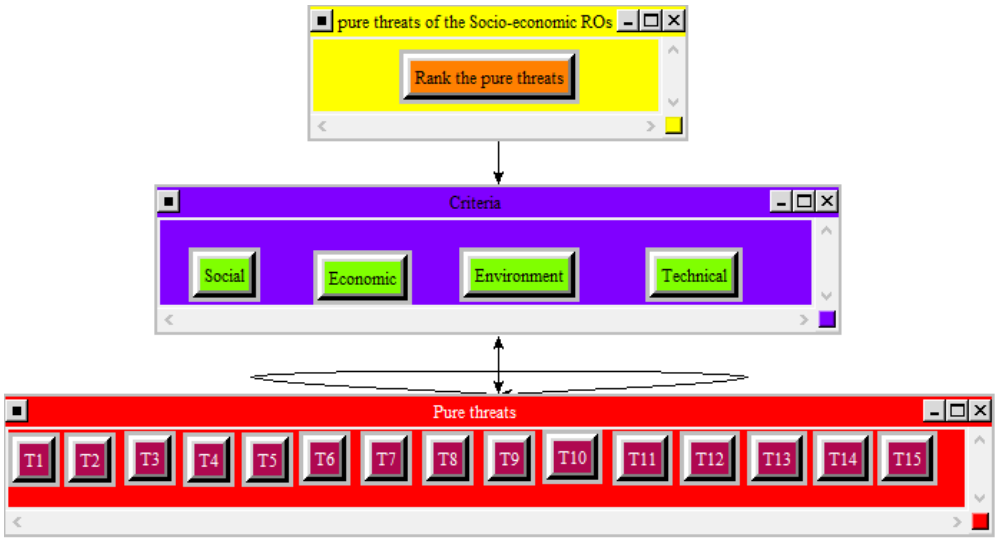


Figure 25 The "Risk" network (Constructed by Super decision Version 3.2)

5.5. The pairwise comparison has been done through data collected by semi-structured interviews and the geometric mean of all numbers are used for constructing the pairwise matrix. Table 24 shows the unweighted supermatrix and the limited supermatrix of the risk network to define the priorities of the pure threats. The final normalized priorities of all parameters are shown in Figure 26-29.

Table 24 Threats unweighted supermatrix in right, Threats limited supermatix in left (exported as text from SuperDecision V3.2)

		Economic	Environ.	Social	Technical	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	Rank the pure threats
Criteria	Economic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.064249
	Environment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.106233
	Social	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.106233
	Technical	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0.723285
Pure threats	T1	0	0	0.034655	0.137056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T2	0	0	0.321675	0.285017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T3	0	0	0.231306	0	0	0	0	0	0	0	0	0	0.888889	0	0	0	0	0	0	0
	T4	0	0	0.035167	0	0	0	0	0	0	0	0	0	0.111111	0	0	0	0	0	0	0
	T5	0	0	0	0.183268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T6	0.465664	0	0	0.064159	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T7	0	0.125	0.055552	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
	T8	0.053636	0.875	0.280392	0.180251	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0
	T9	0	0	0	0.050962	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T10	0	0	0	0.029769	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T11	0.356465	0	0.024449	0.013687	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T12	0.124234	0	0	0.010742	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T13	0	0	0	0.01548	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T14	0	0	0	0.01548	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T15	0	0	0.016805	0.01413	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pure threats of the Socio-economic ROs	Rank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		Criteria				Pure threats															
		Economic	Environment	Social	Technical	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	Rank the pure threats
Criteria	Economic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Environment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Technical	0	0	0.297929	0.297929	0	0	0.3	0	0	0	0	0	0.297929	0	0	0	0	0	0	0.297929
Pure threats	T1	0	0	0.082603	0.082603	0	0	0.1	0	0	0	0	0	0.082603	0	0	0	0	0	0	0.082603
	T2	0	0	0.171778	0.171778	0	0	0.2	0	0	0	0	0	0.171778	0	0	0	0	0	0	0.171778
	T3	0	0	0.05523	0.05523	0	0	0.1	0	0	0	0	0	0.05523	0	0	0	0	0	0	0.05523
	T4	0	0	0.006904	0.006904	0	0	0	0	0	0	0	0	0.006904	0	0	0	0	0	0	0.006904
	T5	0	0	0.110454	0.110454	0	0	0.1	0	0	0	0	0	0.110454	0	0	0	0	0	0	0.110454
	T6	0	0	0.038668	0.038668	0	0	0	0	0	0	0	0	0.038668	0	0	0	0	0	0	0.038668
	T7	0	0	0.003724	0.003724	0	0	0	0	0	0	0	0	0.003724	0	0	0	0	0	0	0.003724
	T8	0	0	0.142155	0.142155	0	0	0.1	0	0	0	0	0	0.142155	0	0	0	0	0	0	0.142155
	T9	0	0	0.030715	0.030715	0	0	0	0	0	0	0	0	0.030715	0	0	0	0	0	0	0.030715
	T10	0	0	0.017941	0.017941	0	0	0	0	0	0	0	0	0.017941	0	0	0	0	0	0	0.017941
	T11	0	0	0.008249	0.008249	0	0	0	0	0	0	0	0	0.008249	0	0	0	0	0	0	0.008249
	T12	0	0	0.006474	0.006474	0	0	0	0	0	0	0	0	0.006474	0	0	0	0	0	0	0.006474
	T13	0	0	0.00933	0.00933	0	0	0	0	0	0	0	0	0.00933	0	0	0	0	0	0	0.00933
	T14	0	0	0.00933	0.00933	0	0	0	0	0	0	0	0	0.00933	0	0	0	0	0	0	0.00933
	T15	0	0	0.008516	0.008516	0	0	0	0	0	0	0	0	0.008516	0	0	0	0	0	0	0.008516
pure threats of the Socio-economic ROs	Rank the pure threats	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Name	Graphic	Ideals	Normals	Raw
T1		0.526833	0.060691	0.047725
T2		0.526833	0.060691	0.047725
T3		0.706088	0.081342	0.063963
T4		0.706088	0.081342	0.063963
T5		0.526833	0.060691	0.047725
T6		0.526833	0.060691	0.047725
T7		0.473167	0.054509	0.042863
T8		1.000000	0.115201	0.090588
T9		0.526833	0.060691	0.047725
T10		0.526833	0.060691	0.047725
T11		0.526833	0.060691	0.047725
T12		0.526833	0.060691	0.047725
T13		0.526833	0.060691	0.047725
T14		0.526833	0.060691	0.047725
T15		0.526833	0.060691	0.047725

Figure 26 Overall synthesize priorities for the threats (Constructed by Super decision Version 3.2)

