INSTITUTO
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“How to do More with Less?”: Investigating Frugal Innovation Determinants using Design Thinking and Interpretive Structural Modeling (ISM)

Margarida Rodrigues Santos

Master in Management

Supervisor:
Doctor Fernando Alberto Freitas Ferreira, Associate Professor w/Habilitation
ISCTE Business School

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"*HOW TO DO MORE WITH LESS?*": ANÁLISE DE DETERMINANTES DE INOVAÇÃO FRUGAL COM RECURSO A DESIGN THINKING E INTERPRETIVE STRUCTURAL MODELING (ISM)

RESUMO

A inovação é parte integrante do quotidiano do mundo atual. As empresas lidam com a mesma diariamente, estando na maximização do seu aproveitamento a base de uma vantagem competitiva face à concorrência. Contudo, as dificuldades enfrentadas no presente, quer ao nível da escassez de recursos, quer ao nível dos constrangimentos financeiros, suscitam a necessidade de as organizações procurarem novas formas de inovação que não comprometam os bons resultados, mas requeiram menos recursos, quer naturais quer financeiros. É neste contexto que a inovação frugal tem vindo a desempenhar um papel crucial no sucesso das empresas, representando uma importância crescente à medida que vai existindo uma clarificação em relação ao conceito e às suas variadas aplicações práticas. Todavia, os aspetos práticos da inovação frugal ainda são insuficientemente abordados pela literatura, constatando-se falta de clareza acerca das suas determinantes e do modo como estas se relacionam entre si. Neste sentido, esta dissertação visa a construção de um modelo multicritério com base na aplicação de metodologias construtivistas, nomeadamente: *Design Thinking* e *Interpretive Structural Modeling*, que esclareçam as questões suprarreferidas, através da contribuição de um grupo de especialistas ligados à inovação empresarial e/ou a Pequenas e Médias Empresas (PMEs). Os resultados deste estudo foram analisados e validados por uma entidade externa à investigação, de forma a tornar o modelo mais robusto. Assim, o modelo criado proporciona uma visão holística acerca dos determinantes de inovação frugal, podendo auxiliar as empresas na compreensão e análise destas temáticas, bem como nos seus processos de tomada de decisão.

Palavras-Chave: Apoio à Tomada de Decisão; *Design Thinking*; Inovação Frugal; *Interpretive Structural Modeling* (ISM); Mapeamento Cognitivo.

Códigos JEL: M10; O30.

“How to do More with Less?”: Investigating Frugal Innovation Determinants using Design Thinking and Interpretive Structural Modeling (ISM)

ABSTRACT

In the modern world, innovation is an essential component of daily living. Companies deal with it on a regular basis, being the maximization of its use the foundation for a competitive advantage over competition. However, the difficulties faced at present, whether in terms of scarcity of resources or financial constraints, raise the need for organizations to seek new forms of innovation that do not compromise good results, but require fewer resources, both natural and financial. It is in this context that frugal innovation has been playing a significant role in the companies’ success, representing a growing importance, as the concept and its various practical applications become more understood. Nevertheless, the practical aspects of frugal innovation are still insufficiently addressed by the literature, with a lack of clarity about its determinants and how they relate to each other. In this regard, this dissertation aims to develop a multicriteria model based on the application of constructivist methodologies, namely Design Thinking and Interpretive Structural Modeling, that clarify the above-mentioned issues, through the contribution of a group of experts linked to corporate innovation and/or Small and Medium Enterprises (SMEs). The results of this study were analyzed and validated by an external entity to the investigation, in order to make the model more robust. Thus, the model created provides a holistic view about the determinants of frugal innovation, being able to assist companies in the understanding and analysis of these matters, as well as in their decision-making processes.

Keywords: Cognitive Mapping; Decision-making Support; Design Thinking; Frugal Innovation; Interpretive Structural Modeling (ISM).

JEL Codes: M10; O30.

EXECUTIVE SUMMARY

Nowadays, innovation is incorporated into most facets of our daily life. The same occurs in companies, being the key to success and outpacing competition the capacity to fully utilize innovation. So, it is essential that organizations embrace innovation as an ally rather than being wary of it. Yet, putting innovation into practice demands financial, material, natural, and other resources that companies may not always have at their disposal. Under these situations, organizations worry that they will not be able to innovate at the same rate as their rivals. In this scenario, frugal innovation arose. While using less resources, whether natural or financial, companies that employ this kind of innovation are still able to achieve good results compare to the more conventional forms of innovation. This scenario prevailed during the COVID-19 pandemic, when organizations were compelled to adapt and overcome these obstacles due to the lack of resources. Despite the fact that frugal innovation was initially thought of as a tool to exclusively support developing economies or to be used only during times of crisis, like the pandemic, there has been an increase in awareness of its features and capabilities, regardless of the environment in which it is applied. Thus, frugal innovation can be a valuable asset in both underdeveloped and developed countries. In order to accomplish that, companies must have the tools necessary to assist them in understanding the concept, its determinants and how they relate to one another to, consequently, maximize the potential of frugal innovation. However, currently, the literature mostly focuses on theoretical aspects, lacking proper approaches regarding the practical application of frugal innovation. Hence, the main objective of this investigation is to overcome these limitations through the development of a model that addresses this subject holistically, identifying frugal innovation determinants and clarifying their relationships toward one another, in order to provide support to the organizations in this matter. For that, two constructivist techniques were applied: Design Thinking, utilized in the structuring phase of the process, to identify frugal innovation determinants, and Interpretive Structural Modeling (ISM), used in the evaluation phase, to establish the relationships between them. The application of both methodologies was based on the contribution of a panel of experts related to corporate innovation and/or Small and Medium Enterprises (SMEs), who shared their knowledge and experience on the topic during two group sessions, one for the application of each technique. Both sessions took place remotely, through digital platforms (*i.e.*, Microsoft Teams and Miro). The first session, which took approximately 4 hours, started with the presentation of a trigger question (*i.e.*, *"Based on your values and professional experience, identify frugal innovation*

factors/determinants in corporate contexts"), based on which the post-its technique was employed, resulting in the definition of criteria related to the subject and their respective allocation in clusters (*i.e.*, concern areas). The outcomes of the first meeting enabled the creation of a cognitive map that identified 134 criteria divided in five main clusters: (1) *Financial Resources*; (2) *Human Resources*; (3) *Innovation and Technological Challenges*; (4) *Sustainability and Surrounding Environment*; and (5) *Corporate Strategy*. This cognitive map was presented to the experts in the beginning of the second session for possible alterations and consequent validation. In this session, which took approximately 3 hours, the ISM methodology was applied. Hence, firstly, through Multi-Voting and Nominal Group Technique (NGT), the experts selected the seven most important criteria within each cluster. Then, it was asked for the specialists to classify the cause-and-effect relationships between the clusters, and then, within each cluster, between the criteria. After that, we were able to perform the following steps of the methodology and hierarchize the criteria. At last, we had a consolidation session with an external party, a member of the National Innovation Agency, which took approximately 1 hour and consisted in the explanation of the study, including the description of the techniques applied and the analysis of the results. The expert validated the results and provided some recommendations, namely regarding the practical application of the model. Overall, the investigation allowed for the creation of a multicriteria model that clarifies the identification of frugal innovation determinants and the comprehension of the relationships between them, with potential to be successfully implemented.

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MAIN ABBREVIATIONS USED

BoP	− Bottom of the Pyramid
DT	– Design Thinking
FI	– Frugal Innovation
FRM	– Final Reachability Matrix
IRM	– Initial Reachability Matrix
ISM	– Interpretive Structural Modeling
MICMAC	– *Matrice d'Impacts Croisés Multiplication Appliquée à um Classement*
NGT	– Nominal Group Technique
OECD	– Organization for Economic Cooperation and Development
OR	– Operational Research
PSMs	– Problem Structuring Methods
R&D	– Research and Development
SCA	– Strategic Choice Approach
SDGs	– Sustainable Development Goals
SMEs	– Small and Medium Enterprises
SODA	– Strategic Options Development and Analysis
SSIM	– Structural Self-Interaction Matrix
SSM	– Soft Systems Methodology
SWOT	– Strengths, Weaknesses, Opportunities and Threats
TBL	– Triple Bottom Line

CHAPTER 1

INTRODUCTION

1.1. Initial Background

Over the past few decades, we have been progressively coming into contact with innovation and its developments, whether directly or indirectly. As a result, the fundamental idea of innovation has evolved with its outcomes, which has given rise to new innovation concepts such as frugal innovation. This topic focus on making more with less, being considered *“a new paradigm challenging traditional innovate solutions for sustainable development through minimal resource use, affordability and inclusivity”* (Ebolor, Agarwal, & Brem, 2022, p. 1). Thus, frugal innovation has proven crucial during difficult times, particularly more recently, during the COVID-19 pandemic, since every organization had to cope with scarcity due to the lack of human, financial, material and other type of resources, which forced them to quickly produce alternatives that required fewer resources to ensure that these were feasible given the circumstances faced (Wu & Ho, 2022). That said, frugal innovation was presented as a solution that not only overcomes these constraints, but also with potential applications in other fields and contexts. Therefore, frugal innovation can be adopted in both emerging economies, where consumers have less purchasing power, and in developed economies, where consumers do, in fact, have greater purchasing power, but are still looking for more affordable and/or more sustainable options.

Despite being an emerging field with a growing number of studies pertaining to it, the literature has prioritized theoretical aspects, such as the concept’s definition, over its practical application, as demonstrated by the lack of studies focusing on this matter. Consequently, the identification of frugal innovation determinants lacks rationality and it is not clear how these determinants are related to one another. In this regard, this study aims to overcome these limitations and serve as a resource to companies’ decision-making processes, through the combination of constructivist methodologies, namely Design Thinking (DT) and Interpretive Structural Modeling (ISM), in order to create a model that approaches the subject holistically, allowing to identify and hierarchize frugal innovation determinants and understand how they influence and/or are influenced by each other.

1.2. Relevance and Objectives

Given the background presented in the previous point, it is perceptible that innovation plays a key role in an increasingly complex world. Hence, it is crucial that companies keep up with innovation and its ramifications, such as frugal innovation, to achieve better results. However, the lack of understanding of frugal innovation determinants restrains the full potential of this subject, which enhances the importance of managers having tools that provide them information regarding this topic and help them fully understand the cause-and-effect relationships between these determinants. These tools will enable managers to make more conscient and informative decisions, which will reduce their risk of failure. Thus, this dissertation's main objective is the ***creation a multicriteria system that will provide a deepen comprehension of frugal innovation determinants through the application of the Design Thinking (DT) methodology with the Interpretive Structural Modeling (ISM) technique***.

Additionally, in order to obtained the aimed results, complementary objectives must be attained, specifically: (1) elaborate the framework of frugal innovation; (2) gather a panel of specialists related to this subject and foment the debate between them; (3) create a cognitive map that comprehends the experts' contribution and defines the main determinants of frugal innovation; (4) apply the ISM methodology in order to classify the relationships between determinants, describing either if they influence, are influenced or both; (5) evaluate which determinants influence more the others and the system; and (6) validate the model created through a consolidation session with an external party.

1.3. Methodology

Considering the topic's complexity and wide range of application, this dissertation will adopt a constructivist approach. This type of methodology offers an advantage over traditional approaches, since it takes into account uncertainty as well as the human nature and its characteristics, such as subjectivity, providing a more complete and viable analysis of the subject. Therefore, this study will combine two constructivist techniques: (1) Design Thinking, to be utilized in the structuring phase of the decision-making process; and (2) Interpretive Structural Modeling, to be used in the evaluation phase. The implementation of these two methodologies will be divided into two distinct stages. First, we will apply the Design Thinking, which will enable to identify frugal innovation determinants and, ultimately, produce a cognitive map. Second, we will apply the ISM, which will permit to establish the cause-and-effect relationships between these determinants and hierarchize them.

In practice, this will be accomplished through two online group sessions, one for the application of each technique, with a panel of specialists related to corporate innovation and/or Small and Medium Enterprises (SMEs). These experts' contribution, based on their knowledge and experience, will be the foundation of the implementation of both methodologies. The combined use of these two techniques will allow to create a more consistent and complete multicriteria system that will provide a broaden understanding of frugal innovation determinants. The model created will be then presented to an external party for validation.

1.4. Structure

Taking into account the objectives and methodologies to be employed, this dissertation is structured into five chapters, along with their corresponding references and appendices.

Chapter 1 comprehends the introduction of this dissertation, beginning with the initial background and the explanation of the significance and objectives of the investigation. Next, the methodologies used are identified and the structure of the document is presented, concluding with the expected results of this study. The focus of *Chapter 2* is on the literature review concerning frugal innovation, starting with the definition and relevance of the concept and moving on to its situational characterization and spillovers. Also, an analysis of the previous studies and their methodology is performed, along with the identification of the general limitations encountered in the existing literature, which justifies the pertinence of the present dissertation. A methodological framework is provided in *Chapter 3* together with the contextualization of decision problem's structuring and the description of the two methodologies utilized in this dissertation (*i.e.*, Design Thinking (DT), employed in the structuring phase of the problem under analysis, and Interpretive Structural Modeling (ISM), used in the evaluation phase). The presentation of the potential contributions of this investigation to the analysis of frugal innovation determinants marks the chapter's conclusion. *Chapter 4* encompasses the practical component of this study, incorporating the application of the two methodologies previously mentioned. Hence, it includes the description of the two group sessions with a panel of specialists that were carried out in order to identify and analyze frugal innovation determinants. In addition, these results were presented to an external party who validated them and gave us some recommendations. At last, *Chapter 5* comprises the conclusion of this dissertation, which comprehends the main results of the DT-ISM application and its limitations. The contributions of the study to the analysis of frugal innovation determinants and leads for future research are also covered in this chapter.

1.5. Expected Results

Overall, this dissertation intends to create a multicriteria system that will: (1) provide a broaden understanding of frugal innovation determinants; (2) enable to approach the topic holistically; and (3) overcome some of the existing limitations. Therefore, this system will give a deeper understanding of frugal innovation determinants, including their relationships with one another, their level of influence toward each other, the way in which they affect the system and which determinants are the most significant.

Moreover, this study aims to provide companies, governments and other entities with tools to enhance their decision-making processes and increase the understanding of the relationships between frugal innovation determinants and, consequently, permit the perception of which determinants are more important, which ones must be invested in and to what extend each one affects the others and the system as a whole. Consequently, this will provide the opportunity to anticipate each action's effects (*i.e.*, how an action on a certain variable will affect the others, allowing time and financial safety). Thus, this investigation seeks to contribute to the field's growth and development. In order to get an unbiased perspective and improve the model developed, it is intended to consolidate it during a session with an external organization that was not involved in this study. At last, it is expected that this study will be published in a scientific journal.

CHAPTER 2

LITERATURE REVIEW

In this chapter, firstly, we will introduce the concept and the importance of frugal innovation, through the analysis of its chronological evolution since its genesis and the explanation of the subject's increasing importance throughout the years. Secondly, we will explore the situational characterization and the spillovers of frugal innovation, describing the current tendencies on the topic as well as its temporal manifestations, highlighting the factors that make the implementation of frugal innovations necessary. In order to identify the areas that require improvements, we will also perform an in-depth literature analysis of previous studies and their methodological guidelines, emphasizing its findings, contributions and limitations. Finally, we will present the subject's general limitations along with the necessity of a different methodology to overcome them.

2.1. Frugal Innovation: Concept and Importance

Frugal innovation refers to *"achieving more value while using fewer resources"* (Dabić, Obradović, Vlačić, Sahasranamam, & Paul, 2022, p. 914). It is a broad concept that applies to a wide spectrum of different fields and represents a resource-scarce solution that can decrease complexity and production costs, being relevant in fighting major challenges, such as the COVID-19 pandemic and environments with high levels of poverty. Frugal innovation creates solutions that are planned and implemented regardless financial, technological, material or other resource limitations, which results in an outcome substantially less expensive than competing offers, while still satisfying consumers' basic needs (Hossain, Simula, & Halme, 2016).

One of the first definitions of the concept was presented by The Economist (2010, p. 8): *"Frugal innovation is not just about redesigning products; it involves rethinking entire production processes and business models"*. Since then, it has suffered several updates throughout the years due to research developments. However, it is still commonly mistaken with similar concepts such as "Gandhian innovation" and "Jugaad innovation" (both associated to India's physical location); or "Bottom of the Pyramid (BoP)" (which refers to individuals earning less than 2.50 dollars per day), that even though are related to frugal innovation, do not completely represent the same concept. According to Brem and Wolfram (2014, p. 19), Gandhian innovation is defined as *"an approach that takes advantage from the adaption of existing technologies by integrating them into local context or/and establishing local expertise by spillovers through collaborations in order to increase social wealth of people from the BoP"*, while Jugaad capability is described as *"the art of overcoming harsh constraints by improving an effective solution using limited resources"* (Prabhu & Jain, 2015, p. 847).

Although there is common agreement in some elements that are shared in the various definitions presented in the literature, since previous studies had made an effort to reach a consent, frugal innovation is yet an emerging field and, as a result, there is still no consensus on the definition of the concept. Nevertheless, it is usually associated with *"*[the provision of] *products or services in contexts of resource scarcity (material, financial or human) that perform well enough to satisfy the need of underserved customers at lower costs"* (Sarkar & Mateus, 2022, p. 2). Weyrauch and Herstatt (2016) tried to attain an universal criterion to define the concept through interviews with managers and researchers, what led to the distinction of frugal innovation from other types of innovation according to three characteristics: (1) substantial cost reduction – *i.e.*, "frugalized" products are less expensive than existing products; (2) concentration on core functionalities – *i.e.*, only the core functionalities are maintained while the extra features are discarded; and (3) optimized performance levels, which refers to a product architecture that has perfect coordination between all of its components. Additionally, several authors tend to base their approach according to the markets that frugal innovations are addressed and originated from (Barnikol & Liefner, 2022).

The difficulty to reach an agreement is also due to the fact that the concept itself is ambiguous regarding quality and novelty, since embraces a large range from low to high quality innovations, as well as improved versions of previously existing products and completely new products (Barnikol & Liefner, 2022). Consequently, the term "advanced frugal innovation" was introduced by Rao (2017a and 2017b), and has been used to define high quality innovations, while the term "unrefined frugal innovation", suggested by Barnikol and Liefner (2022), is used to define non-advanced frugal innovations (*i.e.*, low quality innovations). Advanced frugal innovations share the same three criteria, defined by Weyrauch and Herstatt (2016), with unrefined frugal innovations. However, they differ in distinct topics such as: (1) developers; (2) consumers; (3) input; (4) development process; (5) quality; and (6) frugality achievements. In advanced frugal innovations, (1) developers are more specialized individuals such as engineers and research and development (R&D) employees; (2) the consumers are cost-conscious and sustainability-conscious; (3) the input includes advanced materials, technologies and techniques; (4) the development process is rigorous and based on both R&D and scientific principles; (5) the products have high quality, being reliable and safe to use; and (6) the frugality achievements are not only the low price but also the sustainability, providing social benefits. In unrefined frugal innovations, in turn, (1) any individual with ideas can develop these innovations; (2) the consumers are poor; (3) the input includes cheap components that are at hand; (4) the development process is basic and based on trial and error; (5) the quality is average, being the products not entirely reliable and even partially unsafe; and (6) the frugally achievements are focused primarily on low price, being the sustainability not always assured but rather an extra, which can result in a negative impact for society (Barnikol & Liefner, 2022; Rao, 2017a and 2017b). Concerning novelty, innovations can be new-to-the-world; new-to-the-region or new-to-the-industry; and new-to-the-firm (Organization for Economic Cooperation and Development (OECD) & Eurostat, 2018). Therefore, advanced frugal innovations include both completely new products as well as "frugalized" versions of previously existing ones (Barnikol & Liefner, 2022).

