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COMPLEXITY-BASED VIEW OF THE FIRM: THEORETICAL PERSPECTIVES, METHODOLOGICAL FRAMEWORK AND EMPIRICAL EVIDENCE

A Dissertation Presented

by

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This thesis is dedicated to my wife, María José, without whose unconditional encouragement, enormous patience, hard work and dedication to our family, this thesis would never have been written. Thank you.

***

To my beloved daughters Sofía and Alicia. Let this thesis be an inspiration for you to believe in your dreams and cultivate a passion for learning.

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To my parents, thank you for planting the seed of effort and abiding curiosity.

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This thesis has been an extraordinary journey of learning and discovery for me, indeed one of the most rewarding knowledge experiences in my life. Now the memory of the excitement associated with constructing theory and finding empirical support for it clearly outweighs all the trouble and times of self-doubt. Notwithstanding, this my particular grain of sand to social research would have not been possible without the help and support of many people.

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This thesis has also involved many highly experienced executives from the airlines industry around the world, who took part, to a greater or lesser extent, in the field research Experts' Panel. Despite their busy agendas and responsibilities, they painstakingly sought to address key issues related to our complexity-based approach in airlines, providing the author with key data to test basic assumptions on the thesis. Without their insightful contributions and enthusiasm for sharing their knowledge, the field research would not have been possible. They are simply too many to name here. Thank you all.

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ABSTRACT

The progress made by the theory of the firm has been outstanding in the last 80 years, its central concepts having become foundational for any theoretical and practical work focused on understanding the behavior of the firm. However, in spite of this remarkable achievement, most of the firm's real problems remain intractable. Furthermore, an increasing new class of issues emerge which seemingly fall out of managers' control, relentless challenging our current theories and methods. The above are traits of what investigators call complexity, and a new paradigm centered on tackling and managing it is being formed in the social sciences. To explore the applicability, opportunities and consequences that this paradigm may have for increasing our understanding of the firm, this thesis examines two distinct lines of inquiry: theoretical and methodological. Building upon a novel theoretical characterization of the firm as a complex system, whose fundamental units continuously create and exchange value, and a comprehensive 4-stage methodological approach, both lines converge to form a robust framework to practically grasp, envision and influence the behavior of the firm. Furthermore, empirical evidence from a field research carried out at an international scale by the author on the airline industry is provided that supports the applicability of our proposed complexity-based view in practical areas such as scenario testing, planning and decision-making, using knowledge from experts and Fuzzy Cognitive Mapping. Finally, given the extensive theoretical and practical background covered by our approach and the limitations exposed, guidelines for further research are provided in the thesis that should encourage the next rounds of investigators to dig deeper and seize the yet unrealized opportunities offered by a complexity-based view of the firm.

KEYWORDS: complexity, theory of the firm, field research, methodology, modeling.

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CHAPTER 1.

INTRODUCTION

Much research endeavor has been devoted in the last 80 years to theorizing on the behavior of the firm. Such has been the interest of scholars in this field that the number of papers, articles, books and thesis in the subject is one of the largest among all the branches of economics. As a matter of fact, the study of the firm as an intricate behavioral entity has exponentially grown in last decades to become a fully consolidated stream of research, as evidenced by the large community of dedicated investigators around the world and the various theoretical developments and schools emerged.

In spite of this prolific output, this author submits that there is no certainty that we are today more capable to explain the behavior of the firm than we were 80 years ago; much less to envision or predict as to how a particular firm would behave under real-world circumstances. Notwithstanding the foregoing, few theorists of the firm would usually react to the above critique, partly because taking these critiques would seriously mean questioning fundamental tenets of mainstream economics (Foss, Klein 2005).

The above consideration does not seek to waste or neglect the contributions made by those involved in the advancement of the theory of the firm. Quite the opposite, this author highlights as outstanding the achievements made by the theorists of the firm in helping generations of scholars and practitioners better approach an understanding of the firm.

However, these same people increasingly encounter today a daunting class of problems that current theories of the firm fail to explain, or for which its explanatory power remains limited or subtle. By these problems we do not mean some extraordinary happenings in the life of the firm, but events that are rather familiar to its everyday operations. We refer to problems that generally involve a large number of interacting parts, transcend the conventional boundaries of the firm, and impact its behavior in an unusual variety of ways. Moreover, problems that are seemingly uncontrollable and unforeseeable, and often neglected because they fall out of range for managers.

The above are signs of what researchers and practitioners call *complexity*, and this author contends that most theories of the firm have remained somewhat oblivious of the need to comprehend its significance and produce science-based insights into its sources and effects. It is true that many theories of the firm have worked well at explaining *disorganized complexity* —i.e. when the properties of the firm as a whole can be understood by using probability and statistical methods (Weaver 1991)— but at the end, most of the firm's real problems are left intractable and unexplained.

Nevertheless, as our knowledge of reality grows and our analytical tools become more powerful and sophisticated, many theorists of the firm have started to focus on developing new conceptual and methodological frameworks to further explain firm's *organized complexity* —i.e. the dynamic inter-relationships of the firm as a system, processes, and self-organization—, thus shifting their attention towards new ideas, such as openness, emergent behavior, or dynamic systems, and its collateral multivariate, non-linear, expert-based analytical tools.

Ultimately, these are traits suggesting that a new paradigm devoted to understanding, predicting and influencing the behavior of complex systems is emerging out of our increased awareness and capacity to tackle complexity (OECD 2008). Furthermore, this paradigm centered on discovering and managing complexity has been born in the context of natural sciences —i.e. biology, physics, ecology, to name just a few— and has evolved over the past several decades to spread into diverse fields in social sciences, where its particular potential for the study of the firm remains mostly unrealized and full of possibilities.

This thesis is a research journey dedicated to dig deeper into the development of such paradigm in the field of the theory of the firm. More specifically, this thesis explores *i)* the theoretical implications derived from the application of the idea of complexity to the context of the firm, *ii)* questions whether a complexity-based view of the firm can be brought to practice, and *iii)* investigates the form in which this approach might be replicated. Furthermore, by providing empirical evidence from real-life firms, the author tests in the thesis the feasibility of a complexity-based view of the firm as a means to extend our understanding of the behavior of the firm.

The underlying assumptions made in the thesis require that we address the problem of complexity from a conceptual angle (Jaccard, Jacoby 2010), complementing old concepts with novel ideas to address common difficult firm behavioral issues —i.e. non-linearities, emergent behavior, homeostasis, networks, or hierarchies. Therefore, by integrating old with new, our complexity-based approach further enables researchers and practitioners to decompose the firm complex structure and the relationships between its building blocks in a more realistic fashion, and set them to interact with each other in a simulated environment. Hence the need to put pieces together that past theories of the firm previously have been examining separately.

As we shall see, the above calls for the application of new qualitative research methods (Coughlan, Coughlan 2002) that bridge the gap between theory, reality and practice, as to make our complexity-based view of the firm usable in practical applications that give practitioners some control of situations (Glaser, Strauss 2009). Eventually, our approach should bring new opportunities for researchers to explore collective behavior and validate new theoretical models, and for practitioners, to configure firm's policy settings and try to anticipate performance.

This thesis is organized into four main chapters, in addition to *Introduction*, *Conclusions* and *Further Research*. *Chapter 2* investigates the relations between complexity and the firm as a complex system. Despite the difficulties to arrive at a universal definition of complexity, in this chapter the author examines the different dimensions that complexity of the firm may have, and concludes that the notion of "complexity" is an inherent feature of every firm operating in a competitive environment and a key building block to take into consideration for further advance of the theory of the firm.

Upon the theoretical and practical shortcomings identified by the author, *Chapter 3* sets the basis for a new approach and provides evidence as of why a reality bounded theory is necessary. In particular, the author underlines the importance of a new conceptualization of the firm, as well as the need to refocus the theorizing process around an idiosyncratic notion of complexity of the firm.

Building on the above premises, *Chapter 4* elaborates on the theoretical constituents of our proposed complexity-based view of the firm, with an emphasis on the key features that characterize the firm as an adaptive complex system. Moreover, as our complexity-based approach is decidedly grounded in reality, its practical implementation requires a methodological framework that guides researchers and practitioners on the practicalities of addressing complexity. Therefore, *Chapter 4* provides the basis for the design of such methodology, specifically formulating a method comprised of four stages that covers the key activities, tools and techniques that should serve to systematically untangle complexity of the firm.

As no theory building process would be complete without empirically illustrating the application of the theory, *Chapter 5* presents the results of a field research carried out by the author at an international scale in the airline industry. The results obtained give supporting evidence of the applicability of the theory and method presented in this thesis, and of the replicability of the key assumptions made to further advance the new paradigm of complexity in the firm.

Finally, this thesis is complemented with eight appendices. *Appendix A* provides a summary of the theoretical review carried out by the author on a selected number of seminal theories of the firm, specifically focusing on the extent to which these theories address the problem of complexity in the firm. *Appendix B* shows an example of an expert's benchmarking of responses, drafted and handed out to each and every member of the Experts' Panel participating in the thesis field research. *Appendix C* contains the list of members participating in the Delphi Experts' Panel. *Appendix D* provides a transcript of the questionnaires used across the four stages of the Delphi process. *Appendix E* shows the data captured in the field research. *Appendix F* contains the R programming code used in the field research. Together with the data provided in Appendix E; this code should enable any interested investigator to reproduce the outcomes obtained in the thesis. In *Appendix G* there are screenshots of the website (http://www.valueinairlines.com) created and hosted by the author to serve as the main communication tool with the members of the Experts' Panel along the field research. Finally, *Appendix H* includes a short description of the various software tools used in the thesis.