Name	Graphic	Ideals	Normals	Raw
Assets (Servers)		0.639619	0.276495	0.121983
Budget		1.000000	0.432281	0.190712
Human resource		0.673693	0.291225	0.128481

Figure 27 Overall synthesize priorities for the required resources (Constructed by Super decision Version 3.2)

Name	Graphic	Ideals	Normals	Raw
Op1		0.077074	0.042966	0.021483
Op2		0.233776	0.130323	0.065162
Op3		0.261652	0.145863	0.072932
Op4		1.000000	0.557471	0.278736
Op5		0.050326	0.028055	0.014028
Op6		0.050326	0.028055	0.014028
Op7		0.000000	0.000000	0.000000
Op8		0.080946	0.045125	0.022563
Op9		0.039715	0.022140	0.011070

Figure 28 Overall synthesize priorities for the opportunities (Constructed by Super decision Version 3.2)

Name	Graphic	Ideals	Normals	Raw
Be1		0.102929	0.052110	0.022990
Be2		1.000000	0.506275	0.223356
Be3		0.142857	0.072325	0.031908
Be4		0.729426	0.369290	0.162922

Figure 29 Overall synthesize priorities for the benefits (Constructed by Super decision Version 3.2)

6. *Stress and Strain Calculation:* Stress and Strain will be calculated for each alternative employing the parameters produced in the previous step.

6.1. *Stress* is calculated through Formula 1 from step 6 of section 3.3.6 and relation Table 23 in the current document. In the following the implementation of the Formula 1 is shown for Stress RO_1A_1.

From Table 23, the threats which are related to alternative RO_1A_1 are T_{11}, T_{13}, and T_{14}. The results of ANP in Figure 26 show that, the weights of these threats are all equal to 0.060691. In the same way and using figure 27-29, related resources are Co_1=0.276495, Co_2= 0.432281, and Co_3=0.291225; Opportunities are Op_6= 0.028055, Op_8=0.045125; and benefits are Be_1=0.052110, Be_2=0.506275, Be_3= 0.72325, Be_4=0.369290.

$$\text{Stress } RO_1A_1 = \frac{(0.060691*3)*(0.276495+0.432281+0.291225)}{(0.028055+0.045125)*(0.052110+0.506275+0.72325+0.369290)}$$

Stress RO_1A_1=2.488018

All of the other Stress values are calculated in the same way.

Table 25 The Stress

Alternative	*RO1A1*	*RO1A2*	*RO1A3*	*RO2A1*	*RO2A2*	*RO2A3*
Stress	2.488018	13.51665	2.129059	3.377369	9.801651	12.72224
Normalized Stress	0.0565	0.3070	0.0483	0.0767	0.2226	0.2889

The Stress is a dimensionless value, however, Strain is calculated in Euro currency in this study. On the other hand, the amount of Strain for different alternatives could be very different. Therefore to bring all the values of numeric columns into a common scale, we normalize the values. These values will be rescaled to make all the elements lie between 0 and 1. Linear Normalization is used to normalize the final Stress and Strain values with $nij=rij \,/\, \Sigma\, rij$ formula (Vafaei et al., 2016).

6.2. *Strain* The Strain calculation table is shown in Table 26. In Table 26 the costs are in Iranian Rial, the salary is the average salary for an expert with 10 years of experience in the Persian year of 1398, the price of the thermal paper belongs 7 Jan. 2020, however, this price is subject to high fluctuation regarding the political situation -because it is not internal production and whole demand is imported to Iran-. National Internet cost is negligible in Iran because the government charges the National Internet users very insignificant, aim to encourage companies and users to use National Internet instead of a global system of

interconnected computer networks (Internet). The costs in the following table include the cost of establishing a new service and the first month of implementing the service. To calculate the Strain of each Alternative Formula 2 from step 6 of section 3.3.6 will be employed.

Table 26 Strain calculation table

	COST CALCULATION	COST	STRAIN	NORM.
RO1A1 *	**[** 80 (cost of SMS in Iran in "Iranian Rial") * 4 (length of the text message regarding the characters that are in the SMS is equal to 4 SMS in Persian)* 2 (for each transaction two SMS is required including customer and vendor) * 31973 (Average tax in a specific macro zone regarding the results of Chapter 4) **]** + **[** 2 (switch developer, POS developer) * DS [1] * 160 h (stablish new service)+ DS * 20 h (outsourcing coordination and maintenance)**]**	88462720	1.382	0.1732
RO1A2	2(switch developer, POS developer)*DS* 160h (implementation)	64000000	1.000	0.1253
RO1A3	2 (switch developer, POS developer) * DS * 160h (stablish new service) + DS * 196h (application support service, CRM and cyber security measures)	103200000	1.613	0.2021
RO2A1	**[**(80*4*2*30457(successful tax in macro zone))+ Paper receipt price (26000 (price of each role of the thermal paper) IR / (20 m (length of the role of the thermal paper)/4.5cm(minimum of size))=58.5 IR)* 1472 (unsuccessful tax in macro zone)**]**+ **[** 2 (switch developer, POS developer) * DS (Developer Salary per hour (DS)= average 40000000 IR / 196 h = 200000)* 160 h (stablish new service)+ DS * 20 h(maintenance per month)**]**	87578592	1.368	0.1715
RO2A2	Paper receipt price * 1472 (unsuccessful tax in macro zone) + 2(switch developer, POS developer)*DS* 160h(stablish new service)+ DS*20h (maintenance per month)	64086112	1.001	0.1255

RO2A3	Paper receipt price *1472 (unsuccessful tax in macro zone)+ DS*20h(maintenance per month)* DS * 160h (stablish new service) + 2 * DS * 196h (application support service, CRM and cyber security measures)	103286112	1.614	0.2023

[1] *Developer Salary per hour (DS)= average 40000000 IR / 196 h = 200000*

* $Cost_{RO1A1} = (80*4*2*31973) + (2*160*200000)+(20*200000)= 88462720$

$Strain_{RO1A1} = Cost_{RO1A1} / Cost_{RO1A2} = 1.38223$

$Normalized\ Strain_{RO1A1} = Strain_{RO1A1} / \sum_{i=1}^{2}\sum_{j=1}^{3} StrainROiAj$

7. *Stress-Strain System,* The Stress-Strain system for this case study is shown in Figure 30.