The importance of frugal innovation is as extensive as the concept itself, due to its multidisciplinary application. It can assure that people with less purchase capabilities are able to obtain certain products and services that otherwise they would not be able to acquire. According to Dabić *et al*. (2022, p. 917), Brem (2017) enhances this importance, referring that the ongoing development of technologies as well as the resource-efficient and sustainable solutions make *"expected that frugal innovations will enable the sustainable growth of the business and the nation"*. Initially, frugal innovation was considered a solution focused on addressing local issues on emerging countries. However, the concept has grown to be global, being used not only in the emerging economies but also universally, including in developed countries, where it may have a significant impact, due to the development of the concept and the recognition of the possibility to successfully provide valuable products while consuming less resources and contributing to social and environmental change (Sarkar & Mateus, 2022). Also, the expansion of BoP markets makes them more appealing for advanced economies' leading innovators, who must still expand their perspective of the product and comprehend the needs of poor customers (Jha & Krishnan, 2013). In this scenario and to successfully develop frugal innovations, it is crucial that companies perform R&D activities in emerging countries. For instance, some companies from advanced economies developed frugal products for emerging countries that were successful in western markets as well (*cf.* Agarwal & Brem, 2012). Additionally, due to the growing demand in advanced economies for products that combine affordability and high quality as well as the increased awareness of sustainability, frugal innovations are highly appealing to both emerging and advanced economies (Kroll & Gabriel, 2020). Hence, to provide a better understanding of frugal innovation's manifestations and current situation, both the situational characterization and the spillovers of the subject will be presented in the next point.

2.2. Situational Characterization and Spillovers of Frugal Innovation

As previously referred, frugal innovation has undergone several developments since its genesis and, as a result, the tendencies related to it have evolved along with the concept. The focus on solely low-income nations is overtaken, as *"in the face of emerging medical, social, and economic challenges, the world has discovered a greater potential of innovations targeted at the local innovative endeavors, also known as frugal innovations"* (Melnikova & Gilsanz, 2022, p. 1). Therefore, frugal innovation is now seen as a powerful tool despite the economy's level of growth, since overcomes some obstacles that conventional innovation faces, while still enabling businesses to grow geographically and enter new markets (Melnikova & Gilsanz, 2022).

Govindan (2022) indicates a positive correlation between sustainability and frugal innovation and, as so, currently there is a growing tendency to not associate frugal innovation exclusively with the economic sphere, but also to link the topic to the other two sustainability pillars, namely: (1) environment; and (2) society. The three constitute the foundation of the Triple Bottom Line theory (Elkington, 1997), which enhances the crescent importance of the last two dimensions along with the first one. Consequently, in the past years, companies have been under increasing pressure to focus also on the environmental and social pillars. Furthermore, there has been a raising awareness that frugal innovations can lead firms to achieve sustainability, as well as the understanding that *"the concept of FI originated as one of the win-win solutions for the mutual benefit of business communities, society, and the environment"* (Melnikova & Gilsanz, 2022, p. 1). However, according to Albert (2022), frugal innovation still prioritizes the economic and social dimensions above the ecological one.

Presently, according to Govindan (2022), technology is considered an instrument to accomplish frugal innovation, standing out, in this scope, the artificial intelligence, due to its potential to boost corporate competitiveness amid disruptions in a more sustainable way, providing an advantage in terms of frugal innovation and fostering business progress.

Moreover, technology provides a chance to approach numerous other social concerns, comprehending urbanization, aging populations and climate change, which can contribute to promote the social and ecological pillars of TBL, with emphasis to the latter, since it is currently the least addressed, as formerly said (Albert, 2022; Govindan, 2022).

When disruptions like pandemics, political instability and other natural disasters take place, the main innovation strategies are usually unsuccessful. Consequently, frugal innovation has gained prominence in difficult times as a result of its ability to maximize efficiency while using less resources (Govindan, 2022; Melnikova & Gilsanz, 2022; Sarkar, 2021). More recently, the COVID-19 pandemic reinforced that importance, since it has put pressure on businesses to operate at half their capacity and under economic strain, which has had an impact on the financial health of multinational corporations. As Govindan (2022) observes, it led to the need of new innovation approaches, namely frugal innovation. Furthermore, the critical necessity to purchase large amounts of medical equipment in order to treat the greatest number of patients, as well as the need to lower the cost of the items while preserving their quality, making them also accessible to all population, highlighted the significance of frugal innovation. Hence, following Melnikova and Gilsanz (2022, p. 2), *"it can be stated that FI aims at meeting the basic needs of the populations* […] *during the health crisis period to enhance the quality of life of population"*.

Nevertheless, the pandemic was not the only issue that raised awareness of the value of frugal innovation. There have been spillovers of frugal innovation over the years, particularly in periods marked by unpredictability, instability, intricacy, and ambiguity, such as global warming and financial crises, when conventional innovation was unable to solve the issues at hand and businesses were forced to reconsider how to produce products and services at a low cost. Also, according to Rao (2013), the seriousness of the threat posed by climate change is coming to light, which has been translated into strict regulations to countries on emissions and energy efficiency. This issue, coupled with man-made threats like financial crises and price-conscious costumers who demand high-quality goods and services at a discount, necessitated frugal innovation to overcome them through the consumption of fewer resources, allowing for their preservation, and low prices, which made products accessible to both customers with high purchase power and to those who can only afford cheaper goods, as well as culminated in profitability for companies. Thus, *"it is acknowledged that frugal innovations play a significant role during times of crisis"* (Dabić *et al.*, 2022, p. 924), regardless of its nature, through the adoption of frugal practices in response to these events, which provides solutions that otherwise would not be able to have practical application due to the specific constraints of non-frugal innovations. In the next topic, some previous studies on the subject will be analyzed, highlighting its methods, contributions, findings and limitations.

2.3. Analysis of Previous Studies and Their Methodological Guidelines

Although the notion of frugal innovation is still relatively new, there have been a variety of approaches and opinions from diverse authors over the years as a result of the growing awareness of the concept's importance (*e.g.*, Angelo & Magnusson, 2020; Basu, Banerjee, & Sweeny, 2013; Hossain, 2018; Steinfield & Holt, 2019). Therefore, and taking into consideration the topic's development, the number of studies pertaining to it has increased exponentially owing to the realization of its applicability to several fields, including engineering, sustainability, healthcare, and others, as well as to both emerging-markets and developed-markets. Additionally, there are still several individual perspectives on the concept's definition since the literature has not yet come to an agreement on it. *Table 2.1.* presents some studies about the frugal innovation topic, including their findings, contributions and limitations.

Table 2.1. Methodologies for Assessment and Analysis of Frugal Innovation: Findings, Contributions and Limitations

Author	Method	Findings	Contributions	Limitations
Ojha (2014)	Case-study method	▪ In order to boost competitiveness and growth potential in their home market or other comparable markets, the two-multinational companies under analysis have strengthened R&D in India and adopted the philosophy of frugal innovation, which combines high technology with low costs.	▪ The study analyzes the experiences of multi-national companies in India, as they use the frugal innovation philosophy to create products that are high in technology but low in cost to fulfill the demands of the market conditions in India and other low-income economies.	▪ Only two case studies were included in the study, hence a larger sample size is needed to generalize the results.
Bianchi, Bianco, Ardanche, and Schenck (2017)	Case-study method	▪ Since frugal innovations offered novel and effective technological solutions to health-related problems for which a national or international solution would not be suitable for the local conditions, these allowed the hospital under study to address specific healthcare needs in a particular domain.	▪ The study explains why frugal innovation is a good strategy for the particular subject of health technology in underdeveloped environments.	▪ The processes of frugal innovation took place independently of the market and the public policy. As a result, they are still limited to the application area in which they first appeared.

Cai, Ying, Liu, and Wu (2019)	Statistical methods	▪ Emerging-market firms with more ability for institutional leverage and bricolage and those who deal with perceived dysfunctional competition, tend to create new items that are more affordable and value-added.	▪ The study discusses the difficulties of how emerging-market firms cope with institutional, technological, and market restrictions in developing markets and explains how these limits encourage frugal innovation. ▪ Proposes a revision to the definition of frugal innovation that focuses on measuring the effectiveness of innovation along two dimensions: cost innovation and affordable value innovation.	▪ Any analyzes of the model's causal relationships are constrained by the study's cross-sectional essence. ▪ Institutional supports and obstacles to innovation were not ruled out by the study as potential influencing variables. ▪ Since the study was limited to investigating how frugal innovation affects firm performance, firm-level characteristics and industry-level changes may have an impact on the theoretical model. ▪ The results cannot be generalized as the sample solely consists of companies from five Chinese provinces.
Albert (2022)	Systematic literature review and qualitative content analysis	▪ Assessments based on TBL and Sustainable Development Goals (SDGs) are the major approaches for evaluating the sustainability implications of frugal innovation, with the first approach being preferred over the second.	▪ In addition to presenting new perspectives on the empirical evidence of frugal innovation's sustainability implications, the study outlines the approaches and indicators for evaluating those implications.	▪ The significance of assigning the empirical contributions regarding SDGs to TBL is restricted. ▪ Since the study only includes qualitative evaluations, it is impossible to quantify the sustainability effects and compare with other cases of frugal innovation from distinctive authors.

According to *Table 2.1.*, it is understandable the studies' temporal development. While Ojha (2014) and Cai *et al.* (2019) focused their analysis on frugal innovation in emerging companies and markets (*i.e.*, the first regarding to the use of frugal innovation to create products that combine high technology with low costs, and the second concerning the difficulties some emerging-market firms face due to institutional, technological, and market restrictions, and how these instigate frugal innovation), Bianchi *et al.* (2017) and Albert (2022) approached the application of frugal innovation to different areas such as, respectively: (1) healthcare, analyzing the effective solutions provided by frugal innovation to hospitals; and (2) the sustainability implications of the subject. Nevertheless, every methodology presents weaknesses and every study presents limitations that must be overcome to achieve more reliable results and conclusions.

2.4. General Limitations

The analysis of determinants of frugal innovation is crucial due to the current challenges faced across the world. Not only crisis times enhance the importance of the topic, but also the crescent globalization and industrialization pushes firms to consider frugal innovations as an instrument to succeed in their fields (Govindan, 2022; Melnikova & Gilsanz, 2022). After a careful literature review, it was perceptible that even though the number of studies about the topic is increasing, there are still a few conceptual constrains, due to the topic's recent nature, as well as the lack of consensus about the concept. Moreover, most of the studies presented flawed methodologies, as they narrowed their research to a restricted sample, which compromised the generalization of the results obtained, as well as the environmental variables, such as market, public policy, institutional supports and obstacles to innovation, were not considered (Bianchi *et al*., 2017; Cai *et al*., 2019; Ojha, 2014). Furthermore, there are two main general limitations regarding this subject: (1) the identification of frugal innovation determinants lacks rationality; and (2) it is not clear how these determinants are related with each other.

That being said, and to overcome these limitations, this study will adopt a constructivist approach, through: (1) Design Thinking (DT), to identify frugal innovation determinants; and (2) Interpretive Structural Modeling (ISM), to analyze cause-and-effect relationships between these determinants and, subsequently, create a multicriteria system that will provide a broaden understanding of frugal innovation determinants.

SYNOPSIS OF CHAPTER 2

The focus of this second chapter was to provide a theoretical background concerning frugal innovation. For that, we first provided a brief explanation of the concept and its significance, presenting the perspectives of several authors on the topic explored. In sequence, it was possible to understand the temporal evolution of the topic since the term already contains ramifications like advanced frugal innovation and unrefined frugal innovation. However, there was a lack of studies conducted prior to the last decade. Additionally, despite the literature's significant efforts to obtain agreement on the concept definition, we came across the difficulties that still exist to achieve that. After that, we moved on to analyze the current situation of the thematic as well as its spillovers over time. As a result, it was possible to comprehend that frugal innovation is currently much more widespread than it once was because, initially, it was exclusively associated with underdeveloped economies. Nowadays, due to the increased awareness of the topic's potential, it has also spread to developed economies. In addition, there were several spillovers of frugal innovations, mainly during periods of crisis of different natures, such as financial crisis, climate change and, more recently, the COVID-19 pandemic. During these challenging times, frugal innovations played a key role to companies, by providing them tools to successfully fight the constrains that came along with these crises. Then, we examined some previous studies regarding the concept, including its findings and contributions, and it became clear that, despite a noticeably rising number of studies, each one presented several limitations, namely a small sample size and the despise to exterior variables. At last, we presented the general limitations that currently exist in this field, that prevent frugal innovations from reaching their full potential, namely: (1) the lack of rationality in the identification of frugal innovation determinants; and (2) the lack of clarity regarding the relationships between these determinants. Throughout the chapter, it was perceptible the great importance of frugal innovation, now more than ever, given the current challenges faced across the world as well as given the damaging consequences that the existing limitations bring. Therefore, finding solutions to these issues is essential, which is why we will propose a multicriteria system that will enable to approach the subject holistically and overcome some of the existing limitations. In order to accomplish that, through a constructivist logic, we will use two techniques: (1) Design Thinking (DT); and (2) Interpretive Structural Modeling (ISM). In the next chapter, these techniques will be explained more in-depth.

CHAPTER 3

METHODOLOGY AND SOURCES

This third chapter will begin with a conceptualization of the structuring of complex decision problems, briefly describing the decision-making process and focusing on its structuring phase through the exploration of problem structuring methods (PSMs). Then, the methodologies chosen to overcome some of the limitations previously identified in the previous chapter will be introduced and explained, namely: (1) Design Thinking (DT), as a structuring method; and (2) Interpretive Structural Modeling (ISM), as a structuring and evaluation method. At last, we will enhance the possible contributions that both methodologies can bring to the analysis of frugal innovation determinants.

3.1. Structuring of Decision Problems

In an increasingly complex world, decision making is a vital component of problem resolution. According to Bana e Costa (1993), the decision-making process is an indivisible system of relationships between subjective and objective aspects, which are concerned with the actors' value systems and actions, respectively. Therefore, even though objectivity is a significant concern, it is essential to consider that decision making is a human activity and, as a result, subjectivity will always be involved in these processes.

Every successful decision-making process must include three distinctive phases: (1) the structuring phase, characterized by the use of soft approaches for decision-problem clarification; (2) the evaluation phase, defined by the analysis of actions' impact and overall performance; and (3) the recommendation phase, where the recommendations are elaborated (Bana e Costa, Ferreira, & Côrrea, 2000). In accordance with Keeney (1992), identifying a problematic situation or an opportunity for action should be the first step in decision-making processes. This stage has a great importance for problem solving since, as stated by Belton and Stewart (2002, p. 35), *"a problem well-structured is a problem half solved"*. For Rosenhead (1989), problem structuring can be described as *"the identification of those factors and issues which should constitute the agenda for further discussion and analysis"* (Belton & Stewart, 2002, p. 36). Hence, problem structuring methods (PSMs) play a significant role to succeed in this phase, due also to their widespread and successful application in companies (Mingers & Rosenhead, 2001; Morton, Ackermann, & Belton, 2007).

PSMs have been applied and evolving since mid-1960s, being defined, according to Rosenhead (1996, p. 117), as *"a broad group of problem-handling approaches whose purpose is to assist in structuring problems rather than directly with solving them"*. These methods have been one of the areas of development for operational research (OR), by expanding its approach into problem spheres that OR had formerly not succeed or was not supposed to interact (Rosenhead, 2006). While OR's original problem-solving procedures do not provide sufficient assistance in determining what the problem is, PSMs grant decision makers methodical support in finding an accepted framework for their problem. Thus, PSMs' clear techniques of representation are able to collect divergent perspectives on the problem, which contributes to reach an agreement or eases negotiations (Rosenhead, 1996).

The problematical circumstances for which PSMs intend to offer analytical support are defined by the existence of several participants, divergent viewpoints, partly incompatible interests, substantial intangibles, and significant uncertainties (Rosenhead, 2006). To provide this assistance, PSMs should be able to support a variety of different perceptions, be cognitively understandable to actors with diverse and not specialized background, function iteratively, and allow partial developments to be recognized and dedicated to (Mingers & Rosenhead, 2004). In practice, this translates to the main purposes of PSMs being to: (1) concentrate on structuring the problem; (2) seek to promote communication among stakeholders to increase shared understanding of the problem situation; (3) contemplate "What" questions first; (4) prioritize the debate between the stakeholders to achieve the problem's resolution through debate and compromise; and (5) consider the analyst as a facilitator and an asset that depends on the stakeholders' technical knowledge (Belton & Stewart, 2010; Daellenbach, 1994).

According to Rosenhead (2006, p. 763), who performed a SWOT analysis on the topic, it is perceptible that although there are several strengths and opportunities in the utilization of PSMs, there are also some threats and weaknesses. The author suggests that *"PSM's strengths are likely to be methodological, and* […] *threats to its growth could arise from a failure to map onto pivotal decision areas where current decision support is perceived as inadequate"*. Moreover, the weaknesses include the results' volatility nature, while the opportunities encompass the trade of techniques with related areas. Overall, PSMs have been developing their methodological sophistication throughout the years (Rosenhead, 2006).

PSMs encompasses, for example, Soft Systems Methodology (SSM) (Checkland, 1981; Checkland & Scholes, 1990); Strategic Choice Approach (SCA) (Friend & Hickling, 1987); Strategic Options Development and Analysis (SODA) (Eden, Jones, & Sims, 1983); and Design Thinking (DT). The next topic will explore the DT approach, which is a human-centered PSM.

3.2. Design Thinking

Among the several existing PSMs, DT has been attracting much attention in the literature due to being an innovative and creative approach to complex decision making (*cf.* Manna, Rombach, Dean, & Rennie, 2022; Meinel & Leifner, 2011; Von Thienen, Noweski, Meinel, & Rauth, 2011). The concept can be defined as *"an empathetic, user-centric approach to problem-solving, involving multidisciplinary teams engaging in a holistic, contextual thought process; collaborating, integrating perspectives and iteratively experimenting with possible solutions to indeterminate problems"* (Manna *et al.*, 2022, p. 2). In practice, a creative and interactive process is used to identify possible solutions, assisting users in better handle complexity and, ultimately, leading to an innovative solution's creation according to their preferences (Geldermann, Lerche, & Sepulveda, 2018). In general, *"design thinking engages diverse stakeholders in conversation, offers and tests ideas rapidly and reconciles the objectives of economic and social value generation in implementation"* (Erzurumlu & Erzurumlu, 2015, p. 8).

In order to solve both technical and social concerns, DT has been applied across multiple domains and sectors (Tham, 2022). Therefore, its importance is recognized across different fields since, in accordance with Frisk and Bannister (2021), this approach can offer more effective decision making, through broadening the scope of options considered, increasing the number of people participating in the process, providing novel techniques and expanding data sources. Consequently, organizations that apply design thinking techniques to their decision-making processes will experience major improvements in the process as well as in its outcomes.

However, a consensus has not yet been reached in the literature regarding DT definition (Carlgren, Rauth, & Elmquist, 2016; Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013; Liedtka, 2015; Radnejad, Sarkar, & Osiyevskyy, 2022). For Johansson-Sköldberg *et al.* (2013), the focus should not be on finding a single concept's meaning, but rather on the circumstances in which the term is applied, namely the "where" and the "how". Nevertheless, according to Radnejad *et al.* (2022), besides lacking a consensual definition, DT comprehends three main aspects agreed by authors: (1) empathy (*i.e.*, this topic plays a significant role in DT, since the human-centered nature of the subject is crucial for its success) (Leonard & Rayport, 1997; Patnaik, 2009); (2) collaboration (*i.e.*, innovative ideas are more probable to be produced by cooperative teams) (Beverland, Micheli, & Farrelly, 2016); and (3) prototyping (*i.e.*, this concept allows designers to explore and assess their strategy for balancing user requirements with what is technically possible) (Brown, 2009; Hargadon & Sutton, 1997; Liedtka, 2015; Schrage, 1999). Considering these three components, the majority of research concur that DT has three stages: (1) inspiration; (2) ideation; and (3) implementation. The first one relates to the actions taken to identify issues or opportunities, which then trigger the search for solutions (Brown & Wyatt, 2010). In the second stage, the responsibility of designers is to create, evolve and test ideas (Carlgren *et al.*, 2016). In the last phase, the main objective is to transform the new ideas into a pilot model, seek market integration and define the follow-up steps, such as the model's monitorization and assessment (Brown, 2008; Seidel & Fixson, 2013).