CHAPTER 2.

COMPLEXITY AND THE FIRM

2.1 Introduction

The Oxford English Dictionary defines "complexity" as something "*consisting of parts or elements not simply coordinated, but some of them involved in various degrees of subordination; complicated, involved, intricate; not easily analysed or disentangled".* What this definition invokes is that some of the terms used in the definition of "complexity" are subject to personal consideration, or they are even context-sensitive. What is more, if we add to the above a review of up to date literature on complexity, there seems to be no fixed or universal definition of complexity. This suggests instead that the degree of intricacy, involvement, or complication of a system depends entirely on the observer's assessment and/or a context.

Furthermore, "complexity" is such a general concept that it means something different to different people, even in the academic circles. As an example, the following list illustrates the considerable disparity of what "complexity" entails to the complexity research community:

- *"Simply stated, complexity arises in situations where an increasing number of independent variables begin interacting in interdependent and unpredictable ways" (Sanders 2003).*

- *"A great many quantities have been proposed as measures of something like complexity. In fact, a variety of different measures would be required to capture all our intuitive ideas about what is meant by complexity and by its opposite, simplicity" (Gell-Mann 1995).*
- "To us, complexity means that we have structure with variations" (Goldenfeld, Kadanoff 1999).
- *"In a general sense, the adjective "complex" describes a system or component that by design or function or both is difficult to understand and verify. […] complexity is determined by such factors as the number of components and the intricacy of the interfaces between them the number and intricacy of conditional branches, the degree of nesting, and the types of data structures"* (Weng, Bhalla et al. 1999).
- *"A complex system is literally one in which there are multiple interactions between many different components"* (Rind 1999).
- *"Common to all studies of complexity are systems with multiple elements adapting or re-acting to the pattern these elements create"* (Arthur 1999).
- *"Complexity starts when causality breaks down"* (Editorial 2009).

Most of the foregoing statements characterize "complexity" as a structural feature of a system, in such a way that complexity appears whenever a threshold limit is exceeded by the quantity of components, the nature of the variations, or the number of interactions among components. Thus, one may wonder where this threshold limit is set; and one possible answer would be that this threshold plainly depends on the self-determined assumptions made by the observer, or otherwise imposed by the context.

As pervasive as the idea of *structural complexity* may seem, it is not the only feature or measure that we should consider when attempting to get a comprehensive idea of what complexity is. We must consider other complementary measures, such as “environmental complexity” and “process complexity”, the latter if we are specifically centered on dynamic systems.

Environmental complexity takes into account the physical and metaphysical environments where the firm operates. Conceptually, it addresses the rules and conditions from within and outside the boundaries of the firm, which in turn determine the satisfaction of the firm’s intentions or goals. To grasp a realistic idea of what environmental complexity is all about, it is appropriate to measure various dimensions, including institutional complexity, geo-political complexity, and competitive complexity.

Process complexity is a key measure of the difficulty of describing and executing a process. Specifically, a “process” may be defined as an interactive algorithm used to execute relational orders according to the rules and/or constraints set to satisfy a goal or intention (Howard, Rolland et al. 2004). When a process is so-defined, it indirectly concerns to a system that is led by an objective and organized by a relational order of its components, which is a definition closely related to what the firm stands for.

Furthermore, process complexity addresses the execution of periodic and non-periodic processes within the firm and in relation to its environment. An assessment of process complexity would thus require measuring of relational complexity, action complexity and goal complexity (Howard, Rolland et al. 2004). Note that process complexity is also a measure of the evolution of the complexity of the firm, and the link between structural and environmental complexity.

As described above, the notion of "complexity" is an inherent feature of every firm operating in a competitive environment. As such, complexity may change in terms of magnitude, i.e. some firms may present more complexity than others, but it will always be present in the characterization of the firm as an open system. Fig.1 provides a graphical illustration of the different dimensions of complexity described above.

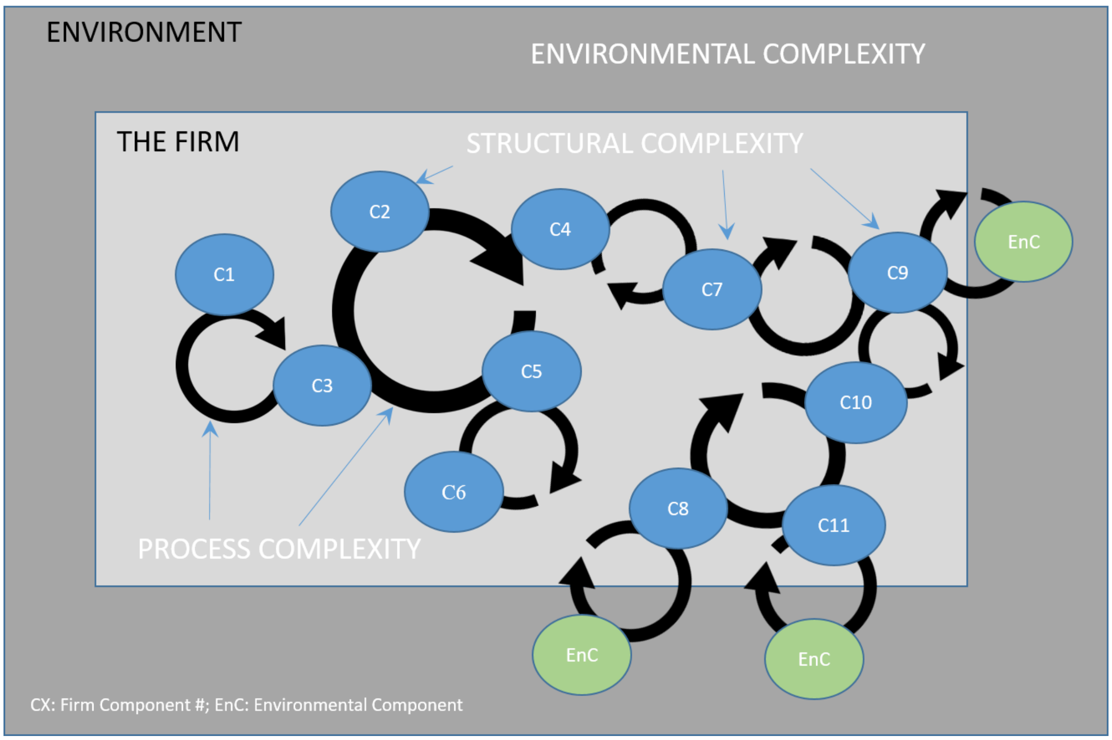

Figure 1. Dimensions of Complexity of the Firm
Source: own elaboration

Complexity is, in short, not only the raison d'être of the complexity-based view of the firm (CBVF) proposed in this thesis, but also the fundamental principle that this author suggests should guide the search for new developments in the theory of the firm useful for explanatory and predictive purposes, and for assisting practitioners in making decisions. For this purpose, as we shall see next, the CBVF particularly calls for the integration of knowledge from other scientific disciplines and the emergence of new idiosyncratic concepts and hybrid tools.

2.2 The Firm as a Complex System

A foundational consideration of our proposed CBVF, to bear in mind throughout this thesis, is the characterization of the firm as an open system, embedded in a complex environmental setting with which it continuously exchanges value.

From a practitioner perspective, this may be a rather intuitive idea, since the interconnectedness between the firm and its outer environment appears both as commonplace and as an apparent determinant of the behavior of the firm. Nevertheless, a closer look at some of the most important theories of the firm (Appendix A) reveals a somewhat different state of affairs, many of which aim at understanding the firm as the sum of the properties of its individual components, without allowing much for the emergence of additional properties from component interactions.

As of today, the reigning paradigm mostly consists of breaking up the firm into as many different components as possible and studying the properties of the resulting parts —i.e. transaction costs, property rights, agent relationships, stakeholders, knowledge. It is thought that by doing so, we should then be able to understand the firm wholly, simply because the parts constitute and determine the whole. This reductionist approach has seemingly provided a powerful research methodology up until now, and become a guiding principle for acquiring knowledge and a relatively consistent view of the firm’s life.

However, “dissecting” the firm to its slightest components and focusing on a single, or a few, component/s, removes virtually all the properties associated with the real behavior of the firm. The alternative offered by advocates of the behavioral theory of the firm to look at the firm as a whole (Cyert, March 1963) is also limited. By focusing on the firm as a whole, we could gather empirical data and explain the behavior of the firm in terms of phenomenological models, the components of which would have no real significance.

We can agree that this reductionist approach has worked well for the last two or three decades, illustrating situations in which its premises are valid and the descriptions provided are useful (Kaneko 2006). But it is not yet clear that maintaining the same strategy in the twenty-first century will suffice. Actually, there are many flaws in the theories of the firm that hamper their explanatory power and, as a result, a new approach is all the more necessary if we are to keep the theory of the firm alive and with practical relevance.

Yet, this is not a trivial task. To embed a higher level of complexity into the “core” of the theory of the firm entails major consequences. The implications affect the way researchers build theories and models of the firm and, even more, how they approach the theory of the firm subject matter. Certainly, these consequences are deep and far reaching as set out below.