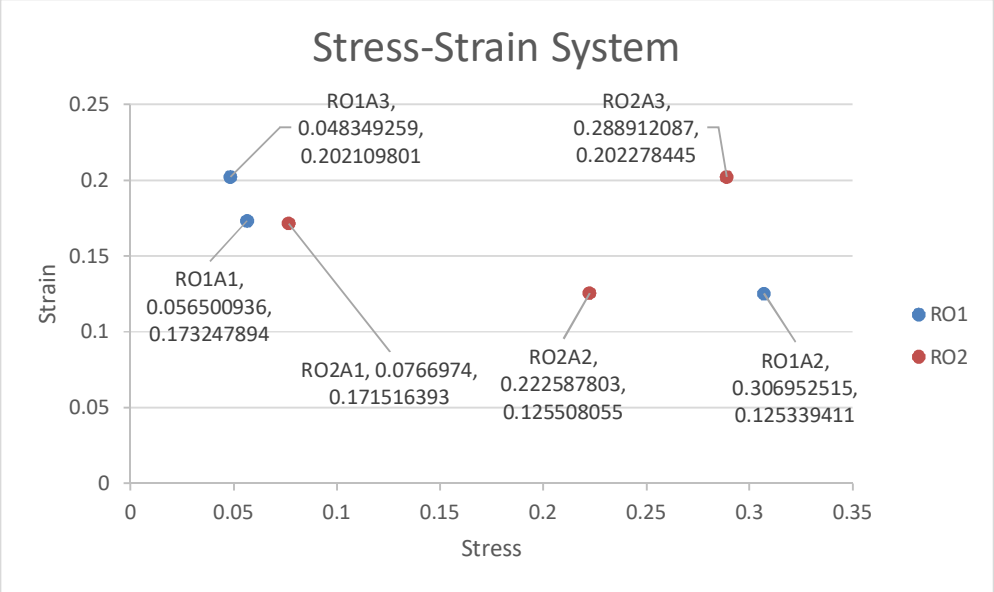


Figure 30 Strain-Stress illustration.

5.4 DISCUSSION

In Figure 30, considering that the vertical axis in the coordinate plane is strain, the significant high Stress and Strain of the RO2A3, shows that the benefits and opportunities of this alternative does not outweigh its threats and costs and also it is very expensive alternative in comparison with the other alternatives. It is a significant reason that the other alternatives are more suitable to accept so this alternative can be removed from further analysis.

Comparing blue and red points, shows that the transitions from RO_2A_2 and RO_1A_2 towards the other alternatives increase the Strain but decrease the Stress. RO_2A_2 and $RO_1A3$are cheaper alternatives but they have a high stress. Therefore, RO_2A_1, RO_1A_1 and RO_1A_3 are better to accept.

Since RO_2A_1 has higher stress, we focus on the transition from this alternative towards RO_1A_1 and RO_1A_3. The strain of RO_1A_3 is higher than RO_2A_1. It points to the fact that with a small amount of higher resource consumption, the stress of the target alternative will decrease. Nevertheless, the strain of RO_2A_1 is almost equal to the strain of RO_1A_1 and this proves that, the cost for establishing the ancillary service of eReceipt by "SMS" is almost equal to "SMS and paper receipt". But, the weight of the threats and costs of providing eReceipt by SMS in case of successful transaction and paper receipt in case of transaction failure is higher than its opportunities and benefits. This strain and stress values confirm that providing eReceipt by SMS in all scenarios is the best alternative.

RO_1A_1 has less Strain than RO_1A_3; however, the Stress is not significantly higher; this support that RO_1A_1 is the best alternative to accept.

In this particular case, RO_1A_2 (the cheapest) and RO_2A_2 have the lowest resource consumption rate; and RO_1A_3 has the lowest Stress. However, RO_1A_1 is selected to accept.

5.5 CONCLUSION

The results support the conclusion that RO_1A_1 (SMS) is the best alternative to accept because the stress decreases significantly with small resource consumption and it means the risk-taking capability of the company for establishing the ancillary service of providing eReceipt is higher than the other alternatives. Nevertheless, in chapter 4 of this document, an MCDM analysis conducted to analyze the same alternatives regardless of the uncertainty and possibility of taking the risks. The TOPSIS shows that RO_1A_3 (Application Notification) is the best option to select. This significant contradiction reveals the importance of taking the positive and negative effects in account when the alternatives of analysis are risky-opportunities. Regarding the results, when we consider the risk-taking capability of the company confronting a Risky-Opportunity, the result of the analysis could be different with using decision making through certainty.

6 Conclusion

6.1 NEW TERMS

Four new concepts are introduced in this thesis to design a method to support risk management and resource allocation in projects based on the concept of risk acceptance. *Combined Risk Response* is a risk response strategy that breaks down the risk and implements a combination of four known strategies (Accept, Mitigate, Reject, and Transfer). *Risky-Opportunity (RO)* is an uncertain event in the future which follows by some opportunities but concurrently associated with some threats. *Stress* and *Stress* are two new concepts, which are used to measure risk taking capability of company respect to a specific risk.

6.2 METHODOLOGICAL AND PRACTICAL LIMITATION

There are two main limitations in this study, which depend on the methodological approach of the quantitative analysis. Therefore, both of this limitations can be considered as methodological limitations more than practical limitations.

First, ROAM is designed to support project risk management decisions. The uncertainty is therefore considered at the project level. This means that the present configuration of the method is not suitable for shop-floor RM decisions. Also this method includes a numerical analysis approach to calculate the unweighted Supermatrix and limited Supermatrix; therefore, its actual application is currently based on a computer application program like Super-Decision that enables such calculations.

Second, real-world cases contain interdependencies among the criteria and alternatives: independency of the items is not a prerequisite for ANP, therefore the method is an effective tool for real-world case analysis. However during the validation of the method it was unveiled that these interrelations increase the number of pairwise comparisons. To fulfill all the pairwise comparisons increases the complexity of the network, makes the method time consuming and increases the human error likelihood during the calculations.

6.3 SCIENTIFIC CONTRIBUTION AND IMPLIMENTATIONS

The scientific value that is added by this study are a method, and new technical terms that fill the gaps of existing RM methods in accepting the opportunities that are associated with some risks. A new method is designed that identifies the most efficient resource and the amount of resource consumption to make the project ready to accept RO. This method is the result of the study in terms of actions, which are under the control of project managers. To indicate the appropriate action that should be taken in response for a risk, a new risk response strategy is introduced in this study. It is combinational risk response strategy (which is the combination of risk acceptance, mitigation, transfer, and reject strategies), which can be implemented to support the RO acceptance during the project. Also, a new index is introduced in this study to measure 'risk-taking capability' of a project associated with the RO. The project manager can evaluate the risk-taking capability associated with each RO separately to compare the situation of the project after accepting the ROs. Finally, this method offers new scientific results for project managers in decision making. According to the reported results in Chapter 2 – Section 2, ROAM provides a novel approach for the R&S GDM process.