The d.school model (Manna *et al.*, 2022; Meinel & Leifner, 2011) presents four vital rules in DT-based frameworks: (1) The Human Rule: *"all design activity is ultimately social"*; (2) The Ambiguity Rule: *"design thinkers must preserve ambiguity"*; (3) The Re-design Rule: *"all design is re-design"*; and (4) The Tangibility Rule: *"making ideas tangible always facilitates communication"*. These four central ideas were later developed within the five stages of the previously referred model, namely: (1) Empathize: being the first step of the process, it aims to prioritize the participants' needs and desires to fully comprehend the problem to be solved; (2) Define: in this stage, all the information collected in the previous phase is gathered and analyzed in order to translate the problems identified into specific user needs; (3) Ideate: after all the information collected in the first two phases, the main objective in this stage is to create new solutions to the defined problems through several methods, such as brainstorming, where idea sharing among all participants is encouraged and will most likely lead to find many potential solutions; (4) Prototype: in this phase, the ideas conceived are materialized through a prototype creation, that will allow to identify limitations and areas of improvement in order to posteriorly generate the end-product; and (5) Test: lastly, the final product is tested, reformed and upgraded to diminish potential problems and achieve the ideal match between the product and the final user (Geldermann *et al.*, 2018; Manna *et al.*, 2022; Plattner, Meinel, & Liefer, 2012 and 2015).

These five steps should be viewed as an iterative process with guiding principles and not milestones, which means that participants are allowed to go back and forth between the steps. Frequently, participants have to start over as new perceptions arise during the process

(Tham, 2022). To complement the DT approach, the present study will apply the Interpretative Structural Modeling (ISM) method, which will be addressed in the next section.

3.3. Interpretive Structural Modeling (ISM)

Once the structuring phase of the decision-making process is completed, through the application of the DT approach to structure the problems identified, we now move on to the evaluation phase. To this end, this study will use the Interpretive Structural Modeling (ISM) as an evaluation method.

First introduced by John Warfield in 1973, ISM can be defined, according to several authors (*e.g.*, Azevedo, Sequeira, Santos, & Mendes, 2019; Raut & Gardas, 2018; Sage 1977; Warfield, 1974), as *"an iterative and structured method belonging to the causal mapping family of methods, which allows studying complex problems, by adopting an interpretive approach based on the judgements of experts"* (Tuni, Rentizelas, & Chipula, 2022, p. 4). Its interpretative nature is due to the fact that the whole mechanics of this method relies on experts who, based on their knowledge and experience, decide the relationship between the aspects under analysis (Raj, Shankar, & Suhaib, 2008). In practice, ISM uses diagraphs to define the structure and linkages of any potential interactions (Tavakolan & Etemadinia, 2017). As a result, the model primarily conducts all the ordering and direction of direct and indirect relationships among different system components, as also assists investigators in understanding when and how the elements are connected (Ansari, Kharb, Luthra, Shimmi, & Chatterji, 2013; Chen, Sun, Tai, & Heng, 2022a; Saxena & Vrat, 1990). Since this approach is considered as one of the most popular methods for determining the complex structural connections between several variables, it is often employed across various fields (Kumar & Goel, 2022). Overall, in accordance with Diabat and Govindan (2011) and Sage (1977), ISM is able to transform *"unclear and poorly articulated models of systems into visible and well-defined models, which offer improved support for decision-making"* (Tuni *et al.*, 2022, p. 4). The ISM application comprehends a set of specific sequential steps (Chen, Cai, Wu, & Zhao, 2022b; Kumar & Goel, 2022; Poduval, Pramod, & Raj, 2015; Yu, Chiang, Le, & Lin, 2022).

Step 1: Identify the set of relevant variables to the problem: $\{V_1, V_2, V_3, \ldots, V_n,\}$.

Step 2: Identify all possible relationships between the variables.

Step 3: Develop the Structural Self-Interaction Matrix (SSIM), which presents the interactions between pairs of variables. The criteria used are *D*, *I*, *DI*, *A*: (1) *D* indicates a forward relationship where V_y (on y-axis) influences or leads to V_x (on x-axis); (2) *I* indicates a reverse relationship where V_x (on x-axis) influences or leads to V_y (on y-axis); (3) *DI* indicates a dual directional relationship, where both V_y (on y-axis) and V_x (on x-axis) influence or leads to each other; and (4) *A* represents the absence of relationship between variables V_x (on x-axis) and V_y (on y-axis).

Step 4: Develop the Initial Reachability Matrix (IRM), which results of the conversion into binary format (0; 1) of SSIM, according to *Table 3.1*.

Table 3.1. Binary Format Conversion from SSIM to IRM

Relationship	D (Forward)	I (Reverse)	DI (Dual)	A (Absence)
V_{yx}	1	0	1	0
V_{xy}	0	1	1	0

Source: Poduval et al. (2015).

Step 5: Include transitivity in the IRM in order to develop the final Reachability Matrix. According to Poduval *et al.* (2015, p. 320), *"in this model, transitivity is defined as if A leads to B and B leads to C, then A leads to C".* The transitivity's integration in the IRM should occur through the next three steps: (1) check the existence of transitive secondary relationships between variables; (2) determine the driving power (number of total variables that influence V_y (including V_y); and (3) determine the dependence power (number of total variables that V_x is influenced for (including V_x).

Step 6: Define the reachability, antecedent and intersection sets for each variable. The reachability set is defined as the set of variables that are influenced by that particular variable, which means that the set includes variables whose cells in the row related to the variable are assigned "1" in the Reachability Matrix. The antecedent set comprehends variables that influence that particular variable, which means that the set includes variables whose cells in the column related to the variable are assigned "1" in the Reachability Matrix. The intersection set identifies the common variables of the reachability and antecedent sets.

Step 7: Develop level partitions (*i.e.*, distinct levels according to the interaction sets between variables, namely: (1) Level 1 – include the variables for which the Reachability and Intersection sets are equal; (2) Level 2 – include the variables that follow the previous criteria, excluding Level 1 variables; and (3) Level *n* – include the variables that follow the previous criteria, excluding the variables of prior levels (from 1 until *n*-1)).

Step 8: Develop the Conical Matrix (*i.e.*, aggregate the variables in the same level within rows and columns of the final Reachability Matrix). The Conical Matrix distinguish from the Reachability Matrix, since, in the first, the allocation of the variables to the x- and y-axes depends on their levels.

Step 9: Build a digraph that consists in a set of nodes, which represents the variables in the Conical Matrix, and a set of arrows that represents all the connections, showing the direction from one node to another (forward or reverse). After removing the transitivity relationships, the final digraph is created.

Step 10: Build the interpretive structural model, based on the final digraph (developed on *Step 9*), through the replacement of the node numbers to descriptions of each variable to be presented in text boxes.

Step 11: Perform the *Matrice d'Impacts Croisés Multiplication Appliquée à um Classement* (MICMAC) analysis, which will allow to understand the intensity to which each variable influences or is influenced by the other variables. In order to do that, the variables should be first allocated into four categories, according to the driving and dependence powers of each one (which were determined on *Step 5*), as stated in *Table 3.2*.

Table 3.2. Variables Classification According to MICMAC Analysis

Categories	Driving Power	Dependence Power	Characteristics	Quadrant in MICMAC graph
Autonomous	Low	Low	These variables do not influence the system since they present low driving and low dependence power.	Bottom-Left
Linkage	High	High	These variables influence and get influenced by the other variables. Any action on these variables will strongly affect the system.	Top-Right
Independent or Influent	High	Low	These variables deeply influence the system but are not influenced by it. Any action on these variables will affect all the other variables that are dependent on them, which means that the greater the number of dependent variables, the bigger the impact on the system.	Top-Left
Dependent	Low	High	These variables are significantly influenced by the system but do not influence it.	Bottom-Right

Source: Poduval et al. (2015).

Second, each variable should be positioned in the MICMAC digraph's quadrants, according to its driving and dependence powers, as shown in *Figure 3.1*.

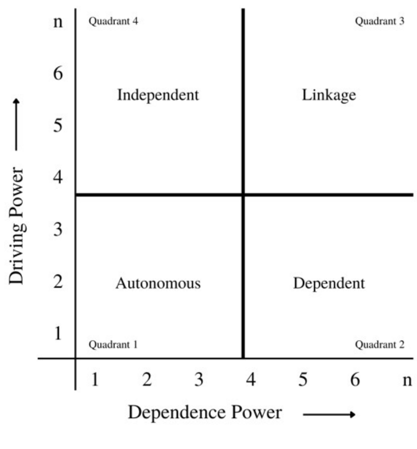

Figure 3.1. MICMAC Digraph

Source: Poduval et al. (2015, adap.).

In general, the ISM approach provides a better understanding of variables' relationships, as well as the degree of influence that each variable has toward the others and toward the system, enabling the comprehension of which actions can lead to the aimed result. In the next topic, the possible contributions of both DT and ISM to the analysis of frugal innovation determinants will be presented.

3.4. Possible Contributions to the Analysis of Frugal Innovation Determinants

Based on the insights provided in *Chapter 2* regarding frugal innovation and its current constraints, it is possible to understand that the existing studies and methodologies contain several limitations that condition frugal innovation's full potential. Hence, the necessity to surpass these limitations led to the search of different and more effective methodologies. The combination of DT and ISM is presented as a fitting methodology to overcome some of the limitations mentioned and to analyze frugal innovation determinants.

DT's capability to identify potential solutions and help participants to better manage complexity makes the approach suitable to the subject of this study, since it allows to filter and structure the most important frugal innovation determinants through new techniques and data sources, always based on experts' knowledge and opinions. The first step of the ISM method (*"Identify the set of relevant variables to the problem"*) is actually completed in the structuring phase, through the DT approach, which marks the connection between both methodologies. Therefore, ISM begins with the determinants selected by the first method and then analyzes the relationships between the aspects under study, permitting the comprehension of the effects each variable has on the others as well on the system.

Overall, both techniques allow for the performance of a complete analysis of frugal innovation determinants and, consequently, the selection of the most important ones, in accordance with the specialists, and provide the understanding of how these factors are related to each other as well as the degree of influence they have toward each other and toward the system. Furthermore, these methods enable the comprehension of what actions must be taken regarding the most important determinants defined throughout the process and support decision making in this topic, through the clarification of the consequences that each action brings to each variable. In the following chapter, both methods will be applied in a real-life situation in order to support frugal innovation determinants' investigation.

SYNOPSIS OF CHAPTER 3

In this third chapter, the main objective was to present and explain the methodologies that will be applied in the present dissertation. Thus, we began with a brief explanation of the decision-making process, presenting its three phases: (1) structuration phase; (2) evaluation phase; and (3) recommendation phase. The structuring phase was then described more deeply through the exploration of problem structuring methods to understand their importance on the process. Next, we introduced the structuring method chosen to be employed in this study: Design Thinking (DT). This approach, considered innovative and creative toward complex decision making, provides, through an interactive process, more effective decision making, given that expands the scope of options considered, includes a high number of people in the process, applies new techniques and broadens data sources. It has been receiving increasing attention in the literature due to its application to diverse domains, since has shown capability to solve both technical and social concerns. Even though there is still a lack of consensus regarding the approach's definition, most authors agree on three DT main aspects: empathy; collaboration; and prototyping, which translate to the three stages of the method: (1) inspiration; (2) ideation; and (3) implementation. Passing to the evaluation phase, we presented the technique selected to this study (*i.e.*, Interpretive Structural Modeling (ISM)). As an interactive methodology, ISM allows for the comprehension of complex problems through an interpretive approach based on experts' knowledge. This method determines the connections between several variables, allowing for the comprehension of how they are related to each other and either if they influence or are influenced, which results in improved support for decision making. The method application comprehends a battery of steps that ultimately clarify the level of influence that each variable represents to the other and to the system, allowing to determine the most important variables analyzed. At last, we explained the possible contributions of both methodologies selected (*i.e.*, DT and ISM), emphasizing its complementarity and how they can enhance the understanding of frugal innovation determinants through a complete and exhaustive analysis that will lead to the selection of the most important determinants, and highlighting their importance to overcome the limitations that the methodologies of previous studies presented. In the following chapter, we will apply DT combined with ISM in a real-life situation.

CHAPTER 4

EMPIRICAL APPLICATION

After explaining the methodologies to be employed in this dissertation in *Chapter 3*, in this chapter we will proceed to the empirical application of DT and ISM. Therefore, firstly we will identify and analyze frugal innovation determinants, resorting to two group sessions with a panel of specialists who will contribute with their knowledge and experience, in order to execute the structuring phase. Then, we will move to the ISM application to carry out the evaluation phase, following the steps described in the previous chapter regarding this technique. At last, we will have a consolidation session with an external decision maker, to guarantee impartiality in the discussion and recommendations of the results obtained. This allow for the model's validation and conclusion of the recommendations phase.

4.1. Identification and Analysis of Frugal Innovation Determinants

As stated in *Chapter 3*, the structuring phase marks the beginning of the decision-making process (Bana e Costa *et al.*, 2000). Since the problem structuring method chosen was DT based on cognitive mapping, the steps to develop this methodology were followed in order to complete this stage and allow for the creation of a more consistent and complete multicriteria system that will provide a broaden understanding of frugal innovation determinants.

To initiate this phase, it was necessary to gather a panel of specialists related to the topics approached, with special attention to assure heterogeneity regarding gender, age and professional experience. According to Salmeron (2009), the panels must include between 5 and 18 experts. Following this guideline, a panel of seven specialists related to corporate innovation and/or to Small and Medium Enterprises (SMEs) was gathered, with each one contributing by sharing opinions based on practical knowledge and experience. These experts had different professional backgrounds in diverse fields such as health, engineering, tourism, sustainability, automobile industry and electric industry. However, some difficulties were faced in this stage, such as: (1) the specificities required for the specialists' selection; (2) the availability of the specialists to be present in the sessions, which took approximately 7 hours in total; and (3) the definition of a schedule that would be suitable for all participants.

To facilitate time and place arrangements, the sessions were fully remotely trough Microsoft Teams (https://www.microsoft.com/microsoft-teams/), which allowed the simultaneous participation of multiple participants in the same session.

The first session took approximately 4 hours and started with a brief presentation of all specialists, who provided insights related to their professional background, experience and current profession. In addition to the experts, two facilitators were present in the session to offer support if requested. This moment was followed by a succinct presentation of the study topics, namely the explanation of the concept of frugal innovation, as well as the description of the methodologies to be applied in this dissertation.

The session was divided in three distinctive phases, using the MIRO platform (https://miro.com/) that allows synchronous participation, where the specialists employed the "post-its technique" (Eden & Ackermann, 2004). In the first phase, after explaining the features of MIRO, we presented a trigger question to the specialists: *"Based on your values and professional experience, what frugal innovation factors/determinants do you consider relevant in corporate contexts?"*. Then, we asked for the experts to write one criteria per post-it, which would be a concept, expression or small sentence based on a measure, initiative or challenge related to the trigger question, and to associate each one of them with a positive signal (+) or a negative signal (–) according to the effect each criteria represented to topic (*i.e.*, a positive signal was written if the criteria promoted frugal innovation and a negative signal if the criteria conditioned it). Throughout this phase, we encouraged the debate and exchange of ideas in order for the participants to come out with new criteria and avoid criteria's repetition. The second phase aimed to group the criteria in clusters (*i.e.*, areas of interest), being the experts given liberty to: (1) name the clusters; (2) decide which criteria should be allocated to each cluster; (3) allocate criteria to more than one cluster; and (4) move criteria to other clusters, if necessary. This resulted in the creation of five clusters, namely: (1) *Financial Resources*; (2) *Human Resources*; (3) *Innovation and Technological Challenges*; (4) *Sustainability and Surrounding Environment*; and (5) *Corporate Strategy*, which accommodated all 134 criteria created on the first phase. The third and final phased aimed to hierarchize the criteria in each cluster by importance levels. Thus, the most important criteria were posted at the top level (*i.e.*, first line), the criteria with medium importance were allocated in the middle level (*i.e.*, second line), and the least important criteria were inserted in the lowest level (*i.e.*, third line). *Figure 4.1.* illustrate some moments of the first work session with the expert panel.

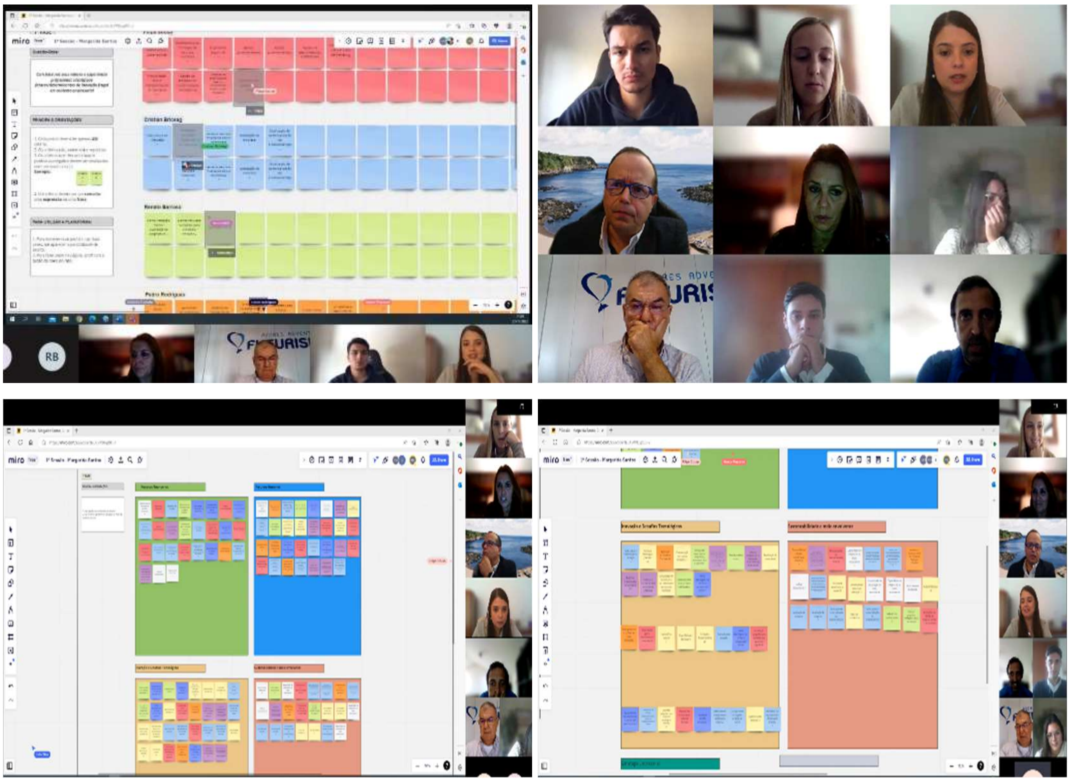

Figure 4.1. Moments of the First Group Session

With the outputs of this session, it was possible to create a group cognitive map using the Decision Explorer software (https://www.banxia.com/). After its elaboration, the map was presented to the specialists at the beginning of the second session, for them to analyze it, suggest changes if they considered it pertinent and, ultimately, to validate the cognitive structure. *Figure 4.2.* presents the validated group cognitive map.