First, if we are to internalize complexity into the theory of the firm we should start by changing our conceptualization of the firm. This fundamentally involves acknowledging that the firm is an open complex system in continuous exchange of inputs and outputs with the environment, and in continuous building up and breaking down of (its) components. Therefore, a key assumption that every new approach to the firm needs to adopt is that the firm is not going to behave as a closed system anymore and is never in equilibrium, but in a state of continuous flow of change and exchange.

Second, to grasp (even a slight) understanding of the complex nature of the firm and of the patterns of interaction between its components, the firm as a whole and its outer environment, we not only need a new conceptualization of the firm, but to further develop a more holistic complexity-based view of the firm. This new approach should be contingent on key concepts, such as hierarchy, system boundaries, holism, network, synergism, etc. thoroughly addressed in systems research and other non-economic complexity-centered disciplines (Kaneko 2006, Jørgensen 2006, Boogerd, Bruggeman et al. 2007, Alberghina, Westerhoff 2007).

Finally, a complexity-based view of the firm entails opening an entirely new set of methodological perspectives, based on *i)* a more interdisciplinary philosophy that addresses the behavior of the firm from simultaneously different knowledge dimensions and, *ii)* the use of qualitative and quantitative hybrid tools specifically designed to tackle complexity —even if they are to be borrowed from other scientific disciplines and were not original designed to solve complex social or economic problems.

2.3 Complexity and Theory of the Firm

So far we have been using concepts such as “firm” and “theory of the firm”, which are central for the development of our proposed complexity-based view of the firm. It is thus all the more necessary that we stop for a moment and ask ourselves, What is that we call “firm”? What do we exactly mean by “theory of the firm”? What scholars are actually doing when they investigate on the theory of the firm? What is the scope and method(s) of such theory? Where are the facts and evidence behind the theory?

Certainly, a number of questions arise when we attempt to recapitulate the key issues under the consideration of the theory of the firm. In fact, the field of the theory of the firm is so extensive that it is challenging to present the theory of the firm as a single, well-defined, distinctive set of assumptions and methods, all of which neatly resemble a unique and round theory of the firm. Quite the contrary, the theory of the firm is best examined as a broad body of theoretical constructs —i.e. organizational theory, strategy management, etc.—, each of which aims at explaining the behavior of the firm from a different perspective and employs a somewhat different methodology. Yet, all these different perspectives share the same subject of research: the firm, and produce fragmented though complementary and interrelated knowledge on the behavior of the firm.

At this point it is also useful to make a distinction between the economics of the firm and the theory of the firm. The former concerns itself with issues related to the structure of the firm, its organization and boundaries, whereas the latter usually refers to the analysis of the behavior and strategies of the firm in certain market scenarios (Dietrich, Krafft 2012).

The author is well aware that the economic literature often characterizes the different theories of the firm through their peculiar definitions of the "firm" and according to the determination of its boundaries. These two issues have helped stress the diversity of theories of the firm and highlighted the difficulties existing to place them under the same theoretical umbrella. As for the purpose of this thesis, a firm may be a corporation, a group of corporations, a part of a corporation, or it may be a partnership, or some combinations of all the above (Papandreou 2000).

Given the large theoretical heterogeneity found, the author supports the idea to use a broad conception of the theory of the firm in this thesis, mainly centered on the following topics: *i)* the firm as a mechanism for the allocation of scarce resources, *ii)* the mechanisms for decision-making within the firm, and *iii)* the organization of the firm (Mahoney 2005). More particularly, the author will refer to the family of theories of the firm and its customary methodologies, as “conventional” theories of the firm. This is meant to differentiate the mainstream paradigms that hinge on premises and authors dating back to the mid-twentieth century, from the multidimensional prone, non-linear, complexity-based view of the firm set out later on this thesis.

For most of the so-called conventional theories of the firm (see Appendix A) the term “complexity” appears more like the ability of the firm to interact with, or grasp resources from, the outside world (market). Cyert et al. summarize this position clearly when they assert with almost watchmaker's precision that “*the information received from the market enables the firm to apply its decision criterion, and the competitive system then proceeds to allocate resources and produce output. The market information determines the behavior of the so- called firm”* (Cyert, Hedrick 1972). Consequently, in a greater or lesser degree within the set of conventional theories of the firm, once the market conditions are described, the behavior of the firm is “automatically” deduced from the assumptions, in a rather aprioristic and programmed-like fashion.

From here on the author will use the term “complexity” in a broad sense to mean not only the intricate number or type of relations held between the firm and the actors in the environment —or the market where the exchange of resources takes place—, but also to refer the emergence of the characteristics of an adaptive open complex system in the firm, where components continuously interact with one another creating and exchanging value. Eventually, "complexity" is used in this thesis to denote how realistically the postulates of the theory of the firm approach the behavior of the firm.

2.4 Literature on Complexity and the Firm

A growing body of literature on complexity of the firm has developed in last years, mainly linked to the fields of management and organizational studies and the attempts made to approach organizations from a complexity perspective. The advancements achieved so far reflect not only the scholars' increasing interest on this topic, but also shows that a new theory of the firm based on complexity might be at sight.

Complexity in management have got inspiration from concepts originating in disciplines like chemistry, physics, biology, mathematics and computing. However, as many of the complexity-related concepts are difficult to "translate" to the field of management, metaphors are most often suggested. The downside of this approach is that it does not help much to remove ambiguity, or make new conceptualizations based on complexity useful.

What follows are some of the key contributions that are shaping today's research on complexity in firm-related disciplines and which further support the case for our CBVF.

Allen et al., for example, have dedicated time to reflect upon how complexity science has influenced management and organization studies over the past two decades. For them, complexity science challenges not only the foundations of our knowledge, but also the economic, political and social institutions we build upon that knowledge. In fact, the very idea of viewing natural and social systems as complex adaptive ones constitutes a major revolution in thinking which, according to these authors, *"will have impacts on society as great as those of the*

Enlightenment". Furthermore, Allen et al. submit that adopting a complexity perspective has important ontological, epistemological and axiological implications with which management researchers and practitioners alike must come to terms. In sum, complexity science provides scholars with a firm and scientifically anchored foundation from which to explore and understand human organizations (Allen, Maguire et al. 2011).

In their comparative analysis of theoretical approaches to managing complexity in organizations, **Bohórquez and Espinosa** echo the central role of self-organization in the life of organizations. Their work attempts to identify the differences and similarities in the way the notion of self-organization is explained in different theories of complex systems used in management, and they end up grouping them as complex systems theories, complex adaptive systems (CAS) and organizational cybernetics (Bohórquez, Espinosa 2015). The different approaches have theoretical and methodological differences.

Gharajedaghi suggests that as the organization as a whole is becoming more interdependent, the parts increasingly display choice and behave independently. This dilemma thus requires a dual shift of paradigm: "*the first shift results in the ability to see the organization as a multi-minded, sociocultural system, a voluntary association of purposeful members who have come together to serve themselves by serving a need in the environment. The second shift helps us see through chaos and complexity and learn how to deal with an interdependent set of variables"* (Gharajedaghi 2011).

For **Gorzeń-Mitka and Okręglicka**, the "complex" view of reality is important in understanding the activities of an organization, actually it is a natural consequence. Complexity and uncertainty of the environment are key determinants for the search of new management methods that fit in with the reality. However, despite the importance of complexity for management, these authors contend that most companies have not introduced or implemented yet a complexity management system/approach, or if they use one, they do not know whether it is efficient and adequate. A literature review conducted by these authors shows that existing complexity management strategies can be organized according to different management approaches. Therefore, for each area of complexity –avoidance, reduction, transfer and control– several strategies or complexity management models exist (Gorzeń-Mitka, Okręglicka 2015).

McMillan's perspective is on management of change *in all its rich complexity*. What complexity involves for organizations, she argues, is *"acting differently and introducing change using complexity-based principle"* (McMillan 2008). On implementing a complexity approach, management has to think differently about organizations and management, focusing on process and dynamics and acknowledging the uncertainty, unpredictability and the paradoxical nature of life in today's organizations. The implications, according to this author, are evident: *"a manager considering change from a complexity standpoint will realize that it is pointless to attempt to control all the key variables in a given situation and will instead focus on what it is possible to know and understand*" (McMillan 2008). She goes as far as to propose twelve principles for introducing a complexity-based change process in organizations.

Stacey et al. are critical of the different ways in which complexity thinking is being taken up by organizations. They understand organizations as complex responsive processes of relating, and draw on the complexity sciences as a source of analogies, interpreting them through a relationship psychology (Stacey, Griffin 2008). The authors show that complexity thinking focuses attention on the emergence of genuine novelty in everyday processes of communicative action through *"the essentially responsive and participative nature of human processes of relating and the radical unpredictability of their evolution"* (Stacey, Griffin et al. 2000). According to these authors, the complexity sciences can be brought together with psychology and sociology in many different ways to form a whole spectrum of theories of human organization.

For **Smith and Mitleton-Kelly** (2011), complexity invokes organizations evolving in a process that is systemic, emergent and context dependent. According to these authors, successful organizations are those that promote feedback, self-organization and create a learning environment, while at the same time become more tolerant and comfortable with emergence, unpredictability and uncertainty (Smith, Mitleton-Kelly 2011).

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CHAPTER 3.

BASIS FOR A NEW APPROACH

3.1 Introduction

A review on some of the most prominent theories of the firm (Appendix A) reveals that though they mostly provide the fundamental “building stones” for understanding the behavior of the firm, there is still much room for enhancing their explanatory power in the form of more realistic constructs.