6.4 WRAP UP

The designed method for RO analysis, Risky-Opportunity Analysis Method or ROAM, considers a combination of the risk response strategies and the concept of Risky-Opportunity during the analyses to take advantage of the opportunities which are associated with some threats and abatement of the negative effects of the threats and emphasize the opportunity; Concurrently with the analysis of the threats, opportunities, benefits and general cost of an RO, the method identifies the most efficient resource and the amount of resource consumption to make the project ready to accept each RO. On the other hand, this method is a support tool to evaluate (or measuring) the 'risk-taking capability' of an organization in accepting specific RO. Following the identified attributes in section 2 of literature review during the decision making process by the novel method, support decision-making with the aim to help the resilience and sustainability of the decision and company and simultaneously accept the risks of changes and improvements. Last but yet important, accepting the changes and taking advantage of the future ROs, motivating the companies in all sectors with the idea of using the positive effects of uncertainty guarantee continuous improvement even in an uncertain situation.

Appendix A

The result of the literature review after the first screening.

N.	Authors	Title	Highlights
1	Kuo R.J., Nugroho Y., Zulvia F.E.	Application of particle swarm optimization algorithm for adjusting project contingencies and response strategies under budgetary constraints	Particle Swarm Optimization (PSO) algorithm, keeping the total budget at the lowest amount
2	Dong B., Tang W., Zhou C.	Managerial flexibility strategies under supply and demand risks: quantity postponement vs. price postponement	The quantity postponement strategy can mitigate the demand risk
3	Grahn T., Jaldell H.	Households (un)willingness to perform private flood risk reduction – Results from a Swedish survey	This study applies the protection motivation theory (PMT), risk reduction
4	Akbari Ahmadabadi A., Heravi G.	Risk assessment framework of PPP-megaprojects focusing on risk interaction and project success	This paper uses structural equation modeling (SEM), The output of the SEM model was used to rank 32 identified risks
5	Wu Y., Zhou J.	Risk assessment of urban rooftop distributed PV in energy performance contracting (EPC) projects: An extended HFLTS-DEMATEL fuzzy synthetic evaluation analysis	An extended HFLTS-DEMATEL fuzzy synthetic evaluation analysis

6	Ravert R.D., Murphy L.M., Donnellan M.B.	Valuing Risk: Endorsed Risk Activities and Motives AcROss Adulthood	taking risks acROss the adult lifespan
7	Wu X., Gao J., Li Y., Wu C.	Development of a safety climate scale for geological pROspecting projects in China	The safety climate scale developed has four dimensions, i.e., project leader's safety commitment, safety institutions, risk response, and employee's safety attitude, containing a total of 17 measurable items, contribute to the benchmarking standards among different enterprises and projects
8	Guerra M., Abebe Y.	Pairwise Elicitation for a Decision Support Framework to Develop a Flood Risk Response Plan	Pairwise Elicitation for a Decision Support Framework
9	Tokdemir O.B., Erol H., Dikmen I.	Delay Risk Assessment of Repetitive Construction Projects Using Line-of-Balance Scheduling and Monte Carlo Simulation	Line-of-Balance Scheduling and Monte Carlo Simulation
10	Alashwal A.M., Al-Sabahi M.H.	Risk factors in construction projects during the unrest period in Yemen	identify risk response strategies
11	Dandage R.V., Mantha S.S., Rane S.B.	Strategy development using TOWS matrix for international project risk management based on prioritization of risk categories	
12	Miller F.	Exploring the consequences of climate-related displacement for just resilience in Vietnam	
13	Wu Y., Song Z., Li L., Xu R.	Risk management of public-private partnership charging infrastructure projects in China based on a three-dimension framework	grey fuzzy method
14	Keshk A.M., Maarouf I., Annany Y.	Special studies in management of construction project risks, risk concept, plan building, risk quantitative and qualitative	

		analysis, risk response strategies	
15	Naji H.I., Al-Zubaidi E.A., Ali R.H.	Risks response failure in construction projects	identify the risk response
16	Hosny H.E., Ibrahim A.H., Fraig R.F.	Risk management framework for Continuous Flight Auger piles construction in Egypt	
17	Faria Correa R.G., Kliemann Neto F.J., Souza J.S., Lampert V.N., Barcellos J.O.J.	Enterprise risk management in integrated crop-livestock systems: A method proposition	the current study aims to develop a method to manage risks for ICLS based on ERM, integrating the management of risks and aligning risk management with the strategic objectives.
18	Winneg K.M., Stryker J.E., Romer D., Jamieson K.H.	Differences Between Florida and the Rest of the United States in Response to Local Transmission of the Zika Virus: Implications for Future Communication Campaigns	
19	Charkhakan M.H., Heravi G.	Risk Manageability Assessment to Improve Risk Response Plan: Case Study of Construction Projects in Iran	
20	Wang L., Zhang X.	Bayesian Analytics for Estimating Risk Probability in PPP Waste-to-Energy Projects	Probability
21	Li Y., Hu Y., Xia B., Skitmore M., Li H.	Proactive behavior-based system for controlling safety risks in urban highway construction megaprojects	
22	Li Y., Wang X.	Risk assessment for public-private partnership projects: using a fuzzy analytic hierarchical process method and expert opinion in China	fuzzy analytic hierarchy process method
23	Budayan C., Dikmen I., Talat Birgonul M., Ghaziani A.	A Computerized Method for Delay Risk Assessment Based on Fuzzy Set Theory using MS Project™	Computerized Method for Delay Risk Assessment Based on Fuzzy Set

			Theory using MS Project
24	Ghassemi A., Darvishpour A.	A novel approach for risk evaluation and risk response planning in a geothermal drilling project using DEMATEL and fuzzy ANP	NP, DEMATEL, and fuzzy theory
25	Yu F., Li X.-Y., Han X.-S.	Risk response for urban water supply network using case-based reasoning during a natural disaster	
26	Gupta V.K., Thakkar J.J.	A quantitative risk assessment methodology for construction project	an integrated approach to prioritize risks using Group Technique for Order Preference by Similarity to Ideal Solution (GTOPSIS) and to quantify risks in terms of overall project delays using Judgemental Risk Analysis Process (JRAP), and Monte Carlo Simulation (MCS)
27	Li Y., Zheng Y., Wang J., Kodaka K., Li K.	Crash probability estimation via quantifying driver hazard perception	probability estimation
28	Zhang Y., Zhao C., Pang B.	Budget allocation in coping with supply chain disruption risks	
29	Adamtey S., Onsarigo L.	Analysis of pipe-bursting construction risks using probability-impact model	probability-impact model
30	Chengappa K.K., Prakash Rao B., Shriharsha, Sreenath V.	The implementation of analytical hierarchy process in risk assessment in a residential project	AHP
31	Degiannakis S., Filis G., Panagiotakopoulou S.	Oil price shocks and uncertainty: How stable is their relationship over time?	
32	Kiat J.E., Cheadle J.E.	Tick-tock goes the croc: A high-density EEG study of risk-reactivity and binge-drinking	
33	Pistoia F., Conson M., Carolei A., Dema M.G.,	Post-earthquake distress and development of	