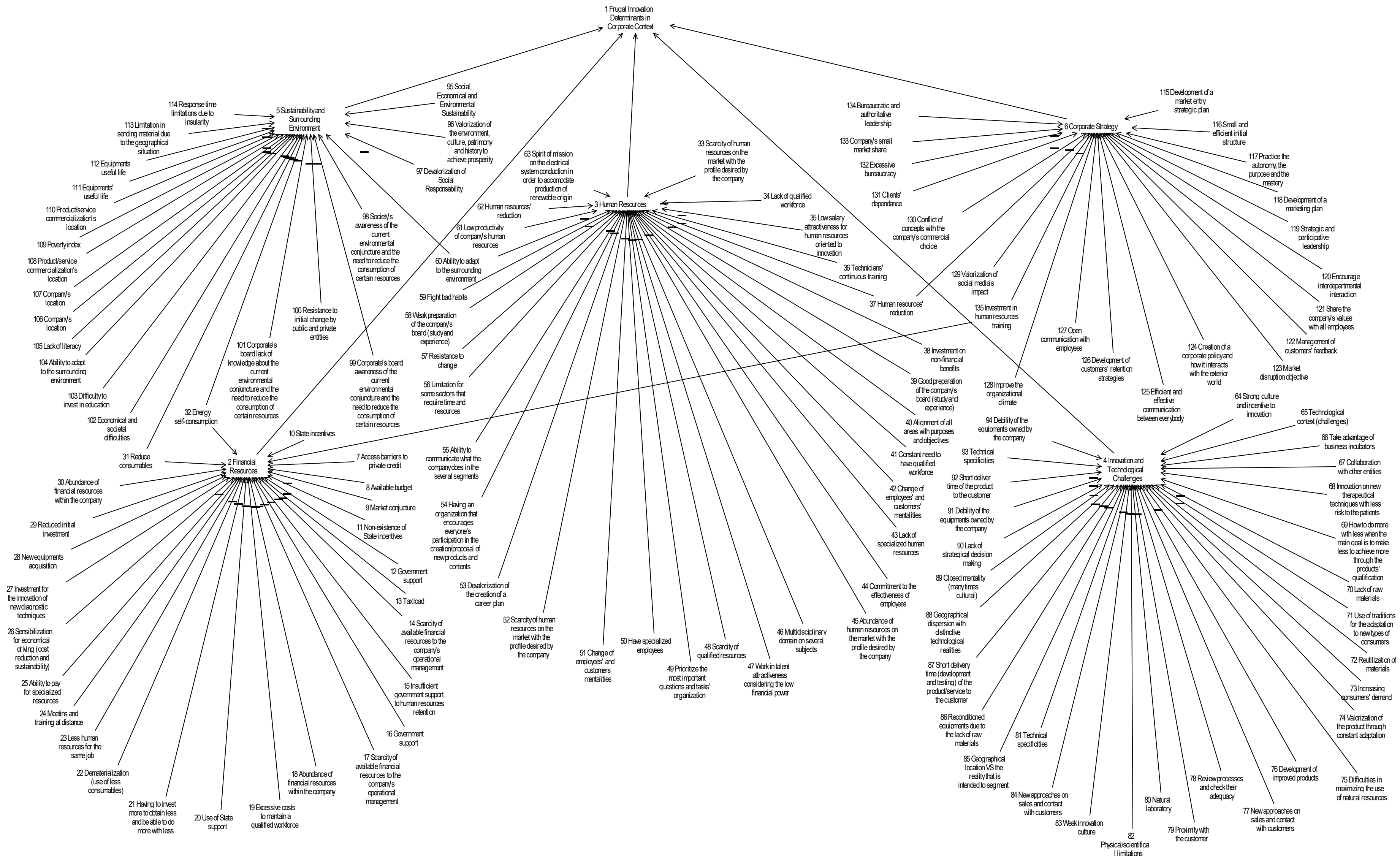

Figure 4.2. Cognitive Map

Figure 4.2. represents graphically the outputs of the first session, being all the criteria connected to their respective cluster(s) and all the clusters connected to the base concept (*i.e.*, *Frugal Innovation Determinants in Corporate Contexts*). The arrows represent the relationship between the criteria and the main concept (*i.e.*, the criteria that have a negative influence on frugal innovation are marked with a negative sign (–)). The criteria allocated to more than one cluster in the first session were also connected to more than one cluster in the cognitive map. This step marked the ending of the structuring phase, which was followed by the evaluation phase, through the application of the Interpretive Structural Modeling (ISM).

4.2. ISM and MICMAC Structure

In the second session, five of the initial seven specialists were present, which does not affect the validity of the study, since the minimum number of participants was assured (Salmeron, 2009). This session had the duration of approximately 3 hours and counted with one facilitator. Firstly, the facilitator presented the cognitive map to the experts for analysis and validation. Secondly, she described the agenda for this session and provided a brief explanation concerning the methodology to be employed (*i.e.*, Interpretive Structural Modeling). Then, an Excel file was shared with the specialists for them to select the most important criteria in each cluster, through Nominal Group Technique (NGT) and Multi-Voting. Some of the moments of the second session are shown in *Figure 4.3.*

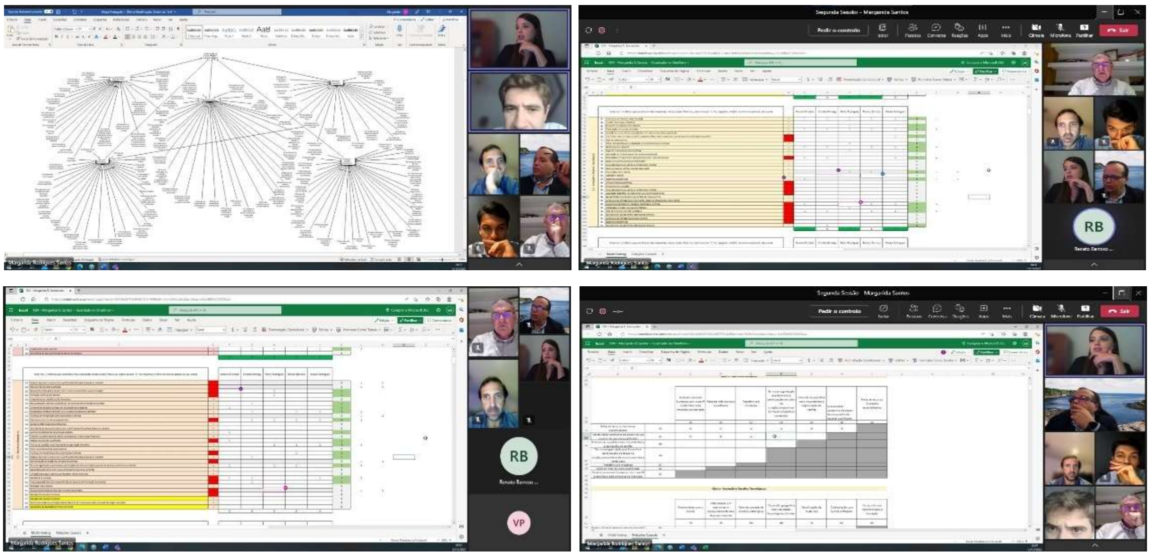

Figure 4.3. Moments of the Second Group Session

After the initial voting, a tie was observed between: (1) five criteria in cluster C2 (*Human Resources*); (2) two criteria in cluster C3 (*Innovation and Technological Challenges*); and (3) two criteria in cluster C5 (*Corporate Strategy*). Consequently, we performed a revoting between the tied criteria to determine the one(s) that would move on to the next phase. However, in the case of cluster C2 (*Human Resources*), after this revoting, there was still a tie between two criteria, so we had to carry out a new voting between these two, to identify the seventh most important criterion of the cluster. *Table 4.1.* presents the seven most important criteria selected in each cluster.

Table 4.1. Select Criteria for the Model

CLUSTER	#	CRITERIA
C1 – Financial Resources	SC7	Access barriers to private credit
	SC8	Available budget (–)
	SC9	Market conjucture
	SC14	Scarcity of available financial resources to the company's operational management
	SC19	Excessive costs to maintain a qualified workforce (–)
	SC20	Use of State support
	SC29	Reduced initial investment
C2 – Human Resources	SC43	Lack of specialized human resources (–)
	SC41	Constant need to have qualified workforce
	SC49	Prioritize the most important questions and tasks' organization
	SC54	Having an organization that encourages everyone's participation in the creation/proposal of new products and contents
	SC57	Resistance to change (–)
	SC34	Lack of qualified workforce (–)
	SC33	Scarcity of human resources on the market with the profile desired by the company (–)
C3 - Innovation and Technological Challenges	SC64	Strong culture and incentive to innovation
	SC67	Collaboration with other entities
	SC72	Reutilization of materials
	SC88	Geographical dispersion with distinctive technological realities (–)
	SC90	Lack of strategical decision making (–)
	SC75	Difficulties in maximizing the use of natural resources (–)
	SC79	Proximity with the customer

C4 – Sustainability and Surrounding Environment	SC95	Social, Economical and Environmental Sustainability
	SC100	Resistance to initial change by public and private entities (–)
	SC98	Society's awareness of the current environmental conjuncture and the need to reduce the consumption of certain resources
	SC107	Company's location
	SC104	Ability to adapt to the surrounding environment (–)
	SC96	Valorization of the environment, culture, patrimony and history to achieve prosperity
	SC103	Difficulty to invest in education (–)
C5 – Corporate Strategy	SC115	Development of a market entry strategic plan
	SC119	Strategic and participative leadership
	SC125	Efficient and effective communication between everybody
	SC132	Excessive bureaucracy (–)
	SC116	Small and efficient initial structure
	SC120	Encourage interdepartmental interaction
	SC126	Development of customers' retention strategies

In the last phase of the session, a second Excel sheet was created for the application of the ISM methodolody. Thereby, the participants were collectively requested to establish causality relationships: (1) between the clusters; and (2) within each cluster, between the criteria selected in the previous stage. This was done based on the following nomenclature: (i) *D* – if it was a forward relationship; (ii) *I* – if it was a reverse relationship; (iii) *DI* – if it was a dual directional relationship; and (iv) *A* – if there was an absence of relationship. This task dictated the end of the meeting and the completion of the *Step 3* of ISM. Therefore, it was possible to elaborate the SSIM, which comprehends the causality relationships between the five clusters, as described in *Figure 4.4.*

	C1	**C2**	**C3**	**C4**	**C5**
C1		DI	DI	D	DI
C2			D	DI	I
C3				D	I
C4					I
C5					

Figure 4.4. Inter-Cluster SSIM Evaluation

After analyzing the SSIM presented in *Figure 4.4.*, it was possible to verify that clusters C1 and C5 highlight from the others, since they influence all clusters: (1) cluster C1 influences clusters C2, C3, C4 and C5, being also influenced by clusters C2, C3 and C5; and (2) cluster C5 influences clusters C1, C2, C3 and C4, being only influenced by cluster C1.

Following the creation of the SSIM to evaluate the relationships between clusters, we proceeded to elaborate the SSIM for each one of the clusters, in order to assess the relationships between criteria within the clusters. *Figure 4.5.* shows the five matrixes, each one regarding each cluster.

SSIM | Financial Resources (C1)

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7		D	I	A	A	D	D
SC8			A	D	D	D	D
SC9				D	D	D	A
SC14					D	D	D
SC19						D	I
SC20							D
SC29							

SSIM | Human Resources (C2)

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43		D	D	A	A	DI	DI
SC41			D	D	A	D	DI
SC49				DI	I	I	I
SC54					I	D	D
SC57						DI	DI
SC34							DI
SC33							

SSIM | Innovation and Technological Challenges (C3)

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64		D	DI	DI	I	D	D
SC67			DI	DI	I	DI	A
SC72				DI	I	I	A
SC88					D	D	D
SC90						D	D
SC75							A
SC79							

SSIM | Sustainability and Surrounding Environment (C4)

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95		D	DI	I	D	DI	I
SC100			I	A	D	I	DI
SC98				A	D	DI	I
SC107					DI	D	I
SC104						DI	I
SC96							I
SC103							

SSIM | Corporate Strategy (C5)

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115		I	D	I	A	D	DI
SC119			DI	DI	A	D	D
SC125				I	I	D	D
SC132					DI	D	D
SC116						DI	D
SC120							DI
SC126							

Figure 4.5. SSIM Evaluation within Clusters

After collecting this data, it was possible to develop the Initial Reachability Matrix (IRM), based on the SSIMs elaborated, replacing the nomenclature "*D*", "*I*", "*DI*" and "*A*" for "0" and "1", according to the relationships presented between pairs of criteria. *Figure 4.6.* presents the inter-cluster IRM.

	C1	C2	C3	C4	C5	Dr Pw
C1	1	1	1	1	1	5
C2	1	1	1	1	0	4
C3	1	0	1	1	0	3
C4	0	1	0	1	0	2
C5	1	1	1	1	1	5
Dp Pw	4	4	4	5	2	

Figure 4.6. Inter-Cluster IRM

Thereafter, we analyzed possible transitivities, in order to verify the existence of indirect relationships between the criteria that were represented with "0". For that, we applied the Warshall Algorithm, following four steps: (1) identify in the column all criteria that presents "1"; (2) identify in the row all criteria that presents "1"; (3) cross check the criteria identified in the column agains the criteria identified in the row; and (4) check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*" (view *Figures A.3.* to *A.5.* of *Appendix A*; *Figures B.4.* to *B.8.* of *Appendix B*; *Figures C.3.* to *C.7.* of *Appendix C*; *Figures D.3.* to *D.6.* of *Appendix D*; *Figures E.3.* to *E.5.* of *Appendix E*; and *Figures F.3.* to *F.5.* of *Appendix F*). Consequently, it was possible to create the Final Reachability Matrix (FRM) regarding the inter-cluster analysis, as illustrated in *Figure 4.7.*

	C1	C2	C3	C4	C5	Dr Pw
C1	1	1	1	1	1	5
C2	1	1	1	1	1*	5
C3	1	1*	1	1	1*	5
C4	1*	1	1*	1	1*	5
C5	1	1	1	1	1	5
Dp Pw	5	5	5	5	5	

Figure 4.7. Inter-Cluster FRM

Thus, it was verified that all clusters have maximum importance between them, having the same driving and dependence powers. Then, we established the reachability set, the antecedent set, the intersection set and the respective partition level for the inter-cluster analysis. Therefore, all clusters have the same reachability, antecedent and intersection sets, and, consequently, belong to the same partition level (*i.e.*, Level 1), as stated in *Figure 4.8.*

	Reachability Set	Antecedent Set	Intersection Set	Level
C1	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C2	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C3	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C4	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1

Figure 4.8. Reachability, Antecedent and Intersection Sets for Inter-Cluster Analysis

Hence, we were able to develop the ISM digraph, that contemplates the relationships between clusters. *Figure 4.9.* presents the inter-cluster ISM.

Figure 4.9. Inter-Cluster ISM

To complete the ISM methodology application, we performed a MICMAC analysis, which allowed to understand the intensity to which each variable influences or is influenced by the others, allocating them into four categories, based on their driving and dependence powers, as shown in *Figure 4.10.*

MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
C1	5	5	Linkage	III
C2	5	5	Linkage	III
C3	5	5	Linkage	III
C4	5	5	Linkage	III
C5	5	5	Linkage	III

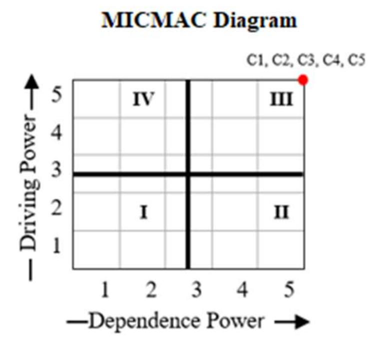

Figure 4.10. Inter-Cluster MICMAC Analysis

In conclusion, it was possible to verify that all five clusters represent areas with maximum and equally importance regarding frugal innovation determinants in corporate contexts. After inter-cluster analysis, we proceeded to perform the analysis of each cluster.

From the 27 criteria included in Cluster C1 – *Financial Resources*, the specialists were asked to choose the most crucial ones and to establish the causality relationships between pairs of variables, which produced the SSIM that served as the foundation for setting the corresponding IRM (view *Figure B.1.* of *Appendix B*). The FRM was ultimately developed after the Warshall Algorithm was used to determine any potential transitivies between criteria (view *Figures B.4.* to *B.8.* of *Appendix B*). After analyzing the FRM, it was possible to verify, on ethe one hand, that the criterion SC9 has the highest driving power (*i.e.*, 7), which means it influences all other criteria, and the lowest dependence power (*i.e.*, 1), which indicates it is unaffected by other criteria. On the other hand, criteria SC19, SC20 and SC29 have the lowest driving power within the cluster (*i.e.*, 3), meaning that they only influence two other variables, and the highest dependence power (*i.e.*, 7), which demonstrates that they are influenced by all the other variables. As a result, within the criteria of this cluster, the reachability set, the antecedent set and the intersection set are distinct. Consequently, the criteria were placed in five partition levels: (1) on Level 1 – SC19, SC20, SC29; (2) on Level 2 – SC14; (3) on Level 3 – SC8; (4) on Level 4 – SC7; and (5) on Level 5 – SC9 (view *Figure B.2.* of *Appendix B*). *Figure 4.11.* shows Cluster C1 – *Financial Resources* ISM digraph.

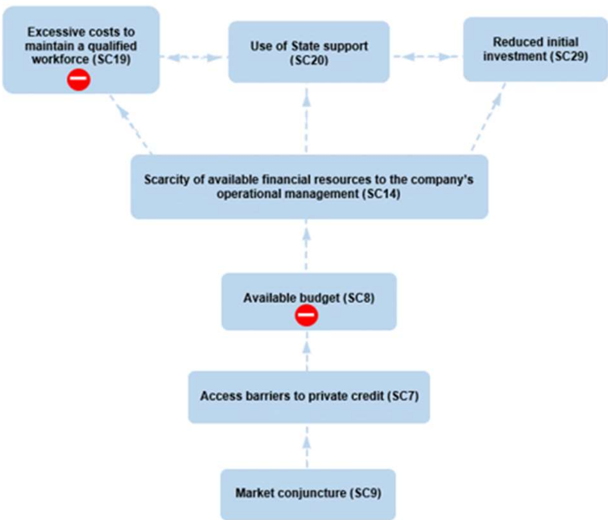

Figure 4.11. ISM of Cluster C1 – *Financial Resources*

At last, in the MICMAC analysis, criteria SC7, SC8 and SC9 were positioned in the 4th Quadrant, (*i.e.*, *Independent*), which reinforces the fact that they have a strong influence component. Thereby, they represent a great impact in the cluster's contribution to the frugal innovation determinants in corporate contexts. Criterion SC14 was placed in the 3rd Quadrant, (*i.e.*, *Linkage*), meaning it influences and is influenced equally, and criteria SC19, SC20 and SC29 were allocated in the 2nd Quadrant, (*i.e.*, *Dependent*), which reinforces the idea that they are strongly influenced and, consequently, will have a smaller relevance on the cluster's overall contribution to the main topic (view *Figure B.2.* of *Appendix B*).

Concerning Cluster C2 – *Human Resources*, from its 31 criteria, the specialists selected the most important ones and defined the cause-and-effect relationships between pairs of criteria. This task originated the SSIM, which served as base to for creating the respective IRM (view *Figure C.1.* of *Appendix C*). Then, using the Warshall Algorithm to identify possible transitivities between variables, the FRM was created (view *Figures C.3.* to *C.7.* of *Appendix C*). Based on the FRM analysis, it was possible to comprehend that all seven criteria have the highest driving and dependence powers (*i.e.*, 7), indicating that they all have the same and greatest significance to the subject under study. Consequently, the reachability set, the antecedent set and the intersection set are also equal for all criteria, so they were all assigned to the same partition level (*i.e.*, Level 1) (view *Figure C.2.* of *Appendix C*). *Figure 4.12.* presents Cluster C2 – *Human Resources* ISM digraph.

Figure 4.12. ISM of Cluster C2 – *Human Resources*

Finally, in the MICMAC analysis, all criteria were placed in the 3rd Quadrant, (*i.e.*, *Linkage*), meaning all variables are strongly connected between them and have a great impact on the model (view *Figure B.2.* of *Appendix B*).