Years of outstanding theoretical and methodological advancements have led us to what we know today about the firm, and how we explain its behavior. In our continuous strive for improvement, questions such as the increasing attention paid by scholars to the role of the environment in the behavior of the firm are an example that illustrates how most recent developments in the theory of the firm are starting to overcome some of its main limitations.

The field of theories of the firm have unquestionably made a quality leap in most recent times, adding more “complexity” to their assumptions, which in turn points the way ahead for making more practical progress. From this trend, the author suggests that a new theory of the firm, centered on the complexity of the firm, might be at sight.

In this chapter the author provides further arguments according to which a new approach to the behavior of the firm seems inevitable, thereby setting the basis for a new conceptualization and theorizing process of the theory of the firm.

3.2 Why a New Approach is Necessary?

The question of why a new approach is necessary might be best answered with a statement of principles: a new approach is necessary because conventional theories of the firm —with their mostly linear, equilibrium-based, cause and effect thinking, and yet to improve empirical evidence—, largely deviates from the real-business life, where firms operate and develop.

It is precisely the author's interest in the flaws evidenced by the conventional theories of the firm to explain the real world and the particular chunks of reality that they ignore, which point to the need for making new improvements in the theory of the firm. As a matter of fact, there are many arguments at play that support this position.

We argue that there is a strong case for challenging the **validity of some fundamental assumptions** made by the conventional theories of the firm, particularly those concerned with propositions such as the firm as a profit-maximizing agent, how firms get started, the role of the entrepreneur in a modern XXI-st century's society (Papandreou 2000), or the way the firm understands value creation. All of them need improvement, since they do not adequately reflect the way actual firms operate.

Another much controversial issue arises from the study of the **boundaries of the firm**. The discussion on the boundaries of the firm has been a hot topic in the field for years, and one that has been useful for analyzing the various historical forms in which economic production and distribution have been organized and coordinated. Over the past century, our notion of boundaries has experienced significant modifications that reflect changes in the way firms have been conceptualized (Martin 2012).

The two strains of work that have dominated the research on the boundaries of the firm, transaction cost and property right economics, are arguably no longer valid to support the significant organizational changes that are taking place (Holmström, Roberts 1998). For some authors, the question of understanding where the boundaries of a firm lie is even a matter of interpretation and *"managers need to consider alternative interpretations which they and others might make in any specific situation as this is a question subject to interpretation"* (Blois 2006).

Whatever the case may be, the very concept of boundaries has become blurred as result of the changes in the environment of business activities and the more open networked formations that are taking place, both within and between firms (Nolan 2007, Cantwell 2013). Reality is stubborn, and constantly remind us that firms are complex entities that deal with a much richer variety of problems than conventional theories can withstand.

But there are still more arguments to consider. The conspicuous lack of a practical focus evidenced by the most salient theories of the firm has led to **serious utilization problems**. By this we do not mean that the theories of the firm must be devoted to the application of scientific knowledge to solve specific managerial problems —which would be the domain of practitioners—, but the development of theoretical knowledge that enables managers to solve a class of managerial problems (van Aken 2004). Perhaps not intentionally, the gap created between the theories of the firm and practical reality has greatly diminished their practical relevance.

3.3 Evidence for a Complexity-based Approach

The approach to the firm as an open complex system is not something new. In fact, the theorizing effort in the last decades on disciplines related to the theory of the firm —i.e. organizational theory, management studies, behavioral economics, social systems, or consumer psychology— is a good example of the aspiration of the research community to explain the behavior of the firm with more detail and precision, though from different theoretical perspectives and with different purposes in mind.

As threshed as the field of the theory of the firm seems can be, why, then, do we suggest a new "view" or approach to the firm? Why is it worth to dedicate more time and brains to this seasoned topic of the theory of the firm, which has produced by the way, hundreds of thoughtful papers and research literature? What else can a complexity-based view of the firm add to our knowledge that we cannot obtain by mixing some of our currently available conventional approaches? The facts are that much evidence suggests that the conventional theories of the firm simply fail to tackle the key challenges posed by real business life of the twenty-first century, and that a **complexity-based view of the firm might be a plausible alternative**.

As Sanders (2003) submits: *"the challenges we face today and those we'll confront in the future require new ways of thinking about and understanding the complex, interconnected and rapidly changing world in which we live and work, and insights arising from the study of complex systems are helping us expand our thinking in new directions".* Building upon this idea, we set forth below what we consider are key evidences supporting the need for our CBVF.

First, it should be noted that significant progress has been made in **complexity-related studies** within a broad range of non-economic scientific disciplines —e.g. theoretical physics, biology, ecology, software computing. This has inevitably pushed forward their respective frontiers of knowledge, building upon innovative and idiosyncratic methods aimed at tackling complexity. No doubt such precedents are an excellent source of methods and tools —as well as inspirational ideas— for the introduction of higher levels of complexity in the general economic theory and, particularly, in the theory of the firm. Add to this picture the fact that never before in the history of economics —and of social sciences— have researchers had the tools and techniques to come face to face with complexity as they have today, hence the chance to seize the opportunities provided by a new complexity-based view of the firm.

Second, a growing number of scholars in the field of general economic theory and in the theory of the firm openly admit that **economic life does not obey laws expressed in terms of $\boldsymbol{F(X, Y, Z)}$**. For years we have realized that the real world of the firm is not describable merely in terms of prices, production and costs, and that the firm does not function in a mechanical way. Instead, we have learned, in one way or another, that the real firm might function like a mechanism, but more like a complex system than a precision machine. This analogy has been noted by some authors, though not yet developed sufficiently to seize all its theoretical and practical possibilities (Jaynes 1991).

What all the above fundamentally means is that our problem is not just one of quantitative nature. Our theories are qualitatively wrong (Jaynes 1991) or incomplete, either because we have chosen the wrong set of variables, or because our techniques are not sufficiently sophisticated to grasp its key relationships and interactions. At this point, no mathematical model or computing power can help us. It may be a matter that we have not yet fully understood what complexity entails for the economic system and the firm.

Third, closely linked to the previous evidences is the acceptance of the premise that **every component of the firm is related to the whole system and vice versa**, and therefore that no meaning can be gathered out if it is excluded from the whole (Karsten 1990). In other words, the firm can no longer be interpreted as a self-contained structure and examined with reference solely to its constituent parts, but instead it forms a holistic construct. In this respect, we could use a metaphor from modern physics to explain the whole/component relationship of our proposed CBVF, saying that the universe is viewed as a dynamic part of an inseparable whole and where the conventional concepts of space and time, and of cause and effect, have lost their (conventional) meaning (Capra 1985).

Fourth, the firm research community seems today more **prone than ever to changing its mood towards complexity**. This is reflected by how complexity is no longer considered the dead end where most investigations come to a halt, or where theories of the firm lose their grip, but the starting point for many innovative approaches. No doubt that the term complexity is not as dreaded today as it was years ago, and that a growing number of scholars is now starting to acknowledge complexity as the basis on which to build their research. This suggests that by embracing a CBVF-like approach, new opportunities for the study of the firm should arise, which might in turn greatly boost the theoretical and practical outcomes.

Last but not least, by embedding complexity into the "core" of the theory of the firm, we are keeping a closer eye on reality and showing commitment to **generate practical outcomes that help practitioners and society in general** —especially at a time when they increasingly demand more and better practical results out of the researchers' work. As argued above, the

CBVF approach is seriously determined to keep the theory of the firm bounded to reality, which in turn involves producing practical theories and fulfil its obligations with society with regards to general progress and wellbeing.

3.4 Conceptualization of the CBVF Approach

Future theoretical and methodological developments in the theory of the firm will necessarily depend upon coming to grips with complexity and open adaptive systems. Such approaches involve a distinct view of the firm that is complex both in its composition —many components interacting with each other and with their environment on multiple levels— and in the rich diversity of behavior of which they are capable. The following section provides a general overview of the key conceptual elements necessary to articulate and realize future developments in the theory of the firm when complexity is introduced.

3.4.1 Open complex system approach

The adoption of an open complex systems approach in the theory of the firm is nothing new. Its philosophical roots can be traced back to the discussions between advocates of the mechanistic and organismic models of the 19th and early 20th centuries (Kast, Rosenzweig 1972, Johnson, Kast et al. 1973), and can be epitomized when Scott asserts that *"the only meaningful way to study organization is to study it as a system (…) Modern organization theory and general system theory are similar in that they look at organization as an integrated whole"* (Scott 1961). In fact, he was not in solitude, Cyert and March also note that organizations are "complex systems" and they went as far as to develop a model comprised of a set of interdependent decision rules, responding to both external feedback and to internal reinforcement (Gavetti, Greve et al. 2012).

Not surprisingly, many firm's practitioners in the last century have been using a systems approach intuitively (and implicitly), without even knowing much about the underlying stream of systems research. As a matter of fact, all that practitioners needed to do is develop an intuitive sense of the situation of the firm, act as if they were flexible diagnosticians, and adjust their actions and decisions accordingly (Kast, Rosenzweig 1972).

Today, the open systems approach is touted as a promising means to better understand the complexity of "live" organizations, and as Simon observes *"its popularity is more a response to a pressing need for synthesizing and analyzing complexity than it is to any large development of a body of knowledge and technique for dealing with complexity"*(Simon 1962a).