	Splendiani A., Curcio G., Sacco S.	emotional expertise in young adults	
34	Zhang Y., Guan X.	Selecting Project Risk Preventive and Protective Strategies Based on Bow-Tie Analysis	Bow-Tie Analysis
35	Dennis S.A., Johnstone K.M.	A natural field experiment examining the joint role of audit partner leadership and subordinates' knowledge in fraud brainstorming	brainstorming
36	Farooq M.U., Thaheem M.J., Arshad H.	Improving the risk quantification under behavioural tendencies: A tale of construction projects	risk quantification
37	Yu M., Zhu F., Yang X., Wang L., Sun X.	Integrating sustainability into construction engineering projects: Perspective of sustainable project planning	
38	Asadi S.S., Rao V.E.	An integrated approach to a critical analysis of risk management in construction projects	5 phases; Risk identification, risk assessment, risk responses, risk monitoring and analysis and finally risk control
39	Zuo F., Zhang K.	Selection of risk response actions with consideration of secondary risks	The optimization model aims to minimize the total risk costs with time constraint
40	Rezaee F., Sabzeparvar M., Tayebee H.	Modeling the problem of choosing an optimal strategy to respond to project risks	A zero-one multiobjective mathematical model
41	Rahimi Y., Tavakkoli-Moghaddam R., Iranmanesh S.H., Vaez-Alaei M.	Hybrid Approach to Construction Project Risk Management with Simultaneous FMEA/ISO 31000/Evolutionary Algorithms: Empirical Optimization Study	FMEA
42	Liu Y., Sun C., Xia B., Liu S., Skitmore M.	Identification of Risk Factors Affecting PPP Waste-to-Energy Incineration Projects in China: A Multiple Case Study	risk identification

43	Dandage R., Mantha S.S., Rane S.B.	Ranking the risk categories in international projects using the TOPSIS method	(TOPSIS)
44	Hamilton-Webb A., Manning L., Naylor R., Conway J.	The relationship between risk experience and risk response: a study of farmers and climate change	risk experience and risk response
45	Wu Y., Li L., Xu R., Chen K., Hu Y., Lin X.	Risk assessment in straw-based power generation public-private partnership projects in China: A fuzzy synthetic evaluation analysis	A fuzzy synthetic evaluation analysis
46	Claassen L., van Dongen D., Timmermans D.R.M.	Improving lay understanding of exposure to electromagnetic fields; the effect of information on perception of and responses to risk	
47	Fang C., Marle F., Xie M.	Applying importance measures to risk analysis in engineering project using a risk network model	Applying importance measures to risk analysis
48	Wang X., Xia N., Zhang Z., Wu C., Liu B.	Human Safety Risks and Their Interactions in China's Subways: Stakeholder Perspectives	risk factors and motives identifications
49	Giordano D., Frasoldati A., Gabrielli E., Pernice C., Zini M., Castellucci A., Piana S., Ciarrocchi A., Cavuto S., Barbieri V.	Long-term outcomes of central neck dissection for cN0 papillary thyroid carcinoma	
50	Gilioli G., Schrader G., Grégoire J.-C., MacLeod A., Mosbach-Schulz O., Rafoss T., ROssi V., Urek G., van der Werf W.	The EFSA quantitative approach to pest risk assessment – methodological aspects and case studies	health
51	Nakandala D., Lau H., Zhao L.	Development of a hybrid fresh food supply chain risk assessment model	This paper proposes a hybrid model comprising both fuzzy logic (FL) and hierarchical holographic modeling (HHM) techniques where risk

			is first identified by the HHM method and then assessed using both qualitative risk assessment model (named risk filtering, ranking, and management Framework) and fuzzy-based risk assessment method (named FL approach).
52	Park J., Lee J.M., Lee D.H., Joo I., Yoon J.H., Park J.Y., Klotz E.	Value of Nonrigid Registration of Pre-Procedure MR with Post-Procedure CT After Radiofrequency Ablation for Hepatocellular Carcinoma	
53	Soofifard R., Gharib M.	A new approach to project risk responses selection with inter-dependent risks	Multiobjective Harmony Search (MOHS)
54	Wan M., D'Amato D., Toppinen A., Rekola M.	Forest company dependencies and impacts on ecosystem services: Expert perceptions from China	risk Identification
55	Pimchangthong D., Boonjing V.	Effects of Risk Management Practices on IT Project Success	
56	Ahmadi M., Behzadian K., Ardeshir A., Kapelan Z.	Comprehensive risk management using fuzzy FMEA and MCDA techniques in highway construction projects	fuzzy FMEA and MCDA
57	Motaleb O.H.	A model of risk response development for managing delays in construction projects	project management maturity model (PMMM)
58	Zhang M., Wang X., Mannan M.S., Qian C., Wang J.Y.	System dynamical simulation of risk perception for enterprise decision-maker in communication of chemical incident risks	
59	Naji H.I., Ali R.H.	Fuzzy decision tree of risks assessment generated from risk response	KNIME combine with WEKA from the results show the WEKA node

60	Zhang M., Wang X., Mannan M.S., Qian C., Wang J.	A system dynamics model for risk perception of lay people in communication regarding risk of chemical incident	SYSTEM DYNAMICS
61	Gu Y., Xie L.	Stochastic Look-Ahead Economic Dispatch with Variable Generation Resources	
62	Dellermann D., Fliaster A., Kolloch M.	Innovation risk in digital business models: the German energy sector	Innovation risk in the digital business model
63	Arias D., Vieira P.A., Mendes P.M.	Managing extreme agriculture risks in BRAZIL	
64	Nyamah E.Y., Jiang Y., Feng Y., Enchill E.	Agri-food supply chain performance: an empirical impact of risk	
65	AlRafea K., Elkamel A., Abdul-Wahab S.A.	Cost-analysis of health impacts associated with emissions from combined cycle power plant	
66	Harclerode M.A., Lal P., Vedwan N., Wolde B., Miller M.E.	Evaluation of the role of risk perception in stakeholder engagement to prevent lead exposure in an urban setting	Risk perception factors
67	Dennis S.A., Johnstone K.M.	A field survey of contemporary brainstorming practices	brainstorming
68	Davies A.B., Tambling C.J., Kerley G.I.H., Asner G.P.	Limited spatial response to direct predation risk by African herbivores following predator reintroduction	response to direct predation risk by African herbivores, nature, wildlife, biological potentials
69	Podlogar M.C., Rogers M.L., Chiurliza B., Hom M.A., Tzoneva M., Joiner T.	Who are we missing? Nondisclosure in online suicide risk screening questionnaires	just survey the risk response, cause, and effects
70	Zhang Y.	Selecting risk response strategies considering project risk interdependence	
71	Reim W., Parida V., Sjödin D.R.	Risk management for product-service system operation	
72	Perrenoud A.J., Smithwick J.B., Hurtado K.C., Sullivan K.T.	Project Risk Distribution during the Construction Phase of Small Building Projects	