Regarding Cluster C3 – *Innovation and Technological Challenges*, from the cluster's 31 criteria, the experts were asked to pick the most important ones and to define the causality relationships between pairs of variables. Consequently, the SSIM was elaborated, being the base for the creation of the respective IRM (view *Figure D.1.* of *Appendix D*). The FRM was then created by using the Warshall Algorithm to detect any possible transitivities between criteria (view *Figures D.3.* to *D.6.* of *Appendix D*). Using the FRM analysis as a basis, it was possible to verify, on the one hand, that criteria SC64, SC67, SC72, SC88, SC90 and SC75 have the highest driving power (*i.e.*, 7) and high dependence power (*i.e.*, 6), which means that they influence all the other variables but are also influenced by a large amount of variables. On the other hand, criterion SC79 has the lowest driving power (*i.e.*, 1) and the highest dependence power (*i.e.*, 7), which indicates that it has no influence on any criteria and is influenced by every other criteria. Consequently, the reachability set, the antecedent set and the intersection set are different within the criteria of this cluster, being the criteria allocated in two partition levels: (1) on Level 1 – SC79; and (2) on Level 2 – SC64, SC67, SC72, SC88, SC90 and SC75 (view *Figure D.2.* of *Appendix D*). *Figure 4.13.* ilustrates Cluster C3 – *Innovation and Technological Challenges* ISM digraph.

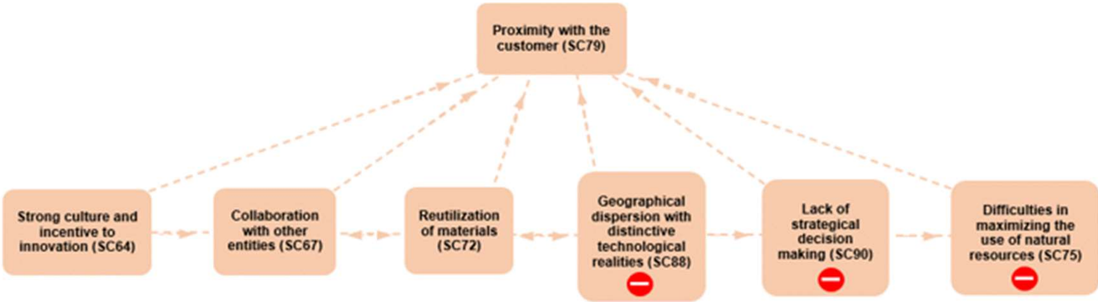

Figure 4.13. ISM of Cluster C3 – *Innovation and Technological Challenges*

At last, in the MICMAC analysis, criteria SC64, SC67, SC72, SC88, SC90 and SC75 were placed in the 3rd Quadrant (*i.e.*, *Linkage*), which means they strongly influence and are influenced by other variables, existing a clear linkage between all of them. In contrast, criterion SC79 was allocated to the 2nd Quadrant, (*i.e.*, *Dependent*), indicating it is highly influenced by all the other criteria, while not providing any influence on them, which translates in an overall weak contribution to the model (view *Figure D.2.* of *Appendix D*).

In relation to Cluster C4 – *Sustainability and Surrounding Environment*, from the 23 criteria, the specialists selected the most important ones and established the cause-and-effect relationships between pairs of criteria. Consequently, we were able to develop the SSIM, which served as the foundation to define the corresponding IRM (view *Figure E.1.* of *Appendix E*). The FRM was then created, through the application of the Warshall Algorithm to determine potential transitivities between variables (view *Figures E.3.* to *E.5.* of *Appendix E*). Based on the FRM analysis, it was possible to understand that all seven criteria have the same relevance to the subject under study, since they all have the highest driving and dependence powers (*i.e.*, 7). As a result, the reachability set, the antecedent set and the intersection set are equal for all criteria, thus they were all placed to the same partition level (*i.e.*, Level 1) (view *Figure E.2.* of *Appendix E*). *Figure 4.14.* presents Cluster C4 – *Sustainability and Surrounding Environment* ISM digraph.

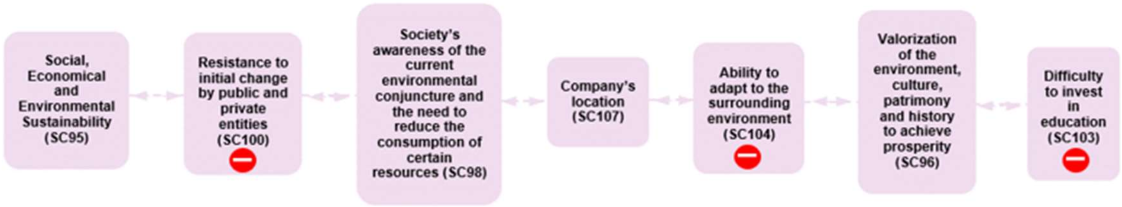

Figure 4.14. ISM of Cluster C4 – *Sustainability and Surrounding Environment*

Finally, in the MICMAC analysis, all criteria were assigned to the 3rd Quadrant (*i.e.*, *Linkage*), which means that all variables are greatly linked between them and have a large impact on the model (view *Figure E.2.* of *Appendix E*).

In regard to Cluster C5 – *Corporate Strategy*, among its 22 criteria, the experts determined the most important ones, and identified the causality relationships between pairs of variables. Then, we were able to develop the SSIM, which was the base for establishing the respective IRM (view *Figure F.1.* of *Appendix F*). After that, using the Warshall Algorithm to identify possible transitivities between criteria, the FRM was created (view *Figures F.3.* to *F.5.* of *Appendix F*). Based on the FRM analysis, it was possible to understand that all seven criteria have the highest driving and dependence powers (*i.e.*, 7), indicating they are all equally relevant to the topic under research. As a result, all criteria have the same reachability set, antecedent set and intersection set, being all allocated to the same partition level (*i.e.*, Level 1) (view *Figure F.2.* of *Appendix F*). *Figure 4.15.* shows Cluster C5 – *Corporate Strategy* ISM digraph.

Figure 4.15. ISM of Cluster C5 – *Corporate Strategy*

At last, in the MICMAC analysis, all criteria were placed in the 3rd Quadrant (*i.e.*, *Linkage*), which indicates that all variables are strongly interconnected and have a significant influence on the model (view *Figure F.2.* of *Appendix F*). In the next topic, we will approach the results, discussion and recommendations regarding the ISM application, with resort to a consolidation session with an external specialist.

4.3. Results, Discussion and Recommendations

Following the implementation of the ISM approach, we moved on to the analysis of the results in order to build a model that encompasses the key factors to take into account when analyzing frugal innovation determinants in corporate contexts. This model, created through the software Mind Map Pro (https://simplemind.eu), included 5 areas that are considered vital for the subject under study: (1) *Financial Resources* (C1); (2) *Human Resources* (C2); (3) *Innovation and Technological Challenges* (C3); (4) *Sustainability and Surrounding Environment* (C4); and (5) *Corporate Strategy* (C5). Nevertheless, there are singularities in each cluster that are important to mention: (1) clusters C1 and C2 are primarily focused on the company's resources (*i.e.*, employees and finances); (2) clusters C3 and C4 present a broaden approach, including both internal and external determinants of frugal innovation (*i.e.*, related to innovation, technology and environment); (3) cluster C5 exclusively comprehends aspects from an internal perspective based on the company's strategy; (4) cluster C1 contains a clear segmentation in the criteria, which is demonstrated by the 5 partition levels, meaning that the relevance and contribution for the final model among the variables is distinctive; (5) even though the segmentation in cluster C3 is not as accentuated as in cluster C1, there is still one criterion (SC79) that has a smaller impact overall on the model than the other criteria of the cluster; and (6) in clusters C2, C4 and C5, all criteria have equal and maximum importance. *Figure 4.16.* presents the model created.

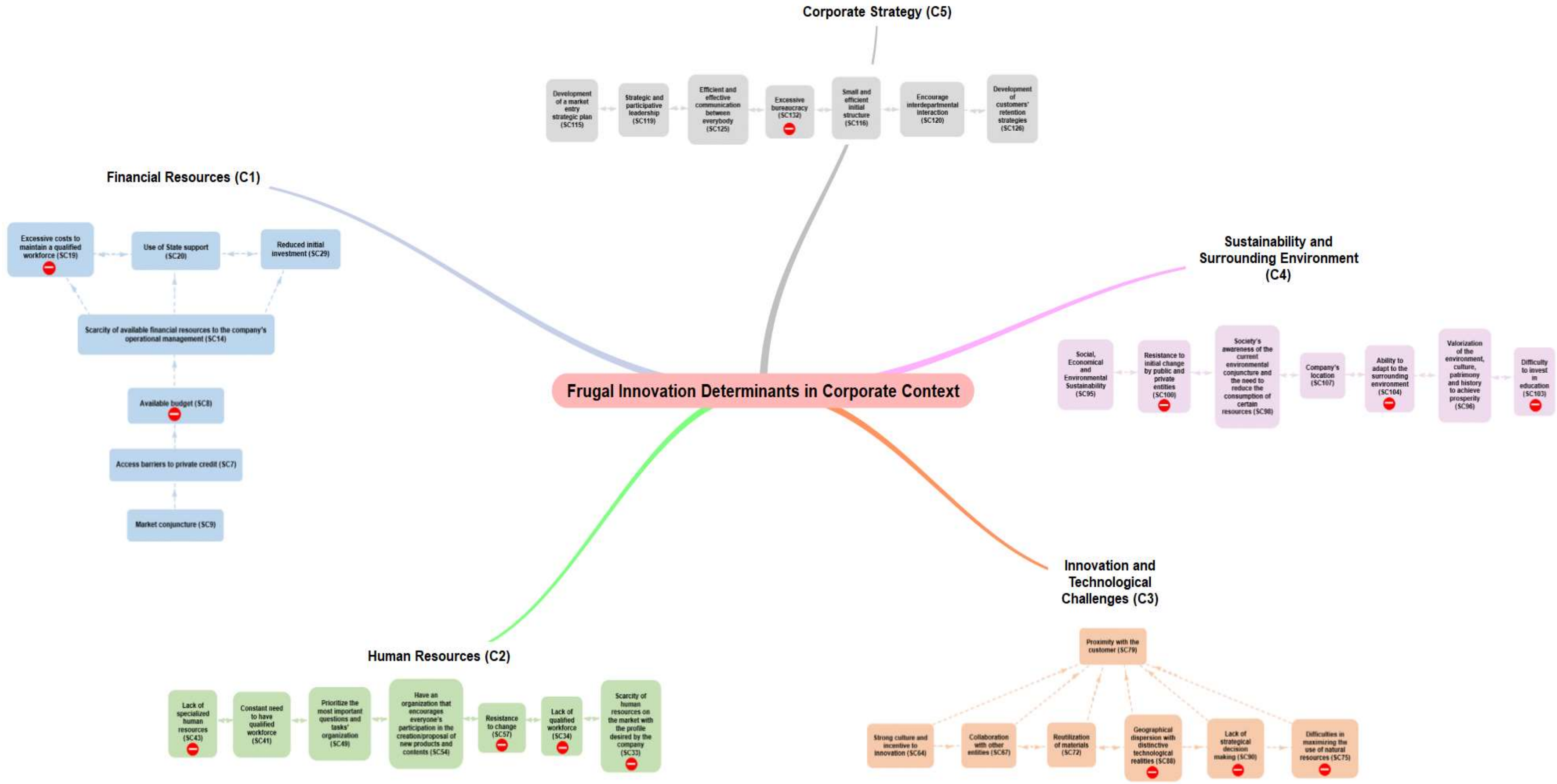

Figure 4.16. Model of Frugal Innovation Determinants in Corporate Contexts

To consolidate the results obtained and validate the final model created, a consolidation session was organized with a representative of the National Innovation Agency (ANI in Portuguese). This ANI representative was considered as a external/impartial party, since he did not participate in the group sessions. This session took aproximately 1 hour, was conducted through the Microsoft Teams platform, and had the following agenda: (1) explanation of the frugal innovation context, namely its definition, characteristics and temporal development; (2) methodological framework regarding the techniques employed in the dissertation (*i.e.*, DT and ISM); (3) demonstration and description of the methodologies' application; (4) analysis of the results obtained; and (5) request for the expert's opinion regarding the methodologies applied, the results obtained, the practical implementation of the model and improvement suggestions. *Figure 4.17.* ilustrates some of the moments of the consolidation session.

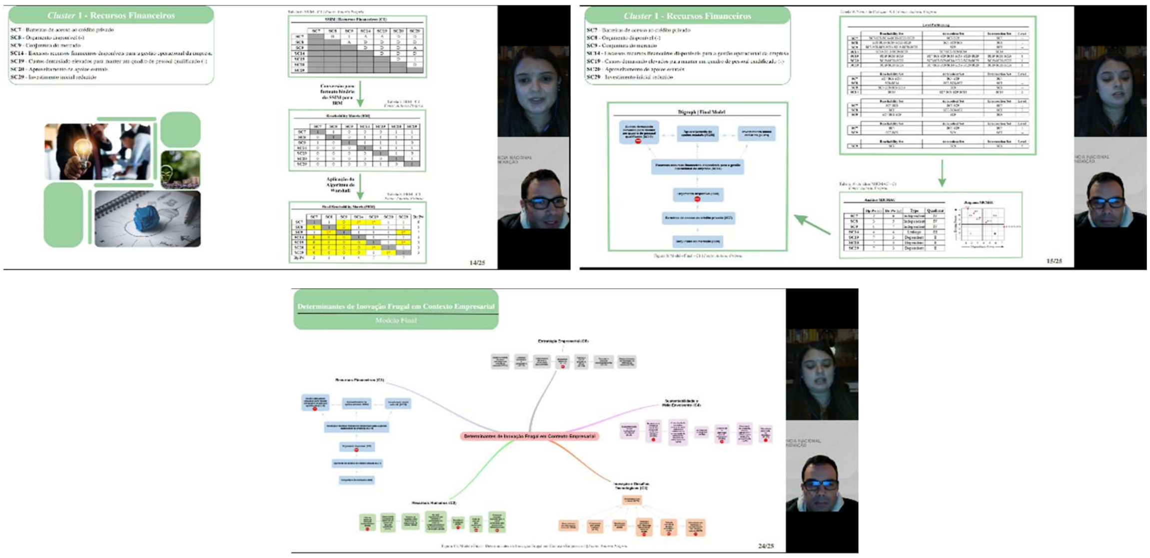

Figure 4.17. Moments of the Consolidation Session

Regarding the methodologies applied, even though the expert was not very familiar with them, he believed that the techniques chosen were appropriate within the scope of this dissertation, since they have already been studied and proved, making them perfectly suitable for the purposes of an academic study.

Concerning the results achieved through these methodologies, the expert considered that they heavily depend on the context in which they were obtained, specifically on the selection of the specialists, since a different panel applying the same methodologies would reach different findings because they would remember other criteria and group them in a different way, as they would have other experience and practical knowledge on the subject. Therefore, he believed it was crucial that the panelists selected were the ideal persons in terms of having expertise and experience on the subject, so that the outcomes would reflect the determinants of frugal innovation in corporate contexts. Nevertheless, he did not view this aspect as a weakness but rather as a characteristic of the methodologies employed, which was supported by the fact that the diversity of the specialists, namely in terms of their professional experience, was verified.

For the process implementation, in general terms, the expert considered that from the perspective of a company, knowing more about the determinants of frugal innovation can raise some awareness about whether or not it is a strategy to adopt. However, he added that there are several criteria that do not depend on the company, enhancing that there are two clusters (*i.e.*, clusters C3 and C4) which are essentially external criteria related to the surroundings, the social, economic and environmental context, that the company does not control, only acts on them. The expert believes that a possible application of the model may be in the context of public policies for innovation, where countries and regions can attempt to understand how they can contribute to and promote this type of innovation and determine if doing so brings benefits, given their economic context, their business fabric, and their availability of financial and human resources. Hence, the implementation of this model in this context may be useful to ascertain the extent to which there is a path for investing in frugal innovation. In order to apply the model in practice, the expert considers that it is first necessary to identify the entities that are interested in exploring this matter further. He believes that these organizations are likely to fall under the purview of the Ministries of Economy and Environment, which deal with issues related to economic development, sustainable development, innovation and poverty. He views frugal innovation as a highly transversal topic, since it also encompasses the internationalization of the economy, given that a company from a developed country may find it profitable to invest in frugal innovation in order to get into less developed markets, broadening its market reach. Thus, it is important to first identify a group of entities from the viewpoint of public policy that may be involved in promoting issues related to frugal innovation.

At last, the expert believes it is critical to have general guidelines and information, through public actors, that introduce this approach and promote awareness of these concepts of frugal innovation, including what they are and what benefits they can bring to companies, so that they perceive the opportunities that the adoption of frugal innovation brings and, consequently, aim at this direction.

SYNOPSIS OF CHAPTER 4

The empirical application of the methodologies previously discussed and explained in this dissertation along with the completion of the three phases of the decision-making process (*i.e.*, structuring phase; evaluation phase; and recommendations phase) were covered in *Chapter 4*. For this purpose, we gathered a heterogeneous panel of seven specialists related to SMEs and/or corporate innovation to perform two online group sessions where they contributed with their knowledge and experience regarding the subject under study. The first session lasted about 4 hours and was divided in three phases: (1) definition of criteria regarding the trigger question presented; (2) allocation of the criteria in clusters; and (3) hierarchization of the criteria within each cluster, according to their importance level. The outcomes of this session resulted in the elaboration of a group cognitive map, which contained 134 criteria divided in five clusters: (1) *Financial Resources*; (2) *Human Resources*; (3) *Innovation and Technological Challenges*; (4) *Sustainability and Surrounding Environment*; and (5) *Corporate Strategy*. The second session counted with five of the initial seven experts, which did not compromise the study's validation, took approximately 3 hours and started with the presentation of the cognitive map for the specialists' analysis and validation. Then, we asked for the participants to choose the seven most important criteria within each cluster, through Nominal Group Technique (NGT) and Multi-Voting. After that, the experts collectively identified cause-and-effect relationships between the clusters and, within each cluster, between the criteria previously selected. This session enabled the execution of the first three steps of the ISM methodology, being the remaining steps, which involved the creation of diagrams that illustrated the relationships between determinants (*i.e.*, determinants of frugal innovation in corporate contexts) and the establishment of their respective hierarchies, subsequently applied. As a result, it was possible to develop the final model that encompassed the final diagrams of each cluster and provided a broaden understanding regarding the determinants of frugal innovation in corporate contexts, including how they are related, their significance to one another and how each of them affects the system as a whole. Lastly, we had a consolidation session with an external party to guarantee an unbiased opinion about the model and, ultimately, its validation. In the following chapter, we will outline the main conclusions of this dissertation.

CHAPTER 5

CONCLUSION

5.1. Main Results of the DT-ISM Application

As stated by Hossain (2020, p. 2), *"effective innovative solutions are essential for solving today's complex problems and FI is a way to accomplish this goal"*. Therefore, the utilization of new innovation techniques such as frugal innovation, which allows to use fewer resources while achieving good or even improved results compared to traditional innovation, is seen as a path to success, having become increasingly important to be adopted by companies in the most diverse fields. To enable the implementation of frugal innovation, it is crucial that managers have access to tools that support them in this matter, facilitating the identification of frugal innovation determinants and the comprehension of the interactions between them (*i.e.*, whether if they influence the others, are influenced or both). In this respect, since the current literature does not cover these aspects, existing a clear lack of guidance in this topic, ***a multicriteria system that provides a deepen comprehension of frugal innovation determinants through the application of the Design Thinking (DT) methodology with the Interpretive Structural Modeling (ISM) technique was created***. Based on a constructivist approach, this model permits a better understanding of frugal innovation determinants and their analysis, supporting companies' decision-making processes.

The current dissertation is divided into five chapters, namely: (1) *Introduction*, where an initial background was provided and the objectives, the methodology, the structure and the expected results of the investigation were established; (2) *Literature Review*, where a contextualization regarding the subjects under study was developed, highlighting the explanation of the concept of frugal innovation and its importance, as well as presenting the temporal analysis of the existing literature, including the limitations faced; (3) *Methodology and Sources*, where we introduced a framework about the structuring of decision problems, complementing it with the explanation of the two constructivist techniques applied in this study: DT and ISM; (4) *Empirical Application*, where the practical component of the study was performed and described, which led to the identification and analysis of frugal innovation determinants and, consequently, to the creation of the model; and (5) *Conclusion*, where the main results, contributions and limitations of the investigation are presented along with leads for future research.