The key idea behind the open system approach is that firms are themselves open systems, maintaining in continuous exchange of inputs and outputs with the outer environment, and in continuous building up and breaking down of their components (Von Bertalanffy 1950). This hardly novel but powerful idea comes to break with the approaches used in conventional theories of the firm, centered almost exclusively on closed or semi-closed systems and fictitious equilibria. Instead, according to the open systems approach, real business life shows that the firm as a whole does not behave as a closed system and is never in equilibrium, but instead in a state of continuous flow of change.

The implications of the open systems approach for the theory of the firm are broad and varied. One of the main concerns has to do with the way in which the firm responds to environmentally generated inputs, and how it adapts internally to these environmental forces.

This fundamentally leads us to a new conceptual model, contingent on concepts such as holism, synergism, hierarchy, system boundaries, dynamic equilibrium, multiple goal-seeking, to name just a few, and the need to define more explicitly certain patterns of relationships and interactions between the firm, its components, and key environmental variables.

As a result of the above considerations, it becomes pressing for the complexity-based approaches to the theory of the firm to extend their assumptions far beyond the boundaries of the firm, and transcend thus far isolated economic disciplines. This shall necessarily involve establishing a broader formulation of the theory of the firm, which comprises states of non-equilibrium as well as those of equilibrium.

In short, it would be highly desirable that the complexity-based approach attempt to “refound” the fundamental underpinnings of the theory of the firm, and incorporate the key principles governing open adaptive systems. Such a consideration of the firm as an open system would most probably lead to relevant quantitative and qualitative new insights, what would itself further increase our abilities to understand the real behavior of the firm.

The author is aware that although the open system approach has been broadly developed in most of the so-called “hard sciences”, further analysis remains to be done on the applicability of open systems to social sciences and, more specifically, to the behavior of the firm. In pursuing this endeavor there will most likely appear difficulties that stem from the novelty of the open system paradigm, and our inability to operationalize “all we think we know” about open systems. It is thus a challenge for the research community to make the open system approach more explicit and try to merge it into existing firm research trends.

Only the time and commitment of the firm research community in their struggle to find new answers to complex behavioral questions will tell how successful the open systems approach can be. After all, it should not be forgotten that one of the major contributions made by the introduction of an open systems mindset is to prevent us from accepting as final a level of theoretical analysis that is below the level of the empirical world we are investigating (Boulding 1956). The open systems approach might well spur that step forward in the scale of complexity that the theory of the firm inexorably deserves.

3.4.2 Interdisciplinarity

There is growing awareness in the research and practitioners communities of the need to accomplish the study of the firm leaving aside the (theoretical and methodological) shortcuts that hamper our ability to understand the behavior of the firm from an interdisciplinary perspective. This call for new means to better understand the behavior of the firm is also reflected in the works of many theorists of the firm, who have long requested a more interdisciplinary approach —see for example the papers published in the *Journal of Interdisciplinary Economics.*

When pursuing an interdisciplinary approach, one of the most important tasks to accomplish is transforming the theory of the firm into a truly hybrid discipline. This basically involves acknowledging that the economic theory alone is not enough to explain firm's behavior, and that we need to gain input from diverse fields of knowledge —such as from sociology, biology, physics, software computing, anthropology, psychology, etc.— to grasp a higher degree of understanding.

A valuable starting framework of reference for the implementation of an interdisciplinary approach within the theory of the firm is provided by the General Systems Theory (GST). GST aims at providing scientists with an integrated frame of knowledge so that they can understand and communicate with each other —i.e. GST would enable firm researchers to find out new answers to key questions by interacting with scientists in related areas of knowledge such as computing scientists, data scientists, sociologists, biologists, etc. (Boulding 1956). GST also supports the idea of isomorphism, which should enable us to identify and make use of common elements from within the scientific universe, as they are all basically concerned with the same phenomena.

The space of opportunities for improvement of the theory of the firm may be substantial, shall we apply a more interdisciplinary approach. In fact, prominent authors like Boulding (1956) specifically cited management science as a field of opportunity to break with old mechanistic methods and foster more powerful and fruitful approaches.

Nevertheless, the advocates of GST are not the only ones pressing for the interdisciplinary approach. Other prominent authors such as Edith Penrose, have also claimed that under complexity and diversity a firm could be approached with many different types of analysis —i.e. sociological, organizational, engineering, economic— as well as from whatever standpoint that seems appropriate to the firm's concrete problem at hand (Penrose 1959).

Simon (1982) even submits that *"there seems to be no escape from psychology",* and he goes as far as saying that as organizational economics and strategic management deal with uncertainty, *"they will have to understand how humans in fact behave in the face of uncertainty, and by what limits of information and computability humans are bound".* Furthermore, in asserting that organizational economics and strategic management are like chess, inevitably culture-bounded and history-bounded, Simon stretches the interdisciplinary focus.

An example of how the interdisciplinary approach may become a key concept for the development of complexity-based theories of the firm is illustrated by the growing importance given to terms like “trust” when it comes to describe the behavior of the firm. As Arrow (1974) denotes, trust is an *“important lubricant of a social system”* and, together with other values such as loyalty and authenticity, portrays a positive externality that cannot be analyzed from a strict economic perspective to become fully understandable, but only through an interdisciplinary approach.

3.4.3 Empirical new modeling tools

A predominant number of investigations carried out under the conventional theories of the firm have involved sample studies using secondary data, most often from public business databases. Standard multiple regression models are the dominant statistical technique, together with the use of correlations and analyses of variance (ANOVAs). In some cases, studies have been performed using a cross-sectional design with static specifications of the relationships under examination, though most studies do not include an effective set of control variables (Hitt, Gimeno et al. 1998).

What the above means is that most conventional theories of the firm have a limited perspective of the big picture. Researchers frequently open their minds to those inputs which they can handle within their bag of tools and they often dismiss variables outside their interest or competence as being irrelevant. As Kast et al. (1972) observe, *“we are hampered because* *each of the academic disciplines has taken a narrow "partial systems view" and find comfort in the relative certainty which this creates"*.

However, as research in the theory of the firm continues to develop —and other related disciplines, such as organizations and strategic management— better research, refined theory, and more powerful and sophisticated analytical methods have entered the arena. New and better sources of data have also been developed, along with a better understanding of the field investigated, all of which is resulting in more and better outcomes (Hitt, Gimeno et al. 1998).

But despite the progress made, the shift from the conventional conceptions of the firm to one consisting of a complex open system entails an entirely new scientific style and use of a full new set of advanced modeling tools. From an emphasis on deductive reasoning within a tight system of axioms, the complexity-based theories of the firm demand that higher attention is paid to a detailed empirical exploration of complex algorithms of thought (Mahoney 2005) and multivariate phenomena, if the goal is to keep the theory relevant.

The classical world of magnitudes thus needs to give way to the analysis of interactions between the different components and subsystems of the firm, and between these and environmental interfaces. Interactions are now key, and researchers need to measure them proficiently.

Along this process, many challenges will arise in complex firm modeling that threaten our research integrity. One of the **major challenges** is that the need to deal with comprehensive systems of relationships overruns our ability to fully understand and predict the firm interactions (Kast, Rosenzweig 1972). Furthermore, most of the current methods and tools used by social scientists may not be sophisticated enough to grasp the relationships among components and subsystems, not to say to gather the informational inputs that are necessary to make the systems approach really work. It is worth noting that only today we are beginning to understand multivariable relationships, at the expense of pushing the limits of our capacities. Consequently, if the theory of the firm is to advance and make contributions of practical relevance, it must either adopt new empirically-oriented modeling tools from outside the discipline, or develop its own.

In this regard, the forecast made by Hitt et al. (1998) on the future tools and methods that strategic management research will use, seem highly applicable in the field of the theory of the firm today. In particular, these authors forecast that future strategic management research will use: *(a)* methods appropriate for longitudinal or panel samples, *(b)* explicitly dynamic analytical methods, *(c)* methods appropriate for studying discrete strategic choices, behaviors, or actions, *(d)* methods that acknowledge the interdependence of firms with other firms or actors in their environment, *(e)* methods that explicitly account for the heterogeneity of firms, *(f)* methods that uncover the causal structure among and the endogeneity of variables, and *(g)* methods that account for the imperfect measurement of strategic constructs.

As we would expect, many of these methods and its related tools will have to be borrowed from other scientific disciplines, such as computer science, systems biology, neuroscience, eco-modeling, structural sociology, marketing, psychology, among others. Note that although the methods described above emphasize quantitative methodologies, an important challenge remains ahead for the complexity-based theories of the firm to integrate qualitative and quantitative research and make use of non-conventional research methods.

3.4.4 Extensive management of information

When carrying out the adoption of the concepts above, information becomes a critical asset. Notwithstanding the grounds for this view is nothing new. The difference today lies in that firms are embedded in environments of varying complexity, thus information impacts the behavior of the firm at a higher rate, and to a deeper extent. In fact, no firm can prosper today unless it is able to articulate knowledge from within the organization and its environment, and to permeate all levels of the organization and drive it to action.

Information is not only key for adjusting internal decision-making procedures that account for environmental variations, but it is also a factor required to create strong relationships and coherent organizational architectures. Consequently, the integration of information management into the new theoretical and practical perspectives of the firm is a necessary condition to improve the scope and depth of the new (complexity-based) theories of the firm.

The next generation of theories of the firm will thus give priority to the processes by which the firm gathers, operates and makes information actionable. This fundamentally concerns the firm’s maturity cycle of information, from the point where the information is captured, to the point where it is turned into usable knowledge and disseminated within and outside the boundaries of the firm.