73	Retchless D.P., Brewer C.A.	Guidance for representing uncertainty on global temperature change maps	
74	Pawan P., Lorterapong P.	A Fuzzy-Based Integrated Framework for Assessing Time Contingency in Construction Projects	fuzzy sets theory in assessing the impact on activity durations subjected to multiple risks
75	Beran M.J., Perdue B.M., Church B.A., Smith J.D.	Capuchin monkeys (Cebus apella) modulate their use of an uncertainty response depending on risk	
76	Dadsena K.K., Naikan V.N.A., Sarmah S.P.	A methodology for risk assessment and formulation of mitigation strategies for trucking industry	Failure Modes and Effect Analysis (MFMEA) to prioritize the mitigation strategy, using the Modified Risk Mitigation Number (MRMN) approach and applies Interval type-2 Fuzzy FMEA to rank the risk factors
77	Liu H., Liu L., Ji X.	Identification and analysis of metro foundation construction safety risk based on fault tree analysis	fault tree analysis
78	Turner N., Kutsch E., Leybourne S.A.	Rethinking project reliability using the ambidexterity and mindfulness perspectives	Purpose: The purpose of this paper is to bring together two seemingly disparate bodies of literature – ambidexterity (the ability both to exploit and explore) and mindfulness – to take a fresh perspective on the management of uncertainty
79	Ayala-Cruz J.	Project risk planning in high-tech new product development [Planificación de Riesgos en Proyectos para el Desarrollo de Nuevos Productos de Alta Tecnología]	
80	Pournader M., Rotaru K., Kach	An analytical model for system-wide and tier-specific assessment of	the multimethod research approach is adopted

	A.P., Razavi Hajiagha S.H.	resilience to supply chain risks	
81	Bi K., Huang P., Ye H.	Risk identification, evaluation and response of low-carbon technological innovation under the global value chain: A case of the Chinese manufacturing industry	Analytic Hierarchy Process (AHP)
82	Soltanmohammadi M., Saberi M., Yoon J.H., Soltanmohammadi K., Pazhoheshfar P.	Risk critical point (RCP): A quantifying safety-based method developed to screen construction safety risks	Risk Critical Point (RCP)
83	Gan J., Jarrett A., Gaither C.J.	Landowner response to wildfire risk: Adaptation, mitigation or doing nothing	
84	Vrhovec S.L.R., Hovelja T., Vavpotič D., Krisper M.	Diagnosing organizational risks in software projects: Stakeholder resistance	
85	Henri C.V., Fernàndez-Garcia D., De BarROs F.P.J.	Probabilistic human health risk assessment of degradation-related chemical mixtures in heterogeneous aquifers: Risk statistics, hot spots, and preferential channels	probabilistic approach
86	Fan Z.-P., Li Y.-H., Zhang Y.	Generating project risk response strategies based on CBR: A case study	
87	Grèze L., Pellerin R., Leclaire P., Perrier N.	Evaluating the effectiveness of task overlapping as a risk response strategy in engineering projects	
88	Roghanian E., Moradinasab N., Afruzi E.N., Soofifard R.	Project risk management using fuzzy failure mode and effect analysis and fuzzy logic	FMEA
89	Marle F.	A structured process to managing complex interactions between project risks	
90	El-Sayegh S.M.	Project risk management practices in the UAE construction industry	
91	Mangla S.K., Kumar P., Barua M.K.	Prioritizing the responses to manage risks in green supply chain: An Indian	fuzzy Analytic Hierarchy Process (AHP) and fuzzy Technique for Order

		plastic manufacturer perspective	Performance by Similarity to Ideal Solution (TOPSIS)
92	Li Y., Huang S.	Landscape ecological risk responses to land use change in the luanhe river Basin, China	
93	Lorenc A., Robinson N.	Evaluating sexual health planning for the London 2012 Olympics	health
94	Lee S.H., Kang H.G.	Integrated societal risk assessment framework for nuclear power and renewable energy sources	probabilistic risk assessment methodology
95	Hashim Motaleb O., Kishk M.	Assessing risk response maturity: A framework for construction projects success in the United Arab Emirates	Assessing risk response maturity: A framework
96	Trangkanont S., Charoenngam C.	Private partner's risk response in PPP low-cost housing projects	
97	Zhang Y., Fan Z.-P.	An optimization method for selecting project risk response strategies	the optimization model is developed, which integrates three critical elements that are the project cost, project schedule, and project quality
98	Bhoola V., Hiremath S.B., Mallik D.	An assessment of risk response strategies practiced in software projects	An assessment of risk response strategies
99	Ali J.S., Maryam M.	Environmental Risk Assessment of Dams by Using Multi-Criteria Decision-Making Methods: A Case Study of the Polrood Dam, Guilan Province, Iran	mcdm
100	Chien K.-F., Wu Z.-H., Huang S.-C.	Identifying and assessing critical risk factors for BIM projects: Empirical study	Identifying and assessing critical risk factors
101	Samadi H., Nazari-Shirkouhi S., Keramati A.	Identifying and analyzing risks and responses for risk management in information technology outsourcing projects under fuzzy environment	fuzzy ANP
102	Lu S.-T., Yu S.-H., Chang D.-S.	Using fuzzy multiple criteria decision-making approach for assessing the risk of railway	fuzzy multiple criteria decision-making approach