According to the inputs provided by the panel of specialists in the group sessions, five main areas of concern regarding frugal innovation determinants in corporate contexts were identified: (1) *Financial Resources*; (2) *Human Resources*; (3) *Innovation and Technological Challenges*; (4) *Sustainability and Surrounding Environment*; and (5) *Corporate Strategy*.

Through the application of the ISM methodology, that allowed to proceed to the clusters' definition and respective criteria's hierarchization, it was possible to verify that all clusters were allocated to the same partition level, meaning that they all represent an equal and maximum importance to the final model. However, in the case of the criteria, the scenario was different within some of the clusters. While clusters C2, C4 and C5 had the same and highest relevance to the model, clusters C1 and C3 had some specificities that are important to note: (1) in cluster C1, the five partition levels established are indicators of the existence of a segmentation in the criteria, meaning that the variables in this cluster have a different relevance and contribution to the final model among them – the first partition level includes criterion SC9 *Market Conjuncture*, the second partition level contains criterion SC7 *Access barriers to private credit*, the third partition level encompasses criterion SC8 *Available Budget* (–), the fourth partition level comprehends criterion SC14 *Scarcity of available financial resources to the company's operational management* and the fifth partition level includes the three remain criteria of the cluster, *i.e.*, criterion SC19 *Excessive costs to maintain a qualified workforce* (–), criterion SC20 *Use of State support* and criterion SC29 *Reduced initial investment*; and (2) in cluster C3, there is one criterion, *i.e.*, criterion SC79 *Proximity with the customer*, that stands out in relation to the others, since its significance to the model is smaller than that of the other criteria, which is demonstrated by its allocation to the second partition level, while the remaining criteria were placed in the first partition level.

Additionally, it is worth mentioning that clusters C1 and C2 focus mainly on the organization's resources, clusters C3 and C4 cover internal and external frugal innovation determinants and cluster C5 only considers factors from an internal point of view, according to the company's strategy.

Notwithstanding the satisfactory results obtained, which were validated by an external party specialist on the matter, our study, as any other, has limitations, namely: (1) the results obtained highly depend on the context in which the data was collected, particularly with regard to the panel of specialists, since a different panel would have reached different results, meaning that one must be careful about considering these results as absolute truths and generalizing them; (2) the clarity/accuracy of the results is dependent on the selection of the experts, namely on their suitability to participate in the study and their knowledge of the topics addressed; (3) some criteria are very similar to each other, ending up to refer to the same; and (4) with the exception of cluster C1, the clusters had a flat hierarchization, with most criteria being allocated to the first partition level, which makes it difficult to understand the individual importance and relevance of these clusters' criteria. Nevertheless, the model created enables a clearer perception of frugal innovation determinants in corporate contexts. In the next point, the main contributions of this investigation to the analysis of frugal innovation determinants will be analyzed.

5.2. Contributions to the Analysis of Frugal Innovation Determinants

As demonstrated in *Chapter 2*, despite the increasing attention that the literature has given to frugal innovation, the current approaches to this matter are still very focused on theoretical features, with the dearth of studies concerning the practical aspects and application of this subject still a reality. Hence, this study sought to fulfil this gap and favourably influence the field's development, namely by clarifying the identification and analysis of frugal innovation determinants, including their relationships toward one another.

Therefore, the main contribution of this dissertation is the ***creation of a model that clarifies, identifies and provides a broaden analysis of frugal innovation determinants in corporate contexts***, in order to provide support to companies in their decision-making processes. Thus, through a constructivist approach that aimed to address the subject holistically and consider both uncertainty and subjectivity, we were able to identify 134 criteria that represent frugal innovation determinants in corporate contexts, divided into five main clusters, according to their concern areas. Consequently, we determined which criteria within the clusters are most crucial, based on the contribution of a panel of specialists. Then, with the application of the ISM methodology, we were able to establish and comprehend the causal relationships between these criteria, emphasizing which ones must be prioritized. These outputs were incorporated in the model created, enabling an improved analysis and understanding of frugal innovation determinants. The following topic will provide some leads for future research.

5.3. Future Research

In light of the results obtained, it seems clear that the application of both methodologies (*i.e.*, DT and ISM), allowed for the development of an in-depth multicriteria system that provided a broaden analysis and comprehension of frugal innovation determinants in corporate contexts. This system can be considered a valuable resource to help companies improve their decision-making processes. However, it is important to refer that these methodologies have limitations, which pave the way for additional future investigations regarding this topic. Hence, the following leads stand out: (1) repeat the study with a different panel of experts and compare the results obtained with those from this dissertation, in order to identify and understand the key differences between them and complement the model; (2) seek the practical application of the model in the context of public policies for innovation; and (3) combine other multicriteria methodologies with those used in this study, to create a stronger and even more complete model.

Overall, frugal innovation has a wide range of applications in a variety of sectors, so any investigation that tackles these issues and contributes to the field's development and growth is positive and must be encouraged.

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APPENDICES

Appendix A – Inter-Cluster Analysis

1. Structural Self-Interaction Matrix (SSIM) - Clusters

	C1	C2	C3	C4	C5
C1		DI	DI	D	DI
C2			D	DI	I
C3				D	I
C4					I
C5					

2. Reachability Matrix (RM)

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	0
C3	1	0	1	1	0
C4	0	1	0	1	0
C5	1	1	1	1	1

3. Analysis of Possible Transitivities

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	0
C3	1	0	1	1	0
C4	0	1	0	1	0
C5	1	1	1	1	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in **Warshall Clusters**]

	C1	C2	C3	C4	C5	Dr Pw
C1	1	1	1	1	1	5
C2	1	1	1	1	1*	5
C3	1	1*	1	1	1*	5
C4	1*	1	1*	1	1*	5
C5	1	1	1	1	1	5
Dp Pw	5	5	5	5	5	

Figure A.1. Steps for Inter-Cluster Analysis

5. Level Partitioning

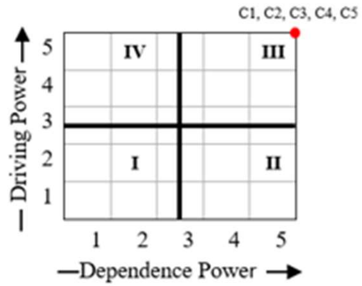
	Reachability Set	Antecedent Set	Intersection Set	Level
C1	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C2	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C3	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C4	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1
C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	C1-C2-C3-C4-C5	1

6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
C1	5	5	Linkage	III
C2	5	5	Linkage	III
C3	5	5	Linkage	III
C4	5	5	Linkage	III
C5	5	5	Linkage	III

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

MICMAC Diagram



6. Digraph | Final Model

Figure A.2. Steps for Inter-Cluster Analysis (Continuation)

1. Reachability Matrix (RM) - Clusters

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	0
C3	1	0	1	1	0
C4	0	1	0	1	0
C5	1	1	1	1	1

Warshall Algorithm:

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {C1, C2, C3, C5}
R1 = {C1, C2, C3, C4, C5}
C1 x R1 = {(C1,C1), (C1,C2), (C1, C3), (C1,C4), (C1,C5), (C2,C1), (C2,C2), (C2,C3), (C2,C4), (C2,C5), (C3,C1), (C3,C2), (C3,C3), (C3,C4), (C3,C5),(C5,C1), (C5,C2), (C5,C3), (C5,C4), (C5,C5)}

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	0	1	0	1	0
C5	1	1	1	1	1

Step 2

C2 = {C1, C2, C3, C4, C5}
R2 = {C1, C2, C3, C4, C5}
C2 x R2 = {(C1,C1), (C1,C2), (C1,C3), (C1,C4), (C1,C5), (C2,C1), (C2,C2), (C2,C3), (C2,C4), (C2,C5), (C3,C1), (C3,C2), (C3,C3), (C3,C4), (C3,C5), (C4,C1), (C4,C2), (C4,C3), (C4,C4), (C4,C5), (C5,C1), (C5,C2), (C5,C3), (C5,C4), (C5,C5)}

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	1*	1	1*	1	1*
C5	1	1	1	1	1

Figure A.3. Steps for Inter-Cluster Transitivity Analysis through Warshall Algorithm

Step 3

C3 = {C1, C2, C3, C4, C5}
R3 = {C1, C2, C3, C4, C5}
C3 x R3 = {(C1,C1), (C1,C2), (C1,C3), (C1,C4), (C1,C5), (C2,C1), (C2,C2), (C2,C3), (C2,C4), (C2,C5), (C3,C1), (C3,C2), (C3,C3), (C3,C4), (C3,C5), (C4,C1), (C4,C2), (C4,C3), (C4,C4), (C4,C5), (C5,C1), (C5,C2), (C5,C3), (C5,C4), (C5,C5)}

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	1*	1	1*	1	1*
C5	1	1	1	1	1

Step 4

C4 = {C1, C2, C3, C4, C5}
R4 = {C1, C2, C3, C4, C5}
C4 x R4 = {(C1,C1), (C1,C2), (C1,C3), (C1,C4), (C1,C5), (C2,C1), (C2,C2), (C2,C3), (C2,C4), (C2,C5), (C3,C1), (C3,C2), (C3,C3), (C3,C4), (C3,C5), (C4,C1), (C4,C2), (C4,C3), (C4,C4), (C4,C5), (C5,C1), (C5,C2), (C5,C3), (C5,C4), (C5,C5)}

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	1*	1	1*	1	1*
C5	1	1	1	1	1

Figure A.4. Steps for Inter-Cluster Transitivity Analysis through Warshall Algorithm (Continuation)

Step 5

C5 = {C1, C2, C3, C4, C5}
R5 = {C1, C2, C3, C4, C5}
C5 x R5 = {(C1,C1), (C1,C2), (C1,C3), (C1,C4), (C1,C5), (C2,C1), (C2,C2), (C2,C3), (C2,C4), (C2,C5), (C3,C1), (C3,C2), (C3,C3), (C3,C4), (C3,C5), (C4,C1), (C4,C2), (C4,C3), (C4,C4), (C4,C5), (C5,C1), (C5,C2), (C5,C3), (C5,C4), (C5,C5)}

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	1*	1	1*	1	1*
C5	1	1	1	1	1

2. Final Reachability Matrix (FRM) - Clusters

	C1	C2	C3	C4	C5
C1	1	1	1	1	1
C2	1	1	1	1	1*
C3	1	1*	1	1	1*
C4	1*	1	1*	1	1*
C5	1	1	1	1	1

Figure A.5. Steps for Inter-Cluster Transitivity Analysis through Warshall Algorithm (Continuation)

APPENDIX B – Analysis of Cluster C1: Financial Resources

1. Structural Self-Interaction Matrix (SSIM) - C1

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7		D	I	A	A	D	D
SC8			A	D	D	D	D
SC9				D	D	D	A
SC14					D	D	D
SC19						D	I
SC20							D
SC29							

2. Reachability Matrix (RM)

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	0	0	1	1
SC8	0	1	0	1	1	1	1
SC9	1	0	1	1	1	1	0
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

3. Analysis of Possible Transitivities

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	0	0	1	1
SC8	0	1	0	1	1	1	1
SC9	1	0	1	1	1	1	0
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in Warshall Clusters]

	SC7	SC8	SC9	SC14	SC19	SC20	SC29	Dr Pw
SC7	1	1	0	1*	1*	1	1	6
SC8	0	1	0	1	1	1	1	5
SC9	1	1*	1	1	1	1	1*	7
SC14	0	0	0	1	1	1	1	4
SC19	0	0	0	0	1	1	1*	3
SC20	0	0	0	0	1*	1	1	3
SC29	0	0	0	0	1	1*	1	3
Dp Pw	2	3	1	4	7	7	7	

Figure B.1. Steps for the Analysis of Cluster C1: Financial Resources

5. Level Partitioning

	Reachability Set	Antecedent Set	Intersection Set	Level
SC7	SC7-SC8-SC14-SC19-SC20-SC29	SC7-SC9	SC7	--
SC8	SC8-SC14-SC19-SC20-SC29	SC7-SC8-SC9	SC8	--
SC9	SC7-SC8-SC9-SC14-SC19-SC20-SC29	SC9	SC9	--
SC14	SC14-SC19-SC20-SC29	SC7-SC8-SC9-SC14	SC14	--
SC19	SC19-SC20-SC29	SC7-SC8-SC9-SC14-SC19-SC20-SC29	SC19-SC20-SC29	1
SC20	SC19-SC20-SC29	SC7-SC8-SC9-SC14-SC19-SC20-SC29	SC19-SC20-SC29	1
SC29	SC19-SC20-SC29	SC7-SC8-SC9-SC14-SC19-SC20-SC29	SC19-SC20-SC29	1

	Reachability Set	Antecedent Set	Intersection Set	Level
SC7	SC7-SC8-SC14	SC7-SC9	SC7	--
SC8	SC8-SC14	SC7-SC8-SC9	SC8	--
SC9	SC7-SC8-SC9-SC14	SC9	SC9	--
SC14	SC14	SC7-SC8-SC9-SC14	SC14	2

	Reachability Set	Antecedent Set	Intersection Set	Level
SC7	SC7-SC8	SC7-SC9	SC7	--
SC8	SC8	SC7-SC8-SC9	SC8	3
SC9	SC7-SC8-SC9	SC9	SC9	--

	Reachability Set	Antecedent Set	Intersection Set	Level
SC7	SC7	SC7-SC9	SC7	4
SC9	SC7-SC9	SC9	SC9	--

	Reachability Set	Antecedent Set	Intersection Set	Level
SC9	SC9	SC9	SC9	5

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
SC7	2	6	Independent	IV
SC8	3	5	Independent	IV
SC9	1	7	Independent	IV
SC14	4	4	Linkage	III
SC19	7	3	Dependent	II
SC20	7	3	Dependent	II
SC29	7	3	Dependent	II

MICMAC Diagram

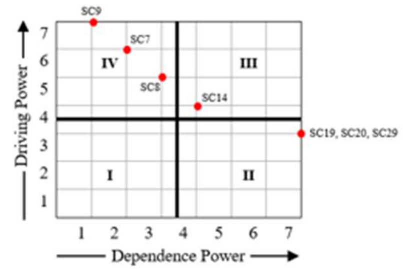


Figure B.2. Steps for the Analysis of Cluster C1: Financial Resources (Continuation)

6. Digraph | Final Model

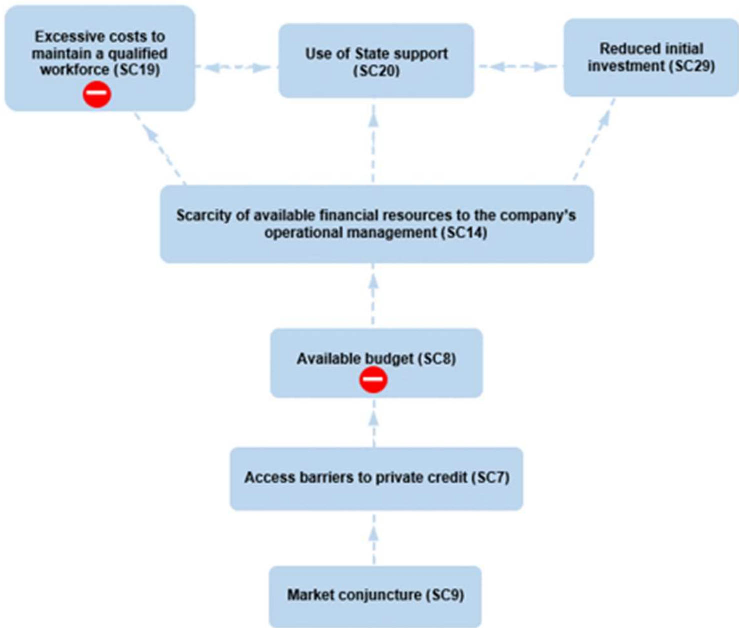


Figure B.3. Steps for the Analysis of Cluster C1: Financial Resources (Continuation)

1. Reachability Matrix (RM) - Financial Resources (C1)

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	0	0	1	1
SC8	0	1	0	1	1	1	1
SC9	1	0	1	1	1	1	0
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {SC7, SC9}
R1 = {SC7, SC8, SC20, SC29}
C1 x R1 = {(SC7,SC7), (SC7,SC8), (SC7, SC20), (SC7,SC29), (SC9,SC7), (SC9,SC8), (SC9,SC20), (SC9,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	0	0	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

Figure B.4. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C1: Financial Resources

Step 2

C2 = {SC7, SC8, SC9}
R2 = {SC8, SC14, SC19, SC20, SC29}
C2 x R2 = {(SC7,SC8), (SC7,SC14), (SC7,SC19), (SC7,SC20), (SC7,SC29), (SC8,SC8), (SC8,SC14), (SC8,SC19), (SC8,SC20), (SC8,SC29), (SC9,SC8), (SC9,SC14), (SC9,SC19), (SC9,SC20), (SC9,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

Step 3

C3 = {SC9}
R3 = {SC7, SC8, SC9, SC14, SC19, SC20, SC29}
C3 x R3 = {(SC9,SC7), (SC9,SC8), (SC9,SC9), (SC9,SC14), (SC9,SC19), (SC9,SC20), (SC9,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

Figure B.5. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C1: Financial Resources (Continuation)

Step 4

C4 = {SC7, SC8, SC9, SC14}
R4 = {SC14, SC19, SC20, SC29}
C4 x R4 = {(SC7,SC14), (SC7,SC19), (SC7,SC20), (SC7,SC29), (SC8,SC14), (SC8,SC19), (SC8,SC20), (SC8,SC29), (SC9,SC14), (SC9,SC19), (SC9,SC20), (SC9,SC29), (SC14,SC14), (SC14,SC19), (SC14,SC20), (SC14,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	0	1

Step 5

C5 = {SC7, SC8, SC9, SC14, SC19, SC29}
R5 = {SC19, SC20}
C5 x R5 = {(SC7,SC19), (SC7,SC20), (SC8,SC19), (SC8,SC20), (SC9,SC19), (SC9,SC20), (SC14,SC19), (SC14,SC20), (SC19,SC19), (SC19,SC20), (SC29,SC19), (SC29,SC20)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	0
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	1*	1

Figure B.6. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C1: Financial Resources (Continuation)

Step 6

C6 = {SC7, SC8, SC9, SC14, SC19, SC20, SC29}
R6 = {SC20, SC29}
C6 x R6 = {(SC7,SC20), (SC7,SC29), (SC8,SC20), (SC8,SC29), (SC9,SC20), (SC9,SC29), (SC14,SC20), (SC14,SC29), (SC19,SC20), (SC19,SC29), (SC20,SC20), (SC20,SC29), (SC29,SC20), (SC29,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	1*
SC20	0	0	0	0	0	1	1
SC29	0	0	0	0	1	1*	1

Step 7

C7 = {SC7, SC8, SC9, SC14, SC19, SC20, SC29}
R7 = {SC19, SC20, SC29}
C7 x R7 = {(SC7,SC19), (SC7,SC20), (SC7,SC29), (SC8,SC19), (SC8,SC20), (SC8,SC29), (SC9,SC19), (SC9,SC20), (SC9,SC29), (SC14,SC19), (SC14,SC20), (SC14,SC29), (SC19,SC19), (SC19,SC20), (SC19,SC29), (SC20,SC19), SC20,SC20), (SC20,SC29), (SC29,SC19), SC29,SC20), (SC29,SC29)}

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	1*
SC20	0	0	0	0	1*	1	1
SC29	0	0	0	0	1	1*	1

Figure B.7. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C1: Financial Resources (Continuation)

2. Final Reachability Matrix (FRM) - Financial Resources (C1)

	SC7	SC8	SC9	SC14	SC19	SC20	SC29
SC7	1	1	0	1*	1*	1	1
SC8	0	1	0	1	1	1	1
SC9	1	1*	1	1	1	1	1*
SC14	0	0	0	1	1	1	1
SC19	0	0	0	0	1	1	1*
SC20	0	0	0	0	1*	1	1
SC29	0	0	0	0	1	1*	1