An example of the impact that the management of information has over the behavior of the firm is the level of attention reached by the search and transmission of information, currently considered a vital step in the decision-making process of every firm. It is hardly surprising that the emphasis given to how the firm acquires and processes information is one way in which “complexity” has been introduced into the theory of the firm.

3.5 Refocus of the Theorizing Process

Theorizing from a complexity standpoint entails the need to deconstruct the very own hierarchical structure of the firm. To apprehend the concept of hierarchy, we resort to Simon’s (1962) definition, which states that a system is composed of interrelated subsystems (or components), each of which is, in turn, hierarchic in structure until it reaches some lowest level of elementary subsystem. The idea of hierarchy greatly simplifies the description of a complex system and, as in the case of the firm, facilitates the understanding of how it behaves.

It is worth noting that considerable discussion has taken place in the research community as to what comes first, whether our vision of the world as a hierarchical system, or our need to use the idea of hierarchy as the only way to get useful knowledge about a complex system (Simon 1962). Of course this is not the place to go deeper into this controversy, although the debate itself denotes the extent to which the term “hierarchy” is a key concept to consider in the study of complexity of the firm.

The idea of the firm as a hierarchical system is thus central for the development of our complexity-based view of the firm. Furthermore, we could hardly understand, describe, or analyze the firm as a whole or its interrelated constituent parts, unless we are able to unravel the hierarchy of the firm. Without such notion at hand, the complexity of the firm will plainly exceed our information processing capacity and our own ability to generate any practical understanding of the firm's behavior. The latter resulting in either an incomplete, or a scarcely useful theory of the firm.

3.5.1 Unraveling of the hierarchy of the firm

The first obstacle that emerges when we attempt to unravel the hierarchy of the firm is to figure out what is the basic building block of the firm; in other words, what is the fundamental piece or "atomic particle" to which the remaining components of the firm can be reduced. For example, in astronomy the basic building blocks are the stars or planets; in biology, the cell or proteins (Simon 1962a).

Within our approach of the firm as an open adaptive system, the fundamental building block that we will consider, from which the firm's components (and subsystems) become differentiated and cohesive, is "value". Value is the brick and mortar that gives consistency to the firm's hierarchical structure. Without creating and exchanging value, the firm's components would collapse inevitably, and the firm would cease to exist.

Notwithstanding the foregoing, the term "value" is a controversial concept that means different things to different people. Moreover, most of the research literature on "value" comes from neoclassical bounded economic theory, and there is little consistency in the approaches.

The term "value" not only invokes an economic game between the firm's components, and between these and external agents, but a perceived preference for a particular way of doing things —i.e. the products and services that a component of the firm produces—, which in turn facilitates (or blocks) their goals. Hence, we can recap as follows: the value created by the firm entails an attitude toward, or an emotional bond with the firm (or its components), comprising an interactive, dynamic, and contextual preference and experience (Brandenburger, Stuart 1996).

Since no universal meaning of "value" seems plausible, in the thesis we will use this term not in a strict economic sense —i.e. the difference between the willingness-to-pay of a buyer minus the opportunity cost of the supplier (Brandenburger, Stuart 1996)— but in a much broader sense. More specifically, we will refer to the firm's Multidimensional Value System Dynamics (see Section 4.3.5, B.1), which comprises both the internal and external value creation and exchange processes flowing to and from the components of the firm.

Upon embracing the idea of "value" as the basic building block of the firm-system, the next step leads us to substantiate the firm's fundamental components as "value repositories". Value repositories exhibit a duality between value creation and exchange or, in other words, between the stock of distinctive value accumulated by the firm —generally in the form of Potential Use Value— and the dynamic realization of that value with a customer —in the form of Exchange Value (Bowman, Ambrosini 2000, Lepak, Smith et al. 2007).

Value repositories have an interconnected nature, thus forming a network that links them together at different levels of hierarchy and strength. For example, as we shall see in Chapter 5, the network of most important value repositories in an airline is made of 15 unique and highly connected value repositories.

An important consideration to bear in mind is that value repositories are different from most firms' organizational units, as the value creation processes usually require inputs from different sources, other than a particular well-delimited organizational unit. For example, the "Process and cost optimization" value repository pinpointed in our airlines field research

(Chapter 5), does not match with any particular organizational unit in an real life airline. Instead, this value repository features the distinctive value created and exchanged by airlines —allegedly involving several organizational units— aimed at simplifying the relationship with the customers and gain internal efficiency.

To effectively unravel the hierarchy of the firm, we shall thus assess the firm's value system dynamics through the interactions taking place between value repositories. This involves mapping the strength of the interactions, its temporality, and where and with whom the strongest and weakest interactions happen.

In this process it is important to realize that only a small fraction of the interactions between value repositories will have real influence on the behavior of the firm. At this point it is useful to bring up Simon's notion of "redundancy" (Simon 1962a), which states that the underlying complexity of a system can be reduced to only a limited amount of subsystems and interactions that are truly relevant and differentiated.

The idea of redundancy shall enable us to limit the number of components (value repositories) in which we should focus to only a fraction, provided that we have accomplished an iterative assessment process that discerns between strong and weak interactions (Simon 1976). Once we get to know the strongest fraction of all possible interactions, we will be closer to achieve a better representation of the behavior of the firm —as the remaining interactions are most likely weak and not so relevant for our analysis of complexity.

3.5.2 Decomposition of the interactions among firm's components

Let us first explain what we mean by "interactions", and how other scientific disciplines use this term.

Usually when molecular biologists say that cells interact, what they are most probably thinking is that some effect is communicated between cells through receptors, or the exchange of certain molecules. Ecologists most likely would consider "interaction" as the relation of individuals in an ecological system such as prey–predator relationship. Physicists and chemists would consider interaction to be the influences communicated by forces –intermolecular, electromagnetic, etc. (Kaneko 2006).

For the purpose of this thesis, we use the term "interaction" in a broad sense, meaning the mutual effects resulting from exchanges among the firm's value repositories. For example, we regard as an interaction the exchange of value flowing from value repository A to value repository B, or the redistribution of resources between two value repositories.

The interactions between the firm's value repositories can be decomposed according to the following set of variables:

- ***Intensity.*** The intensity or strength of the interactions between value repositories provide us an idea of the firm's different levels of hierarchy. Some interactions may be labeled as weak, whereas others can be strong. In order to identify the firm's levels of hierarchy, we must first examine with whom do the value repositories interact, both inside and outside the firm. The stronger bonds among value repositories will shape the firm's core value creation architecture, which in turn is linked by the weaker, second-order bonds, into the larger value system of the firm.

In a rather similar way as ecologists observe, we should expect that a firm ecosystem had strong interactions among its key value repositories, and weak interactions across its boundaries (Jørgensen 2006). For the purpose of this thesis field research (Chapter 5), the intensity of the interactions between the airlines value repositories are scaled in five different levels: Zero, Very Weak, Weak, Strong, and Very Strong.

- ***Type.*** Interactions between value repositories can be of two main types: intra-component interactions, and inter-component interactions. Each type of interaction usually features a distinctive level of intensity and dynamics. As Simon (1962) observes, inter-component interactions are generally of a lower intensity than intra-component interactions. Although this may be true in the field of natural sciences, further analysis remains to be done in the case of the firm. In some cases, inter-component interactions may be so weak that some value repositories might be studied in a stand-alone fashion. For example, in the thesis field research (Chapter 5) the main type of interactions investigated are those among value repositories from inside the firm, these being influenced by up to 10 environmental constraints.
- ***Dynamics.*** Interactions among value repositories can be sorted out by high and low frequency interactions. High frequency interactions usually take place inside value repositories, whereas low frequency interactions are more common among different value repositories.

Decomposing the interactions among the firm's value repositories is an iterative process that involves the particularization of both the strong and weak interactions (see Chapter 5). This process may start focusing on the intra-component level of interactions and, as the process unfolds, make refinements to address the next round of inter-component interactions. Note that a parsimonious approach, as the 4-round Delphi process used in this thesis field research, should be used for decomposing the interactions and strike a balance between excessive detail and simplicity.

Eventually, the analysis and categorization of the interactions among the firm's value repositories should allow researchers and practitioners not only to characterize the interactions but also to obtain a measure of the *"Total Interaction Capacity (TIC)"* of the firm as a whole —or of a particular value repository. The TIC would be contingent on the three decomposition variables described before —intensity, type and dynamics— and may be used to determine the maximum number of simultaneous interactions that a value repository, or the firm as a whole, may assume at any given time. Limitation of the firm to continue interacting may be a sign of the firm's own information processing capacity.

3.5.3 Modeling of the firm's network dynamics

Once the firm's hierarchy has been revealed and the interactions between value repositories decomposed, the next step in the new theorizing process based on complexity should focus on accomplishing a tentative modeling procedure. This way we may offer new possibilities for the exploration of key behavioral questions, simulate specific firm's behavioral scenarios, and investigate new theories of the way the firm behaves.

Furthermore, modeling compels researchers to formulate hypotheses, determine what data are available and what data are needed, and assess the degree of understanding about key components and interactions of the firm. Altogether, modeling is a big step forward in the run to get a better understanding of complexity of the firm.

Several model formulations can be envisaged —e.g. dynamic models, stochastic models, agent-based models, fuzzy models, etc.— and the ability to choose among them requires that sound constraints are imposed on the model not to make it more complex than the data can bear; in other words, researchers must manage the trade-offs between knowing much about little or little about much (Jørgensen, Bendoricchio 2001). In some cases, there might be environments where the levels of complexity imposed cannot be managed by firms, unless they set considerable simplifying constraints on the information processed.