		reconstruction project in Taiwan	
103	Brouwers F.P., Asselbergs F.W., Hillege H.L., Gansevoort R.T., de Boer R.A., van Gilst W.H.	Elevated urinary albumin excretion complements the Framingham Risk Score for the prediction of cardiovascular risk - response to treatment in the PREVEND IT trial	
104	Niles M.T., Lubell M., Haden V.R.	Perceptions and responses to climate policy risks among California farmers	
105	Van Dongen D., Claassen L., Smid T., Timmermans D.	Peoples responses to risks of electromagnetic fields and trust in government policy: The role of perceived risk, benefits and control	Peoples responses to risks of electromagnetic fields
106	Yang X.-L., Ding J.-H., Hou H.	Application of a triangular fuzzy AHP approach for flood risk evaluation and response measures analysis	fuzzy AHP approach
107	Yamada T., Demura S.	Useful questionnaire items for fall risk screening in communities of Japanese elderly	
108	Zhang C., Fan J.	A study of the perception of health risks among college students in China	Health
109	Hopewell J.C., Parish S., Offer A., Link E., Clarke R., Lathrop M., Armitage J., Collins R.	Impact of common genetic variation on response to simvastatin therapy among 18 705 participants in the Heart Protection Study	
110	Franklin C.A.	Anticipating Intimacy or Sexual Victimization? Danger Cue Recognition and Delayed Behavioral Responses to a Sexually Risky Scenario	
111	Fang C., Marle F., Xie M., Zio E.	An integrated framework for risk response planning under resource constraints in large engineering projects	structure matrix representation is used to capture risk interactions and build a risk propagation model for predicting the global mitigation effects of risk response actions. For exemplification, a

			genetic algorithm is used as a tool for choosing response actions and allocating budget reserves
112	Li C., Lu G., Li P.	Risk element transmission model of construction project chain based on system dynamic	system dynamics
113	Arena M., Azzone G., Cagno E., Ferretti G., Prunotto E., Silvestri A., Trucco P.	Integrated Risk Management through dynamic capabilities within project-based organizations: The Company Dynamic Response Map	
114	Sato T., Hirao M.	Optimum budget allocation method for projects with critical risks	risk-based project value (RPV)
115	Niven R.J., Bardsley D.K.	Planned retreat as a management response to coastal risk: A case study from the Fleurieu Peninsula, South Australia	
116	Yang X., Zhou J., Ding J., Zou Q., Zhang Y.	A fuzzy AHP-TFN based evaluation model of flood risk analysis	A fuzzy AHP-TFN based evaluation model
117	Odeyinka H., Lowe J., Kaka A.	Regression modeling of risk impacts on construction cost flow forecast	Regression modeling of risk impacts on construction cost flow forecast
118	Xu Y., Lu Y., Chan A.P.C., Skibniewski M.J., Yeung J.F.Y.	A computerized risk evaluation model for public-private partnership (PPP) projects and its application	A computerized risk evaluation model
119	Harries T.	The anticipated emotional consequences of adaptive behaviouröimpacts on the take-up of household flood-protection measures	
120	Murali P., Ordóñez F., Dessouky M.M.	Facility location under demand uncertainty: Response to a large-scale bio-terror attack	formulate a special case of the maximal covering location problem (MCLP) with a loss function
121	Alhawari S., Karadsheh L., Nehari Talet A., Mansour E.	Knowledge-Based Risk Management framework for Information Technology project	

122	Mousavi S.M., Makui A., Raissi S., Mojtahedi S.M.H.	A multi-criteria decision-making approach with interval numbers for evaluating project risk responses	multi-criteria decision-making
123	Zhang X., Pandey M.D., Zhang Y.	A numerical method for structural uncertainty response computation	A novel numerical procedure, which realizes the stochastic analysis with dimensional reduction integration (DRI), C-type Gram-Charlier (CGC) series, and finite element (FE) model
124	Cerić A., Marčić D., Ivandić K.	A risk-assessment methodology in tunnelling [Metodologija procjene rizika u tunelogradnji]	
125	Wickboldt J.A., Bianchin L.A., Lunardi R.C., Granville L.Z., Gaspary L.P., Bartolini C.	A framework for risk assessment based on analysis of historical information of workflow execution in IT systems	
126	Wierts R., De Jong J.R., Lazarenko S.V., Paans A.M., Dierckx R.A., Willemsen A.M.	Characteristics of a new system for monitoring the leakage factor during regional hyperthermic isolated limb perfusion	
127	Banaitiene N., Banaitis A., Norkus A.	Risk management in projects: Peculiarities of Lithuanian construction companies [Rizikos valdymas projektuose: Lietuvos statybos i{ogonek}moniu{ogonek} savitumai]	
128	Abdelgawad M., Fayek A.R.	Fuzzy reliability analyzer: Quantitative assessment of risk events in the construction industry using fuzzy fault-tree analysis	fuzzy fault-tree analysis
129	Zhang X.	Social risks for international players in the construction market: A China study	
130	Chen W.-K.	A framework for nuclear power plant emergency response system	

131	Kujawski E., Angelis D.	Monitoring risk response actions for effective project risk management	
132	Ling F.Y.Y., Hoang V.T.P.	Political, economic, and legal risks faced in international projects: Case study of Vietnam	
133	Sun B., Luo H.-T.	Selection method of risk response schemes for mining project based on	fuzzy preference relation and consistency induced ordered weighted averaging (C-IOWA) operator
134	Ebrahimnejad S., Mousavi S.M., Seyrafianpour H.	Risk identification and assessment for build-operate-transfer projects: A fuzzy multi attribute decision making model	A fuzzy multi-attribute decision-making model
135	Seyedhoseini S.M., Hatefi M.A.	Two-pillar risk management (TPRM): A generic project risk management process	A conventional Risk Management Process (RMP) contains two main phases: (a) risk assessment that includes risk identification and risk analysis, and (b) risk response that decides what, if anything, should be done about the analyzed risks
136	Lee K.L., Meyer R.J., Bradlow E.T.	Analyzing risk response dynamics on the web: The case of Hurricane Katrina	
137	Zhao X., Cai X.	The role of risk, efficacy, and anxiety in smokers' cancer information seeking	
138	Seyedhoseini S.M., Noori S., Hatefi M.A.	An integrated methodology for assessment and selection of the project risk response actions	
139	Hoseini S.M.S., Noori S., Hatefi M.A.	An integrated decision support system for project risk response planning	The present paper introduces a Decision Support System (DSS) including a modeling approach with the objective of selecting a set of RAs that minimizes the undesirable deviation

			from achieving the project scope
140	Hlaing N.N., Singh D., Tiong R.L.K., Ehrlich M.	Perceptions of Singapore construction contractors on construction risk identification	perception
141	Lee D., Park S., Shin S.	Non-stochastic interval arithmetic-based finite element analysis for structural uncertainty response estimate	Finite element methods
142	Banas J.	A tailored approach to identifying and addressing college students' online health information literacy	risk assessment
143	Van Thuyet N., Ogunlana S.O., Kumar Dey P.	Risk management in oil and gas construction projects in Vietnam	identify and rank
144	Hassanein A.A.G., Afify H.M.F.	A risk identification procedure for construction contracts - A case study of power station projects in Egypt	risk identification
145	Binder E.M.	Managing the risk of mycotoxins in modern feed production	risk reduce
146	Mbachu J., Nkado R.	Factors constraining successful building project implementation in South Africa	Influence-Frequency matrix
147			
148	Xie G., Zhang J., Lai K.K.	Risk avoidance in bidding for software projects based on life cycle management theory	
149	De La Cruz M.P., Del Caño A., De La Cruz E.	Downside risks in construction projects developed by the civil service: The case of Spain	Delphi analysis
150	Ling F.Y.Y., Hoi L.	Risks faced by Singapore firms when undertaking construction projects in India	
151	Wagner S.M., Bode C.	An empirical investigation into supply chain vulnerability	