Figure B.8. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C1: Financial Resources (Continuation)

APPENDIX C – Analysis of Cluster C2: Human Resources

1. Structural Self-Interaction Matrix (SSIM) - C2

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43		D	D	A	A	DI	DI
SC41			D	D	A	D	DI
SC49				DI	I	I	I
SC54					I	D	D
SC57						DI	DI
SC34							DI
SC33							

2. Reachability Matrix (RM)

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	0	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	0	1	0	1	1	1
SC33	1	1	1	0	1	1	1

3. Analysis of Possible Transitivities

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	0	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	0	1	0	1	1	1
SC33	1	1	1	0	1	1	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in **Warshall Clusters**]

	SC43	SC41	SC49	SC54	SC57	SC34	SC33	Dr Pw
SC43	1	1	1	1*	1*	1	1	7
SC41	1*	1	1	1	1*	1	1	7
SC49	1*	1*	1	1	1*	1*	1*	7
SC54	1*	1*	1	1	1*	1	1	7
SC57	1*	1*	1	1	1	1	1	7
SC34	1	1*	1	1*	1	1	1	7
SC33	1	1	1	1*	1	1	1	7
Dp Pw	7	7	7	7	7	7	7	

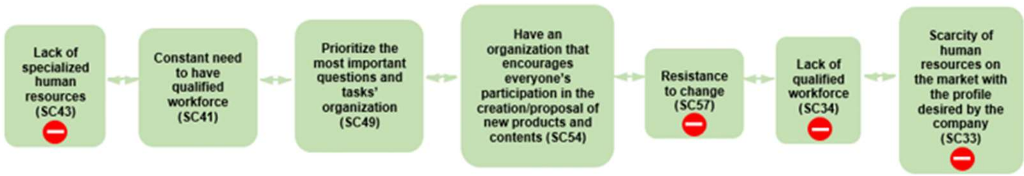
Figure C.1. Steps for the Analysis of Cluster C2: Human Resources

5. Level Partitioning

	Reachability Set	Antecedent Set	Intersection Set	Level
SC43	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC41	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC49	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC54	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC57	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC34	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1
SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	SC43-SC41-SC49-SC54-SC57-SC34-SC33	1

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

6. Digraph | Final Model



6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
SC43	7	7	Linkage	III
SC41	7	7	Linkage	III
SC49	7	7	Linkage	III
SC54	7	7	Linkage	III
SC57	7	7	Linkage	III
SC34	7	7	Linkage	III
SC33	7	7	Linkage	III

MICMAC Diagram

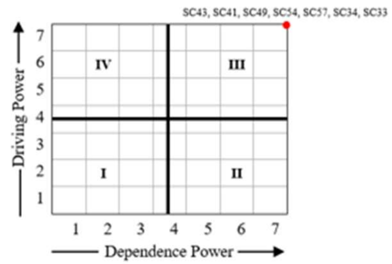


Figure C.2. Steps for the Analysis of Cluster C2: Human Resources (Continuation)

1. Reachability Matrix (RM) - Human Resources (C2)

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	0	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	0	1	0	1	1	1
SC33	1	1	1	0	1	1	1

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {SC43, SC34, SC33}
R1 = {SC43, SC41, SC49, SC34, SC33}
C1 x R1 = {(SC43, SC43), (SC43, SC41), (SC43, SC49), (SC43, SC34), (SC43, SC33), (SC34, SC43), (SC34, SC41), (SC34, SC49), (SC34, SC34), (SC34, SC33), (SC33, SC43), (SC33, SC41), (SC33, SC49), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	0	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	1*	1	0	1	1	1
SC33	1	1	1	0	1	1	1

Figure C.3. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C2: Human Resources

Step 2

C2 = {SC43, SC41, SC34, SC33}
R2 = {SC41, SC49, SC54, SC34, SC33}
C2 x R2 = {(SC43, SC41), (SC43, SC49), (SC43, SC54), (SC43, SC34), (SC43, SC33), (SC41, SC41), (SC41, SC49), (SC41, SC54), (SC41, SC34), (SC41, SC33), (SC34, SC41), (SC34, SC49), (SC34, SC54), (SC34, SC34), (SC34, SC33), (SC33, SC41), (SC33, SC49), (SC33, SC54), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Step 3

C3 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
R3 = {SC49, SC54}
C3 x R3 = {(SC43, SC49), (SC43, SC54), (SC41, SC49), (SC41, SC54), (SC49, SC49), (SC49, SC54), (SC54, SC49), (SC54, SC54),(SC57, SC49), (SC57, SC54), (SC34, SC49), (SC34, SC54), (SC33, SC49), (SC33, SC54)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	0	0
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Figure C.4. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C2: Human Resources (Continuation)

Step 4

C4 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
R4 = {SC49, SC54, SC34, SC33}
C4 x R4 = {(SC43, SC49), (SC43, SC54), (SC43, SC34), (SC43, SC33), (SC41, SC49), (SC41, SC54), (SC41, SC34), (SC41, SC33), (SC49, SC49), (SC49, SC54), (SC49, SC34), (SC49, SC33), (SC54, SC49), (SC54, SC54), (SC54, SC34), (SC54, SC33), (SC57, SC49), (SC57, SC54), (SC57, SC34), (SC57, SC33), (SC34, SC49), (SC34, SC54), (SC34, SC34), (SC34, SC33), (SC33, SC49), (SC33, SC54), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	1*	1*
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Step 5

C5 = {SC57, SC34, SC33}
R5 = {SC49, SC54, SC57, SC34, SC33}
C5 x R5 = {(SC57, SC49), (SC57, SC54), (SC57, SC57), (SC57, SC34), (SC57, SC33), (SC34, SC49), (SC34, SC54), (SC34, SC57), (SC34, SC34), (SC34, SC33), (SC33, SC49), (SC33, SC54), (SC33, SC57), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	0	1	1
SC41	0	1	1	1	0	1	1
SC49	0	0	1	1	0	1*	1*
SC54	0	0	1	1	0	1	1
SC57	0	0	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Figure C.5. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C2: Human Resources (Continuation)

Step 6

C6 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
R6 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
C6 x R6 = {(SC43, SC43), (SC43, SC41), (SC43, SC49), (SC43, SC54), (SC43, SC57), (SC43, SC34), (SC43, SC33), (SC41, SC43), (SC41, SC41), (SC41, SC49), (SC41, SC54), (SC41, SC57), (SC41, SC34), (SC41, SC33), (SC49, SC43), (SC49, SC41), (SC49, SC49), (SC49, SC54), (SC49, SC57), (SC49, SC34), (SC49, SC33), (SC54, SC43), (SC54, SC41), (SC54, SC49), (SC54, SC54), (SC54, SC57), (SC54, SC34), (SC54, SC33), (SC57, SC43), (SC57, SC41), (SC57, SC49), (SC57, SC54), (SC57, SC57), (SC57, SC34), (SC57, SC33), (SC34, SC43), (SC34, SC41), (SC34, SC49), (SC34, SC54), (SC34, SC57), (SC34, SC34), (SC34, SC33), (SC33, SC43), (SC33, SC41), (SC33, SC49), (SC33, SC54), (SC33, SC57), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	1*	1	1
SC41	1*	1	1	1	1*	1	1
SC49	1*	1*	1	1	1*	1*	1*
SC54	1*	1*	1	1	1*	1	1
SC57	1*	1*	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Step 7

C7 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
R7 = {SC43, SC41, SC49, SC54, SC57, SC34, SC33}
C7 x R7 = {(SC43, SC43), (SC43, SC41), (SC43, SC49), (SC43, SC54), (SC43, SC57), (SC43, SC34), (SC43, SC33), (SC41, SC43), (SC41, SC41), (SC41, SC49), (SC41, SC54), (SC41, SC57), (SC41, SC34), (SC41, SC33), (SC49, SC43), (SC49, SC41), (SC49, SC49), (SC49, SC54), (SC49, SC57), (SC49, SC34), (SC49, SC33), (SC54, SC43), (SC54, SC41), (SC54, SC49), (SC54, SC54), (SC54, SC57), (SC54, SC34), (SC54, SC33), (SC57, SC43), (SC57, SC41), (SC57, SC49), (SC57, SC54), (SC57, SC57), (SC57, SC34), (SC57, SC33), (SC34, SC43), (SC34, SC41), (SC34, SC49), (SC34, SC54), (SC34, SC57), (SC34, SC34), (SC34, SC33), (SC33, SC43), (SC33, SC41), (SC33, SC49), (SC33, SC54), (SC33, SC57), (SC33, SC34), (SC33, SC33)}

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	1*	1	1
SC41	1*	1	1	1	1*	1	1
SC49	1*	1*	1	1	1*	1*	1*
SC54	1*	1*	1	1	1*	1	1
SC57	1*	1*	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Figure C.6. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C2: Human Resources (Continuation)

2. Final Reachability Matrix (FRM) - Human Resources (C2)

	SC43	SC41	SC49	SC54	SC57	SC34	SC33
SC43	1	1	1	1*	1*	1	1
SC41	1*	1	1	1	1*	1	1
SC49	1*	1*	1	1	1*	1*	1*
SC54	1*	1*	1	1	1*	1	1
SC57	1*	1*	1	1	1	1	1
SC34	1	1*	1	1*	1	1	1
SC33	1	1	1	1*	1	1	1

Figure C.7. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C2: Human Resources (Continuation)

APPENDIX D – Analysis of Cluster C3: Innovation and Technological Challenges

1. Structural Self-Interaction Matrix (SSIM) - C3

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64		D	DI	DI	I	D	D
SC67			DI	DI	I	DI	A
SC72				DI	I	I	A
SC88					D	D	D
SC90						D	D
SC75							A
SC79							

2. Reachability Matrix (RM)

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	0	1	1	1	0	1	0
SC72	1	1	1	1	0	0	0
SC88	1	1	1	1	1	1	1
SC90	1	1	1	0	1	1	1
SC75	0	1	1	0	0	1	0
SC79	0	0	0	0	0	0	1

3. Analysis of Possible Transitivities

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	0	1	1	1	0	1	0
SC72	1	1	1	1	0	0	0
SC88	1	1	1	1	1	1	1
SC90	1	1	1	0	1	1	1
SC75	0	1	1	0	0	1	0
SC79	0	0	0	0	0	0	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in Warshall Clusters]

	SC64	SC67	SC72	SC88	SC90	SC75	SC79	Dr Pw
SC64	1	1	1	1	1*	1	1	7
SC67	1*	1	1	1	1*	1	1*	7
SC72	1	1	1	1	1*	1*	1*	7
SC88	1	1	1	1	1	1	1	7
SC90	1	1	1	1*	1	1	1	7
SC75	1*	1	1	1*	1*	1	1*	7
SC79	0	0	0	0	0	0	1	1
Dp Pw	6	6	6	6	6	6	7	

Figure D.1. Steps for the Analysis of Cluster C3: Innovation and Technological Challenges

5. Level Partitioning

	Reachability Set	Antecedent Set	Intersection Set	Level
SC64	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC67	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC72	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC88	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC90	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC75	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	--
SC79	SC79	SC64-SC67-SC72-SC88-SC90-SC75-SC79	SC79	1

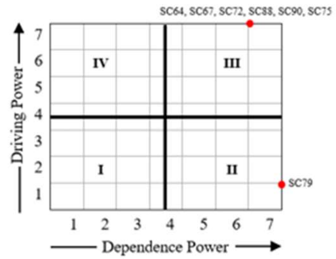
	Reachability Set	Antecedent Set	Intersection Set	Level
SC64	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2
SC67	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2
SC72	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2
SC88	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2
SC90	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2
SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	SC64-SC67-SC72-SC88-SC90-SC75	2

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
SC64	6	7	Linkage	III
SC67	6	7	Linkage	III
SC72	6	7	Linkage	III
SC88	6	7	Linkage	III
SC90	6	7	Linkage	III
SC75	6	7	Linkage	III
SC79	7	1	Dependent	II

MICMAC Diagram



6. Digraph | Final Model

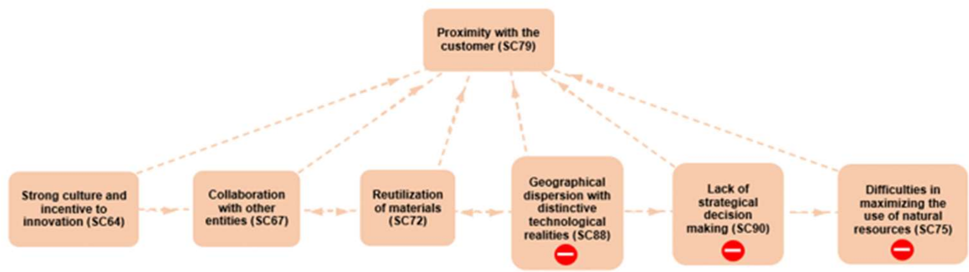


Figure D.2. Steps for the Analysis of Cluster C3: Innovation and Technological Challenges (Continuation)

1. Reachability Matrix (RM) - Innovation and Technological Challenges (C3)

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	0	1	1	1	0	1	0
SC72	1	1	1	1	0	0	0
SC88	1	1	1	1	1	1	1
SC90	1	1	1	0	1	1	1
SC75	0	1	1	0	0	1	0
SC79	0	0	0	0	0	0	1

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {SC64, SC72, SC88, SC90}

R1 = {SC64, SC67, SC72, SC88, SC75, SC79}

C1 x R1 = {(SC64, SC64), (SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC75), (SC64, SC79),(SC72, SC64), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC75), (SC72, SC79), (SC88, SC64), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC75), (SC88, SC79), (SC90, SC64), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC75), (SC90, SC79)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	0	1	1	1	0	1	0
SC72	1	1	1	1	0	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	0	1	1	0	0	1	0
SC79	0	0	0	0	0	0	1

Step 2

C2 = {SC64, SC67, SC72, SC88, SC90, SC75}

R2 = {SC67, SC72, SC88, SC75}

C2 x R2 = {(SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC75), (SC67, SC67), (SC67, SC72), (SC67, SC88), (SC67, SC75), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC75), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC75), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC75), (SC75, SC67), (SC75, SC72), (SC75, SC88), (SC75, SC75)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	0	1	1	1	0	1	0
SC72	1	1	1	1	0	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	0	1	1	1*	0	1	0
SC79	0	0	0	0	0	0	1

Figure D.3. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C3: Innovation and Technological Challenges

Step 3

C3 = {SC64, SC67, SC72, SC88, SC90, SC75}
R3 = {SC64, SC67, SC72, SC88, SC75, SC79}
C3 x R3 = {(SC64, SC64), (SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC75), (SC64, SC79), (SC67, SC64), (SC67, SC67), (SC67, SC72), (SC67, SC88), (SC67, SC75), (SC67, SC79), (SC72, SC64), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC75), (SC72, SC79), (SC88, SC64), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC75), (SC88, SC79), (SC90, SC64), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC75), (SC90, SC79), (SC75, SC64), (SC75, SC67), (SC75, SC72), (SC75, SC88), (SC75, SC75), (SC75, SC79),

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	0	1	1
SC67	1*	1	1	1	0	1	1*
SC72	1	1	1	1	0	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	0	1	1*
SC79	0	0	0	0	0	0	1

Step 4

C4 = {SC64, SC67, SC72, SC88, SC90, SC75}
R4 = {SC64, SC67, SC72, SC88, SC90, SC75, SC79}
C4 x R4 = {(SC64, SC64), (SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC90), (SC64, SC75), (SC64, SC79), (SC67, SC64), (SC67, SC67), (SC67, SC72), (SC67, SC88), (SC67, SC90), (SC67, SC75), (SC67, SC79), (SC72, SC64), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC90), (SC72, SC75), (SC72, SC79), (SC88, SC64), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC90), (SC88, SC75), (SC88, SC79), (SC90, SC64), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC90), (SC90, SC75), (SC90, SC79), (SC75, SC64), (SC75, SC67), (SC75, SC72), (SC75, SC88), (SC75, SC90), (SC75, SC75), (SC75, SC79)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	1*	1	1
SC67	1*	1	1	1	1*	1	1*
SC72	1	1	1	1	1*	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	1*	1	1*
SC79	0	0	0	0	0	0	1

Step 5

C5 = {SC64, SC67, SC72, SC88, SC90, SC75}
R5 = {SC64, SC67, SC72, SC88, SC90, SC75, SC79}
C5 x R5 = {(SC64, SC64), (SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC90), (SC64, SC75), (SC64, SC79), (SC67, SC64), (SC67, SC67), (SC67, SC72), (SC67, SC88), (SC67, SC90), (SC67, SC75), (SC67, SC79), (SC72, SC64), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC90), (SC72, SC75), (SC72, SC79), (SC88, SC64), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC90), (SC88, SC75), (SC88, SC79), (SC90, SC64), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC90), (SC90, SC75), (SC90, SC79), (SC75, SC64), (SC75, SC67), (SC75, SC72), (SC75, SC88), (SC75, SC90), (SC75, SC75), (SC75, SC79)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	1*	1	1
SC67	1*	1	1	1	1*	1	1*
SC72	1	1	1	1	1*	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	1*	1	1*
SC79	0	0	0	0	0	0	1

Figure D.4. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C3: Innovation and Technological Challenges (Continuation)

Step 6

C6 = {SC64, SC67, SC72, SC88, SC90, SC75}
R6 = {SC64, SC67, SC72, SC88, SC90, SC75, SC79}
C6 x R6 = {(SC64, SC64), (SC64, SC67), (SC64, SC72), (SC64, SC88), (SC64, SC90), (SC64, SC75), (SC64, SC79), (SC67, SC64), (SC67, SC67), (SC67, SC72), (SC67, SC88), (SC67, SC90), (SC67, SC75), (SC67, SC79), (SC72, SC64), (SC72, SC67), (SC72, SC72), (SC72, SC88), (SC72, SC90), (SC72, SC75), (SC72, SC79), (SC88, SC64), (SC88, SC67), (SC88, SC72), (SC88, SC88), (SC88, SC90), (SC88, SC75), (SC88, SC79), (SC90, SC64), (SC90, SC67), (SC90, SC72), (SC90, SC88), (SC90, SC90), (SC90, SC75), (SC90, SC79), (SC75, SC64), (SC75, SC67), (SC75, SC72), (SC75, SC88), (SC75, SC90), (SC75, SC75), (SC75, SC79)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	1*	1	1
SC67	1*	1	1	1	1*	1	1*
SC72	1	1	1	1	1*	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	1*	1	1*
SC79	0	0	0	0	0	0	1

Step 7

C7 = {SC64, SC67, SC72, SC88, SC90, SC75, SC79}
R7 = {SC79}
C7 x R7 = {(SC64, SC79), (SC67, SC79), (SC72, SC79), (SC88, SC79), (SC90, SC79), (SC75, SC79), (SC79, SC79)}

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	1*	1	1
SC67	1*	1	1	1	1*	1	1*
SC72	1	1	1	1	1*	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	1*	1	1*
SC79	0	0	0	0	0	0	1

Figure D.5. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C3: Innovation and Technological Challenges (Continuation)

2. Final Reachability Matrix (FRM) - Innovation and Technological Challenges (C3)

	SC64	SC67	SC72	SC88	SC90	SC75	SC79
SC64	1	1	1	1	1*	1	1
SC67	1*	1	1	1	1*	1	1*
SC72	1	1	1	1	1*	1*	1*
SC88	1	1	1	1	1	1	1
SC90	1	1	1	1*	1	1	1
SC75	1*	1	1	1*	1*	1	1*
SC79	0	0	0	0	0	0	1

s

Figure D.6. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C3: Innovation and Technological Challenges (Continuation)

APPENDIX E – Analysis of Cluster C4: Sustainability and Surrounding Environment

1. Structural Self-Interaction Matrix (SSIM) - C4

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95		D	DI	I	D	DI	I
SC100			I	A	D	I	DI
SC98				A	D	DI	I
SC107					DI	D	I
SC104						DI	I
SC96							I
SC103							