To illustrate the above considerations, it may be useful to start working with tools such as the adjacency or incidence matrix, a matrix made of ones and zeros, which assigns a value of 1 to the interactions between an element i with another j, and 0 to the absence of any interaction. Most real-world incidence matrices are sparse and they usually concentrate the larger interactions close to the diagonal of the matrix. Incidence matrices can also be useful to infer subsystems with different degrees of clusterization (Simon 1976).

After formulating a model of the value system of the firm, researchers will need to undertake verification tasks in order to conveniently assess the behavior of the model, as well as to check how the model reacts before changes of inputs and/or of the basic assumptions. Finally, validation of how well the model outputs fit the data should also be performed. As we shall see in Chapter 4, these modeling activities are covered within *Stage 4: Modeling and Simulation* of our proposed CBVF methodology.

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CHAPTER 4.

COMPLEXITY-BASED VIEW OF THE FIRM

4.1 Introduction

The CBVF's subject matter is not different from that of many other theories of the firm: the study of the behavioral phenomena produced by the firm as a living social and economic structure.

If I may use the simile of systems biology, the CBVF approach aims at understanding how the behavioral properties of the firm are brought about by the interactions of their constituents (Kitano 2002, Alberghina, Westerhoff 2007). In other words, the CBVF aims to decipher how the components of the firm (value repositories) jointly bring about firm behavior.

The problem addressed by the CBVF is therefore one of understanding the behavior of the firm that does not rely on simple enumeration of its components and processes, thereby it is perhaps necessary to define what we regard as constituting "understanding".

For the purpose of obtaining an actual understanding of the behavior of the firm, extracting and elucidating the general properties of the firm, together with a simplified, condensed description that removes nonessential details through abstraction, is necessary (Kaneko 2006). However, the CBVF is not an approach that simply reduces everything to a description of the firm’s components. Instead it is an approach that seeks the properties of the firm as a complex system, using a coarse-grained description of the properties emerging from collective interactions between components.

In order to achieve that goal, the CBVF aims to envision systemic firm behavior from their constituent value creation and value exchange processes , rather than by describing them independently. The premise is that there is something to be inferred from the firm constituents that cannot be discovered and understood by economics alone; properties that are embedded in its components alone, but that emerge from its network collective behavior (Kaneko 2006, Boogerd, Bruggeman et al. 2007).

Ultimately, the CBVF approach is concerned with the relationship and interaction between value repositories, the firm as a whole, and its environment. It treats value repositories as nodes in an organized network system with functional and behavioral properties. It uses models to describe particular value repositories and their links to arrive at new explanations of the firm. And last but not least, it is concerned with explaining and envisioning firm behavior on the basis of the value repositories behavior.

Hence, a fundamental pillar of the CBVF is to seek patterns that can be used for explanatory and predictive purposes —i.e. of the way the firm behaves, operates, organizes, and evolves— and not scientific laws that explain the behavior of the firm in a deterministic way. Consequently, precise and comprehensive experimental analyses of the firm, at levels between the firm-system level and its value repositories, is a requirement for the CBVF, as it should also be the accurate interpretation of the resulting experimental data.

The above entails that the CBVF approach does not conform entirely to the “canonical” —more naturalist— way of building up theories, as it is not expected to contain lawful statements. Paraphrasing Morgenbesser, to say that the firm is complex may be a well confirmed statement but a too general and commonplace one to be credited as a scientific approach. Many times such lawful statements are simply not useful for the tasks that a good theory of the firm needs to accomplish (Morgenbesser 1966).

Of course, this does not mean that our proposed CBVF does not aim to become a genuine scientific approach to understanding the behavior of the firm. Quite the contrary, what this author contends is the need for the CBVF to look beyond lawful statements, as they are not of unique interest to the understanding of the firm. We want to know not just that the firm is complex, but also the reasons that explain why the firm is so complex, the factors contributing to firm’s complexity, and what complexity entails for the firm and its environment.

For all said above, the aim of this chapter is to tackle the problem of complexity of the firm as a more comprehensive extension of the preceding theories of the firm covered elsewhere in the literature. In this chapter we introduce the fundamental features constituting our proposed CBVF, as an extended and complementary approach to the conventional theories of the firm, yet with a deeper analytical scope towards the reality of the firm.

As we shall see, the CBVF is an approach to old and new problems, which builds upon valuable ideas of the past, but also breaks even in the field of complexity with some tools and ideas borrowed from more experienced scientific disciplines. Furthermore, in our struggle to comprehend the behavior of the firm within its complexity, this chapter proposes a theoretical characterization of the CBVF for the first time. On the basis of this characterization, a methodological framework to tackle complexity from a practical angle is also presented.

The ideas contained in this chapter should contribute to our overall understanding of the firm as a complex system and, paraphrasing Einstein's popular quote, to figure out how to practically think about the complexity of the firm.

4.2 Theoretical Constituents of the CBVF

Complexity has remained somewhat invisible to most prominent theories of the firm, to the extent that when firms' theorists stumble upon complexity they usually use vagueness and ambiguity, or they refer to issues that are simply *"hard to explain with more traditional economic methods"* (Amman, Tesfatsion et al. 2006).

For this author, one of the major reasons explaining the absence of a comprehensive approach to complexity within the theory of the firm is the lack of a framework of reference that assists scholars and practitioners in properly characterizing complexity, in objectively featuring its subject matter, and in providing practical guidance to cope with it. These are precisely the goals that the CBVF aims to cater for.

Upon considering that every scientific discipline has its own particularities that intrinsically define a complex system (Sanders 2003), and that the notion of complexity cannot be featured universally and be the same for all disciplines, in this section we abstract some of the key features that may characterize the firm under the CBVF approach. Such a list, inevitably idiosyncratic from our perspective and not comprehensive in aspiration, contains only those features that characterize the firm as a complex system and are foundational to the CBVF approach:

- Value as the basic building block of the firm.

- Nonlinear behavior.
- Large number of interacting components.
- Hierarchical structure.
- Multi-level network dependency.
- Descriptive-predictive uncertainty.
- Structural homeostasis.
- Differentiation by specialization.

Set forth below is a more detailed description of each of the constituents of the CBVF.

4.2.1 Value as the basic building block of the firm

Within the CBVF approach, we take the notion of “value” as the basic building block of the firm. What this means is that “value” is the fundamental element from which the firm’s interacting components (value repositories) originate, differentiate and become cohesive. In other words, “value” is the brick and mortar of the firm’s architecture, without which the components of the firm would inevitably collapse.

The discussion on the conceptualization of “value” lies at the very heart of economic thought. Most likely no other single term in the history of economics has engaged the minds of so many thinkers and philosophers as the theories surrounding the notion of “value”, the concept thus becoming a recurrent topic in the most influential schools and streams of economic knowledge.

But, what is the intrinsic reason why “value” is such a relevant concept? We might answer this question arguing that understanding “value” reveals the foundational nature of economic life and the very basic structure of economic facts. In fact, all theories of value known to this author, from the oldest to the newest, aim at understanding and characterizing the nature of value in economic systems, as well as focus on the whys and hows value is produced and its localization within the economic system. Furthermore, for most theories what matters is not really that “value” can be isolated in one way or another, but rather that “value” is the outcome of a complicated web of interactions and relations between the various components of an economic system.

In addition to the above epistemological arguments, the term “value” plays a central role in the firm’s decision-making process, and is also a focal variable in the creation of competitive advantage (Day 2002). In both cases, the “forces” behind value creation —i.e. technologies of production, intersection of utility and cost, etc.— are considered key factors that explain the distribution of income and economic growth. Last but not least, the relevance of value is such that for many practitioners in the business arena, the maximization of “value” is not only a vision or strategy, but rather the sole purpose of the firm and the scorecard for the organization (Jensen 2002).

More evidence on the prominence of “value” as the basic building block of the firm is provided by recent investigations, which demonstrate that customer-perceived value is a cornerstone in relationship marketing and customer loyalty (DeSarbo, Jedidi et al. 2001, Day 2002, Priem 2007). Some authors even go as far as to compare value creation with the customer's use value, or customer’s utility (Bowman, Ambrosini 2000); and yet for others, customers are key value creators and they play an active role in co-producing value (Parolini 1996, Ramírez 1999).

Consequently, if we are to tackle complexity of the firm we must first gather a good understanding on the problematic of value for the customer (Woodall 2003), as a key driver of the firm's value dynamics and given its proven capacity to tie *"the surface phenomena of economic life to some inner structure or order"* (Heilbroner 1983). As we shall see next in the thesis, unraveling the multidimensional value system dynamics —as described in Section 4.3.5, B.1— using the analyst's practical knowledge and experience becomes particularly important for the later application of the CBVF approach.

4.2.2 Nonlinear behavior

Nonlinearity is a key feature that characterizes the behavior of the firm as a complex system and, as an extension, the CBVF approach. A nonlinear behavior occurs whenever a response is neither directly, nor inversely proportional to its cause. Themes invoked by this notion include process, emergence, and ongoing, perpetual novelty (Meyer, Gaba et al. 2005).

Additionally, a system is nonlinear when it does not satisfy the *superposition principle*, meaning that the output of a nonlinear system is not directly proportional to the input. This, in turn, involves that the system does not satisfy the homogeneity and additive properties together —inversely, a linear system is one that satisfies both properties.