152	Öztaş A., Ökmen O.	Judgmental risk analysis process development in construction projects	judgmental risk analysis process (JRAP)
153	Marshall R.	Environmental impact assessment follow-up and its benefits for industry	
154	Ferguson R.W.	A project risk metric	
155	Lyons T., Skitmore M.	Project risk management in the Queensland engineering construction industry: A survey	qualitative methods of risk assessment
156	Coram P., Ng J., Woodliff D.R.	The effect of risk of misstatement on the propensity to commit reduced audit quality acts under time budget pressure	
157	Siegel P.B., Alwang J., Jorgensen S.L.	Rediscovering vulnerability through a risk chain: Views from different disciplines	
158	Agumya A., Hunter G.J.	Responding to the consequences of uncertainty in geographical data	
159	Kujawski E.	Selection of technical risk responses for efficient contingencies	
160	Ben-David I., Raz T.	An integrated approach for risk response development in project planning	
161	Cady G., Lindberg D.	2000 200-city survey. Operational & clinical EMS trends in large, urban areas.	
162	Baker S., Ponniah D., Smith S.	Risk response techniques employed currently for major projects	risk reduction
163	Backus G.B.C., Eidman V.R., Dijkhuizen A.A.	Farm decision making under risk and uncertainty	
164	Rahayu Harkunti P., Carmichael David.G.	New model of risk allocation for construction contracts based on fair liabilities between parties	The model, Hierarchical Exposure Tree & Alternative Risk Responses (HETARR), defines risk as an exposure attributable to the failure of reaching the project's aims
165	Zhi H.	Risk management for overseas construction projects	

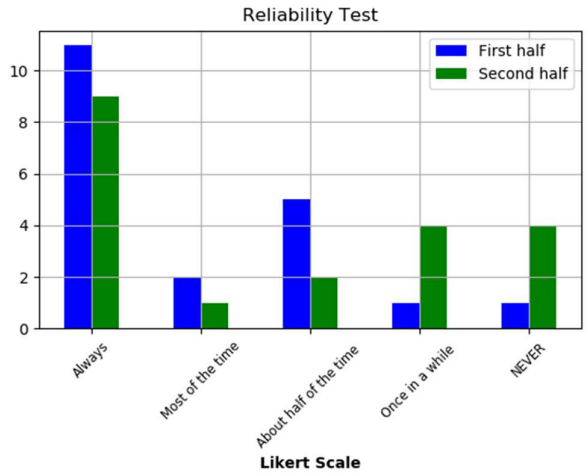
166	Johnson B.B.	Risk and Culture Research: Some Cautions	
167	Zaragoza L.J.	Routine emissions and accidental releases of toxic air pollutants - risk, response and planning	
168	DARDIS R.	Consumer Risk Response and Consumer Protection: An Economic Analysis of Seat Belt Usage	
169	Deisler Jr. P.F., Berger J.E., Brunner R.L.	A systematic approach to reducing the risk of industrially related cancer	reduction
170	Mayer T., Junginger-Dittel K.O.	Risk response in Kenyan agriculture: The case of major export crops	
171	Just R.E.	Risk response models and their use in agricultural policy evaluation	

Appendix B

Pilot Survey Analysis Code in Python

```
import pandas as pa
import numpy as np
import matplotlib
matplotlib.use('TkAgg')
import matplotlib.pyplot as plt
Missing_values = ["nan", " ", "  ", "NaN", "-", "n/a"]
Pi_Qu = pa.read_csv("\\...Adress…\\PilotQues.csv", na_values = Missing_values)
Is_null = Pi_Qu.isnull()
Null_sum = Pi_Qu.isnull().sum()
Pi_Qu = Pi_Qu.replace(r'^\s*$', np.nan, regex=True)
Pi_Qu["WHICH OPTION IS MORE SUITABLE FOR YOU"].replace(to_replace = np.nan,
value ="No Idea", inplace=True, regex=True)
Pi_Qu["AWARENESS"].replace(to_replace = np.nan, value ="NO", inplace=True,
regex=True)
Null_sum_nanFilled = Pi_Qu.isnull().sum()
Pi_Qu.drop("NO.", axis=1, inplace=True)
Headers = Pi_Qu.columns
print(Pi_Qu.dtypes)
print(Pi_Qu.describe())
Pi_Qu_AgeSort = Pi_Qu.sort_values("AGE", ascending=True)
SEX = Pi_Qu['SEX'].value_counts()
print(SEX)
Education = Pi_Qu['EDU'].value_counts()
print(Education)
Outlier_Detection = Pi_Qu.loc[(Pi_Qu["NESSECITY OF TAKE A RECIEPT "] == "NOT AT
AL") & (Pi_Qu["SUGGEST TO OTHERS"] == "YES")]
Pi_Qu1 = Pi_Qu[:19]
Pi_Qu2 = Pi_Qu[20:]
Pi_Qu2 = Pi_Qu2.reset_index()
Pi_Qu2.drop("index", axis=1, inplace=True)
Catagorical_Comparison1 = Pi_Qu1['RECIEPT AFTER
TRANSACTION.GENERAL'].value_counts()
Catagorical_Comparison2 = Pi_Qu2['RECIEPT AFTER
TRANSACTION.GENERAL'].value_counts()
```

```
reorder_list = ['Always', 'Most of the time', 'About half of the time ', 'Once in a while ', 'NEVER']
Catagorical_Comparison1r = Catagorical_Comparison1.reindex(reorder_list)
Catagorical_Comparison2r = Catagorical_Comparison2.reindex(reorder_list)
plt.style.use('default')
x=np.arange(5)
plt.bar(x + 0.00, Catagorical_Comparison1r, color = 'b', width = 0.25, label='First half')
plt.bar(x + 0.25, Catagorical_Comparison2r, color = 'g', width = 0.25, label='Second half')
plt.title('Reliability Test')
plt.xlabel('Likert Scale', fontweight='bold')
plt.xticks([x + 0.125 for x in range(5)], ['Always', 'Most of the time', 'About half of the time ', 'Once in a while ', 'NEVER'], rotation=45, fontsize='small')
plt.legend()
plt.grid()
plt.autoscale()
plt.show()
```



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