2. Reachability Matrix (RM)

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	0
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	0
SC107	1	0	0	1	1	1	0
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	0
SC103	1	1	1	1	1	1	1

3. Analysis of Possible Transitivities

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	0
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	0
SC107	1	0	0	1	1	1	0
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	0
SC103	1	1	1	1	1	1	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in **Warshall Clusters**]

	SC95	SC100	SC98	SC107	SC104	SC96	SC103	Dr Pw
SC95	1	1	1	1*	1	1	1*	7
SC100	1*	1	1*	1*	1	1*	1	7
SC98	1	1	1	1*	1	1	1*	7
SC107	1	1*	1*	1	1	1	1*	7
SC104	1*	1*	1*	1	1	1	1*	7
SC96	1	1	1	1*	1	1	1*	7
SC103	1	1	1	1	1	1	1	7
Dp Pw	7	7	7	7	7	7	7	

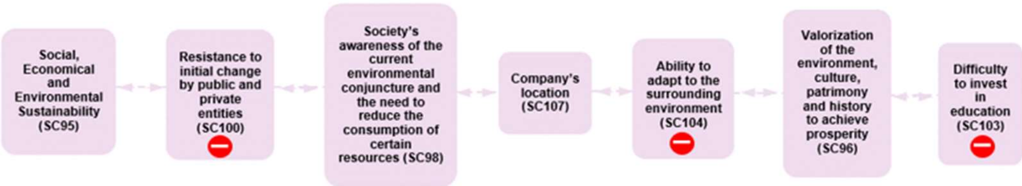
Figure E.1. Steps for the Analysis of Cluster C4: Sustainability and Surrounding Environment

5. Level Partitioning

	Reachability Set	Antecedent Set	Intersection Set	Level
SC95	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC100	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC98	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC107	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC104	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC96	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1
SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	SC95-SC100-SC98-SC107-SC104-SC96-SC103	1

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

6. Digraph | Final Model



6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
SC95	7	7	Linkage	III
SC100	7	7	Linkage	III
SC98	7	7	Linkage	III
SC107	7	7	Linkage	III
SC104	7	7	Linkage	III
SC96	7	7	Linkage	III
SC103	7	7	Linkage	III

MICMAC Diagram

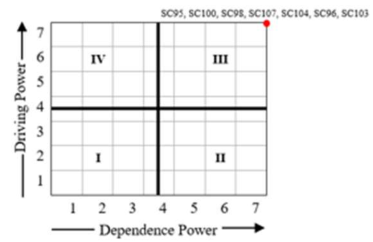


Figure E.2. Steps for the Analysis of Cluster C4: Sustainability and Surrounding Environment (Continuation)

1. Reachability Matrix (RM) - Sustainability and Surrounding Environment (C4)

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	0
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	0
SC107	1	0	0	1	1	1	0
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	0
SC103	1	1	1	1	1	1	1

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {SC95, SC98, SC107, SC96, SC103}
R1 = {SC95, SC100, SC98, SC104, SC96}
C1 x R1 = {(SC95, SC95), (SC95, SC100), (SC95, SC98), (SC95, SC104), (SC95, SC96),(SC98, SC95), (SC98, SC100), (SC98, SC98), (SC98, SC104), (SC98, SC96), (SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC104), (SC107, SC96), (SC96, SC95), (SC96, SC100), (SC96, SC98), (SC96, SC104), (SC96, SC96), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC104), (SC103, SC96)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	0
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	0
SC107	1	1*	1*	1	1	1	0
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	0
SC103	1	1	1	1	1	1	1

Step 2

C2 = {SC95, SC100, SC98, SC107, SC96, SC103}
R2 = {SC100, SC104, SC103}
C2 x R2 = {(SC95, SC100), (SC95, SC104), (SC95, SC103), (SC100, SC100), (SC100, SC104), (SC100, SC103), (SC98, SC100), (SC98, SC104), (SC98, SC103), (SC107, SC100), (SC107, SC104), (SC107, SC103), (SC96, SC100), (SC96, SC104), (SC96, SC103), (SC103, SC100), (SC103, SC104), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	1*
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	1*
SC103	1	1	1	1	1	1	1

Figure E.3. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C4: Sustainability and Surrounding Environment

Step 3

C3 = {SC95, SC98, SC107, SC96, SC103}
R3 = {SC95, SC100, SC98, SC104, SC96, SC103}
C3 x R3 = {(SC95, SC95), (SC95, SC100), (SC95, SC98), (SC95, SC104), (SC95, SC96), (SC95, SC103), (SC98, SC95), (SC98, SC100), (SC98, SC98), (SC98, SC104), (SC98, SC96), (SC98, SC103), (SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC104), (SC107, SC96), (SC107, SC103), (SC96, SC95), (SC96, SC100), (SC96, SC98), (SC96, SC104), (SC96, SC96), (SC96, SC103), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC104), (SC103, SC96), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	1*
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	0	0	0	1	1	1	0
SC96	1	1	1	0	1	1	1*
SC103	1	1	1	1	1	1	1

Step 4

C4 = {SC107, SC104, SC103}
R4 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
C4 x R4 = {(SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC107), (SC107, SC104), (SC107, SC96), (SC107, SC103), (SC104, SC95), (SC104, SC100), (SC104, SC98), (SC104, SC107), (SC104, SC104), (SC104, SC96), (SC104, SC103), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC107), (SC103, SC104), (SC103, SC96), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	0	1	1	1*
SC100	0	1	0	0	1	0	1
SC98	1	1	1	0	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	1*	1*	1*	1	1	1	1*
SC96	1	1	1	0	1	1	1*
SC103	1	1	1	1	1	1	1

Step 5

C5 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
R5 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
C5 x R5 = {(SC95, SC95), (SC95, SC100), (SC95, SC98), (SC95, SC107), (SC95, SC104), (SC95, SC96), (SC95, SC103), (SC100, SC95), (SC100, SC100), (SC100, SC98), (SC100, SC107), (SC100, SC104), (SC100, SC96), (SC100, SC103), (SC98, SC95), (SC98, SC100), (SC98, SC98), (SC98, SC107), (SC98, SC104), (SC98, SC96), (SC98, SC103), (SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC107), (SC107, SC104), (SC107, SC96), (SC107, SC103), (SC104, SC95), (SC104, SC100), (SC104, SC98), (SC104, SC107), (SC104, SC104), (SC104, SC96), (SC104, SC103), (SC96, SC95), (SC96, SC100), (SC96, SC98), (SC96, SC107), (SC96, SC104), (SC96, SC96), (SC96, SC103), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC107), (SC103, SC104), (SC103, SC96), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	1*	1	1	1*
SC100	1*	1	1*	1*	1	1*	1
SC98	1	1	1	1*	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	1*	1*	1*	1	1	1	1*
SC96	1	1	1	1*	1	1	1*
SC103	1	1	1	1	1	1	1

Figure E.4. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C4: Sustainability and Surrounding Environment (Continuation)

Step 6

C6 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
R6 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
C6 x R6 = {(SC95, SC95), (SC95, SC100), (SC95, SC98), (SC95, SC107), (SC95, SC104), (SC95, SC96), (SC95, SC103), (SC100, SC95), (SC100, SC100), (SC100, SC98), (SC100, SC107), (SC100, SC104), (SC100, SC96), (SC100, SC103), (SC98, SC95), (SC98, SC100), (SC98, SC98), (SC98, SC107), (SC98, SC104), (SC98, SC96), (SC98, SC103), (SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC107), (SC107, SC104), (SC107, SC96), (SC107, SC103), (SC104, SC95), (SC104, SC100), (SC104, SC98), (SC104, SC107), (SC104, SC104), (SC104, SC96), (SC104, SC103), (SC96, SC95), (SC96, SC100), (SC96, SC98), (SC96, SC107), (SC96, SC104), (SC96, SC96), (SC96, SC103), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC107), (SC103, SC104), (SC103, SC96), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	1*	1	1	1*
SC100	1*	1	1*	1*	1	1*	1
SC98	1	1	1	1*	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	1*	1*	1*	1	1	1	1*
SC96	1	1	1	1*	1	1	1*
SC103	1	1	1	1	1	1	1

Step 7

C7 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
R7 = {SC95, SC100, SC98, SC107, SC104, SC96, SC103}
C7 x R7 = {(SC95, SC95), (SC95, SC100), (SC95, SC98), (SC95, SC107), (SC95, SC104), (SC95, SC96), (SC95, SC103), (SC100, SC95), (SC100, SC100), (SC100, SC98), (SC100, SC107), (SC100, SC104), (SC100, SC96), (SC100, SC103), (SC98, SC95), (SC98, SC100), (SC98, SC98), (SC98, SC107), (SC98, SC104), (SC98, SC96), (SC98, SC103), (SC107, SC95), (SC107, SC100), (SC107, SC98), (SC107, SC107), (SC107, SC104), (SC107, SC96), (SC107, SC103), (SC104, SC95), (SC104, SC100), (SC104, SC98), (SC104, SC107), (SC104, SC104), (SC104, SC96), (SC104, SC103), (SC96, SC95), (SC96, SC100), (SC96, SC98), (SC96, SC107), (SC96, SC104), (SC96, SC96), (SC96, SC103), (SC103, SC95), (SC103, SC100), (SC103, SC98), (SC103, SC107), (SC103, SC104), (SC103, SC96), (SC103, SC103)}

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	1*	1	1	1*
SC100	1*	1	1*	1*	1	1*	1
SC98	1	1	1	1*	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	1*	1*	1*	1	1	1	1*
SC96	1	1	1	1*	1	1	1*
SC103	1	1	1	1	1	1	1

2. Final Reachability Matrix (FRM) - Sustainability and Surrounding Environment (C4)

	SC95	SC100	SC98	SC107	SC104	SC96	SC103
SC95	1	1	1	1*	1	1	1*
SC100	1*	1	1*	1*	1	1*	1
SC98	1	1	1	1*	1	1	1*
SC107	1	1*	1*	1	1	1	1*
SC104	1*	1*	1*	1	1	1	1*
SC96	1	1	1	1*	1	1	1*
SC103	1	1	1	1	1	1	1

Figure E.5. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C4: Sustainability and Surrounding Environment (Continuation)

APPENDIX F – Analysis of Cluster C5: Corporate Strategy

1. Structural Self-Interaction Matrix (SSIM) - C5

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115		I	D	I	A	D	DI
SC119			DI	DI	A	D	D
SC125				I	I	D	D
SC132					DI	D	D
SC116						DI	D
SC120							DI
SC126							

2. Reachability Matrix (RM)

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	0	1	0	0	1	1
SC119	1	1	1	1	0	1	1
SC125	0	1	1	0	0	1	1
SC132	1	1	1	1	1	1	1
SC116	0	0	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	0	0	0	0	1	1

3. Analysis of Possible Transitivities

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	0	1	0	0	1	1
SC119	1	1	1	1	0	1	1
SC125	0	1	1	0	0	1	1
SC132	1	1	1	1	1	1	1
SC116	0	0	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	0	0	0	0	1	1

4. Final Reachability Matrix (FRM) [view auxiliary calculations in Warshall Clusters]

	SC115	SC119	SC125	SC132	SC116	SC120	SC126	Dr Pw
SC115	1	1*	1	1*	1*	1	1	7
SC119	1	1	1	1	1*	1	1	7
SC125	1*	1	1	1*	1*	1	1	7
SC132	1	1	1	1	1	1	1	7
SC116	1*	1*	1	1	1	1	1	7
SC120	1*	1*	1*	1*	1	1	1	7
SC126	1	1*	1*	1*	1*	1	1	7
Dp Pw	7	7	7	7	7	7	7	

Figure F.1. Steps for the Analysis of Cluster C5: Corporate Strategy

5. Level Partitioning

	Reachability Set	Antecedent Set	Intersection Set	Level
SC115	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC119	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC125	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC132	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC116	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC120	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1
SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	SC115-SC119-SC125-SC132-SC116-SC120-SC126	1

Reachability Set - Read on FRM's "rows" | **Antecedent Set** - Read on FRM's "columns".
Level 1 - Factors for which **Reachability Set = Intersection Set**.
Level 2 - Factors for which **Reachability Set = Intersection Set**, after excluding the Level 1 factors.
Level n - Factors for which **Reachability Set = Intersection Set**, after excluding the factors from the previous levels.

6. Digraph | Final Model

6. MICMAC Analysis

	Dp Pw (x)	Dr Pw (y)	Type	Quadrant
SC115	7	7	Linkage	III
SC119	7	7	Linkage	III
SC125	7	7	Linkage	III
SC132	7	7	Linkage	III
SC116	7	7	Linkage	III
SC120	7	7	Linkage	III
SC126	7	7	Linkage	III

MICMAC Diagram

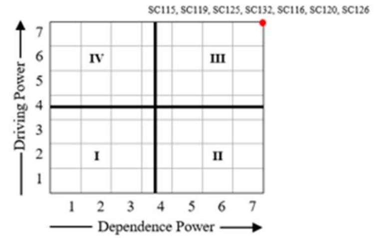


Figure F.2. Steps for the Analysis of Cluster C5: Corporate Strategy (Continuation)

1. Reachability Matrix (RM) - Corporate Strategy (C5)

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	0	1	0	0	1	1
SC119	1	1	1	1	0	1	1
SC125	0	1	1	0	0	1	1
SC132	1	1	1	1	1	1	1
SC116	0	0	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	0	0	0	0	1	1

- Identify in the column all criteria that presents "1".
- Identify in the row all criteria that presents "1".
- Cross check the criteria identified in the column against the criteria identified in the row.
- Check all intersections in the table and if there is an intersection in a "0" relationship, it becomes "1*".

Step 1

C1 = {SC115, SC119, SC132, SC126}
R1 = {SC115, SC125, SC120, SC126}
C1 x R1 = {(SC115, SC115), (SC115, SC125), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC125), (SC119, SC120), (SC119, SC126), (SC132, SC115), (SC132, SC125), (SC132, SC120), (SC132, SC126), (SC126, SC115), (SC126, SC125), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	0	1	0	0	1	1
SC119	1	1	1	1	0	1	1
SC125	0	1	1	0	0	1	1
SC132	1	1	1	1	1	1	1
SC116	0	0	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	0	1*	0	0	1	1

Step 2

C2 = {SC119, SC125, SC132}
R2 = {SC115, SC119, SC125, SC132, SC120, SC126}
C2 x R2 = {(SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC120), (SC132, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	0	1	0	0	1	1
SC119	1	1	1	1	0	1	1
SC125	1*	1	1	1*	0	1	1
SC132	1	1	1	1	1	1	1
SC116	0	0	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	0	1*	0	0	1	1

Figure F.3. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C5: Corporate Strategy

Step 3

C3 = {SC115, SC119, SC125, SC132, SC116, SC126}
R3 = {SC115, SC119, SC125, SC132, SC120, SC126}
C3 x R3 = {(SC115, SC115), (SC115, SC119), (SC115, SC125), (SC115, SC132), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC120), (SC132, SC126), (SC116, SC115), (SC116, SC119), (SC116, SC125), (SC116, SC132), (SC116, SC120), (SC116, SC126), (SC126, SC115), (SC126, SC119), (SC126, SC125), (SC126, SC132), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	0	1	1
SC119	1	1	1	1	0	1	1
SC125	1*	1	1	1*	0	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	1*	1*	1*	0	1	1

Step 4

C4 = {SC115, SC119, SC125, SC132, SC116, SC126}
R4 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
C4 x R4 = {(SC115, SC115), (SC115, SC119), (SC115, SC125), (SC115, SC132), (SC115, SC116), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC116), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC116), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC116), (SC132, SC120), (SC132, SC126), (SC116, SC115), (SC116, SC119), (SC116, SC125), (SC116, SC132), (SC116, SC116), (SC116, SC120), (SC116, SC126), (SC126, SC115), (SC126, SC119), (SC126, SC125), (SC126, SC132), (SC126, SC116), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	1*	1	1
SC119	1	1	1	1	1*	1	1
SC125	1*	1	1	1*	1*	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	0	0	0	0	1	1	1
SC126	1	1*	1*	1*	1*	1	1

Step 5

C5 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
R5 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
C5 x R5 = {(SC115, SC115), (SC115, SC119), (SC115, SC125), (SC115, SC132), (SC115, SC116), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC116), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC116), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC116), (SC132, SC120), (SC132, SC126), (SC116, SC115), (SC116, SC119), (SC116, SC125), (SC116, SC132), (SC116, SC116), (SC116, SC120), (SC116, SC126), (SC120, SC115), (SC120, SC119), (SC120, SC125), (SC120, SC132), (SC120, SC116), (SC120, SC120), (SC120, SC126), (SC126, SC115), (SC126, SC119), (SC126, SC125), (SC126, SC132), (SC126, SC116), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	1*	1	1
SC119	1	1	1	1	1*	1	1
SC125	1*	1	1	1*	1*	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	1*	1*	1*	1*	1	1	1
SC126	1	1*	1*	1*	1*	1	1

Figure F.4. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C5: Corporate Strategy (Continuation)

Step 6

C6 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
R6 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
C6 x R6 = {(SC115, SC115), (SC115, SC119), (SC115, SC125), (SC115, SC132), (SC115, SC116), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC116), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC116), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC116), (SC132, SC120), (SC132, SC126), (SC116, SC115), (SC116, SC119), (SC116, SC125), (SC116, SC132), (SC116, SC116), (SC116, SC120), (SC116, SC126), (SC120, SC115), (SC120, SC119), (SC120, SC125), (SC120, SC132), (SC120, SC116), (SC120, SC120), (SC120, SC126), (SC126, SC115), (SC126, SC119), (SC126, SC125), (SC126, SC132), (SC126, SC116), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	1*	1	1
SC119	1	1	1	1	1*	1	1
SC125	1*	1	1	1*	1*	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	1*	1*	1*	1*	1	1	1
SC126	1	1*	1*	1*	1*	1	1

Step 7

C7 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
R7 = {SC115, SC119, SC125, SC132, SC116, SC120, SC126}
C7 x R7 = {(SC115, SC115), (SC115, SC119), (SC115, SC125), (SC115, SC132), (SC115, SC116), (SC115, SC120), (SC115, SC126), (SC119, SC115), (SC119, SC119), (SC119, SC125), (SC119, SC132), (SC119, SC116), (SC119, SC120), (SC119, SC126), (SC125, SC115), (SC125, SC119), (SC125, SC125), (SC125, SC132), (SC125, SC116), (SC125, SC120), (SC125, SC126), (SC132, SC115), (SC132, SC119), (SC132, SC125), (SC132, SC132), (SC132, SC116), (SC132, SC120), (SC132, SC126), (SC116, SC115), (SC116, SC119), (SC116, SC125), (SC116, SC132), (SC116, SC116), (SC116, SC120), (SC116, SC126), (SC120, SC115), (SC120, SC119), (SC120, SC125), (SC120, SC132), (SC120, SC116), (SC120, SC120), (SC120, SC126), (SC126, SC115), (SC126, SC119), (SC126, SC125), (SC126, SC132), (SC126, SC116), (SC126, SC120), (SC126, SC126)}

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	1*	1	1
SC119	1	1	1	1	1*	1	1
SC125	1*	1	1	1*	1*	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	1*	1*	1*	1*	1	1	1
SC126	1	1*	1*	1*	1*	1	1

2. Final Reachability Matrix (FRM) - Corporate Strategy (C5)

	SC115	SC119	SC125	SC132	SC116	SC120	SC126
SC115	1	1*	1	1*	1*	1	1
SC119	1	1	1	1	1*	1	1
SC125	1*	1	1	1*	1*	1	1
SC132	1	1	1	1	1	1	1
SC116	1*	1*	1	1	1	1	1
SC120	1*	1*	1*	1*	1	1	1
SC126	1	1*	1*	1*	1*	1	1

Figure F.5. Steps for Transitivity Analysis through Warshall Algorithm for Cluster C5: Corporate Strategy (Continuation)