The property of homogeneity defines a homogeneous function of degree λ as a function f, such that for all points $(x_1, x_2, \dots . x_n)$ in its domain and all real $t > 0$, the equation

$$f(tx_1, \dots, tx_n) = t^{\lambda} f(x_1, \dots, x_n)$$

holds, where λ is a real number. It is assumed that for every point $(x_1, x_2, \ldots . x_n)$ in the domain of f, the point $(tx_1, \ldots, tx_n)$ also belongs to this domain for any $t > 0$ (Kudryavtsev 2001). As we can see this is a function with multiplicative scaling behavior.

The additive property means the system preserves the addition operation for any two elements x and y in the system, thus:

$$f(x + y) = f(x) + f(y)$$

If input A produces X and input B produces Y, then input $(A + B)$ produces $(X + Y)$.

Similarly, a nonlinear system of equations is one in which the equation(s) to be solved cannot be written as a linear combination of the unknown variables or functions that appear in the system. The differential equations governing some systems, including some thermal, fluidic, or biological systems, are nonlinear in nature.

Nonlinear science has its origins in Poincaré’s solution to the "N-body Problem" nearly a century ago —the problem of predicting the individual motions of a group of celestial objects interacting with each other gravitationally. However, it is only recently that nonlinear explorations have become commonplace in a widespread number of scientific disciplines. Gradually scholars have begun to suggest that nonlinear processes are much more ubiquitous than we could have ever imagined, and that they are a fundamental feature of natural systems (Daneke 1997).

Nonlinear dynamics is characterized by emergence, self-organization and evolution, all of them concepts familiar to our proposed CBVF. Emergence refers to new properties that were not present in, or predictable from, the initial conditions (Holland 2000, Stace, Goldstein 2006).

Emerging processes arise from the interaction between components of the system, which make it impossible to predict future states. Emergent conditions allow the system to self-organize and acquire a new order, thus making self-organization a mechanism for systems evolution (Bohórquez, Espinosa 2015).

What this author suggests is that there is compelling evidence by which the firm would behave in a nonlinear manner. Factors such as the use of advanced information technologies, the organization of resources in complex networks, or the development of innovation activities that affect productivity and transaction costs, to name just a few, provide evidence as to why the superposition property would not be met by the firm.

Notwithstanding, it is worth noting that being subject to nonlinear dynamics is not a necessary condition for the firm to be considered a complex system (Ladyman, Lambert et al. 2013). Actually, we can find examples of network systems performing linear behavior, which are studied by complexity disciplines. Moreover, it is also perfectly possible to think in a linear way about systems which exhibit nonlinear dynamics —i.e. complex systems subject to game-theoretic, or quantum dynamics subject to linear dynamics (McKay 2008).

4.2.3 Large number of interacting components

"Many more than a handful of individual elements need to interact in order to generate complex systems" (Ladyman, Lambert et al. 2013). What this assertion highlights is that complexity emerges when a large number of components are present in a system and, subsequently, if they are engaged in many interactions. Upon relying on the above premise, we might then wonder, what is a "component"? and, why does this author submit that the firm has a large number of them?

Most definitions of complexity from various scientific disciplines establish the large number of components as a key property of complex systems. However, when authors approach the idea of "component" much of vagueness and ambiguity is found. In fact, both terms —complexity and component— invoke problems that are not unique to economics or the theory of the firm, but which are also characteristic of other highly respected scientific disciplines, such as systems biology or quantum mechanics.

In the complexity jargon, a "component" is usually assimilated to the fundamental functional unit of a system and, as such, it may be built up and broken down. Relations or "forces" among components make them interact either in a static or dynamic manner, and they can adopt a heterogeneous configuration as well.

Under our proposed CBVF, the firm's components are represented as "value repositories" (see Section 3.5.1). Value repositories group together those activities, processes and resources aimed at creating unique exchangeable value, thus exhibiting a duality in their behavior between value creation and exchange (Section 3.5.2). It is worth noting that it is the very existence of value in the firm-system, and the flows of exchange, what matters most to the CBVF, and not the particular incentives —i.e. maximization, optimization— or the managerial actions needed to create and exchange value —the latter falling out of the scope of this thesis.

Notwithstanding the foregoing, value repositories are not constructs that can be unequivocally defined by any observer from inside or outside the firm, but components that reflect a real firm's value system dynamics, its structural and behavioral attributes being dependent on the particular rationale of value made by the firm.

Furthermore, uniqueness is a key principle that researchers and practitioners should carefully observe when they attempt to symbolically represent value repositories. This basically means that no two different value repositories should create and exchange the same value, thus reflecting the intrinsic division and specialization that exist within the firm's value system dynamics.

Therefore, as far as we make sure that no two value repositories cover the same value dynamics (Fig.6), we will be able to avoid redundant components analysis and creating a misleading or overly too complex picture of the firm's value system dynamics. For example, two value repositories previously outlined as delivering up-to-date performance information on different products to a customer should be symbolically represented as a single value repository under the CBVF analysis, as their value dynamic is the same.

It is also important to note that value repositories take the form of nodes in a complex web of networks in continuous interaction with one another. The composition, boundaries, and processes comprising the firm's value repositories (VRs) are determined by the idiosyncratic (value creation and exchange) interactions that are characteristic of every firm, and the particular path taken in creating and capturing value. Without the logic of a network of interacting VRs, the firm would merely become a meeting of independent individuals with no feasible goals to attain.

Ultimately, the firm is made up and interacts with a large number of interacting VRs, not only from inside the organization, but also from its outside environment. Moreover, not all the VRs are intrinsically of the same kind —i.e. some may be mainly focused on internal customers, whereas others may be more focused on external customers— nor do they interact in the same way —i.e. some may pursue exchanges for money while others may prioritize exchanges of information or other specialized resources.

As we shall note, the complex network of interactions among VRs thus formed increases the difficulty to grasp the behavior of the firm as a whole and hinders any attempt to build any theory of the firm in a simplistic way. At the end, containing a large number of interacting VRs is a necessary but not sufficient condition for the firm to be deemed as a complex system.

4.2.4 Hierarchical structure

Firm's VRs form a structure of hierarchical levels. This means that the firm is structured in a variety of levels that interact with the levels above and below, and may exhibit some kind of causal regularities and predictable behavior (Ladyman, Lambert et al. 2013). Hierarchical structures similar as that of the firm, abound in living and non-living systems, from natural ecosystems to stars and galaxies.

Nonetheless, the VR-based hierarchy of the firm does not convey a structure of power (Simon 1962b, Simon 1999), but rather a network-within-network arrangement of interactions among tangible (people, resources) and intangible (rules, processes) factors, all of them attracted by the same "guiding force": the creation and exchange of value. Within this hierarchy, each level is connected with another by feedback mechanisms, thus forming one dissipate structure where the cycle moves from the lower to the higher VRs and back (Karsten 1990).

Unlike in the hierarchical structures of physical and biological systems, the higher levels in the hierarchy of the firm may not necessarily assemble all levels below under special circumstances. This does not mean that the "downward causation" or "emergence" property characterizing natural complex systems is no longer valid under the CBVF. Instead what this author suggests is that the resulting dynamics of the firm's value system can be very complex and unpredictable, therefore not always the value exchanged in the higher levels is the sum total of the value created in the levels below. For example, some value created at the levels below may "dissipate" in non-productive processes when scaling up to the higher levels of the firm, or the managers at the higher levels may decide not to fully incorporate all value created in the lower levels into their Value Offerings, based on their particular vision of the market conditions, or tactics with specific segments of customers.

Hierarchical processes also help explain why and how the firm evolves from a grouping of individuals to a complex system. As Simon points out, in the process of evolution each intermediate level forms a stable configuration, which may be selected for further levels to build on top (Simon 1999). In this way, the hierarchy of the firm may well be explained by the efficiency and stability of a hierarchical building process (Ladyman, Lambert et al. 2013), where higher levels are built on top of lower levels following a gradient of value exchange.

From a practical perspective, the idiosyncratic hierarchical structure of the firm can help generate meaningful and predictive theories for higher levels without knowing much about the lower levels. This is particularly the case in those firms where a particular higher level of the hierarchy can be explained with only a broad picture of the VRs below or with no picture of them at all.

Notwithstanding, in more complex firms —i.e. transnational corporations— a good understanding of the particular levels above and below is critical to grasp a comprehensive and idiosyncratic view of complexity of the firm. This is so because the value dynamics phenomena in highly complex firms are well beyond the scope of any particular level of the hierarchy.

4.2.5 Multi-level network dependency

As described above, complex firms contain a large number of VRs structured in hierarchical levels in continuous interaction. From a CBVF perspective, VRs are represented by a number of nodes (vertices) and its connected relations (edges), the later corresponding to the flows of value exchange. Furthermore, firm's VRs are themselves nodes in higher levels of the hierarchy, forming a "web of networks" which hosts the firm's value system dynamics (Fig.2).

This conceptualization of the firm transcends conventional theories of the firm, which mostly do not offer a glimpse on networks, and somewhat resembles Thorelli's own idea of the economy as a network of organizations with a vast hierarchy of subordinate, crisscrossing networks (Thorelli 1986).

The multi-level network structure in which the firm becomes, entails that the VRs can only be understood if we account for all the internal and external VRs to which each VR is recursively linked, eventually forming the firm as a "whole" (Mella 2009). In other words, each VR takes on significance in the context of the relationships with the sub-networks it is made up of, and the supra-network higher level structure to which it belongs to.

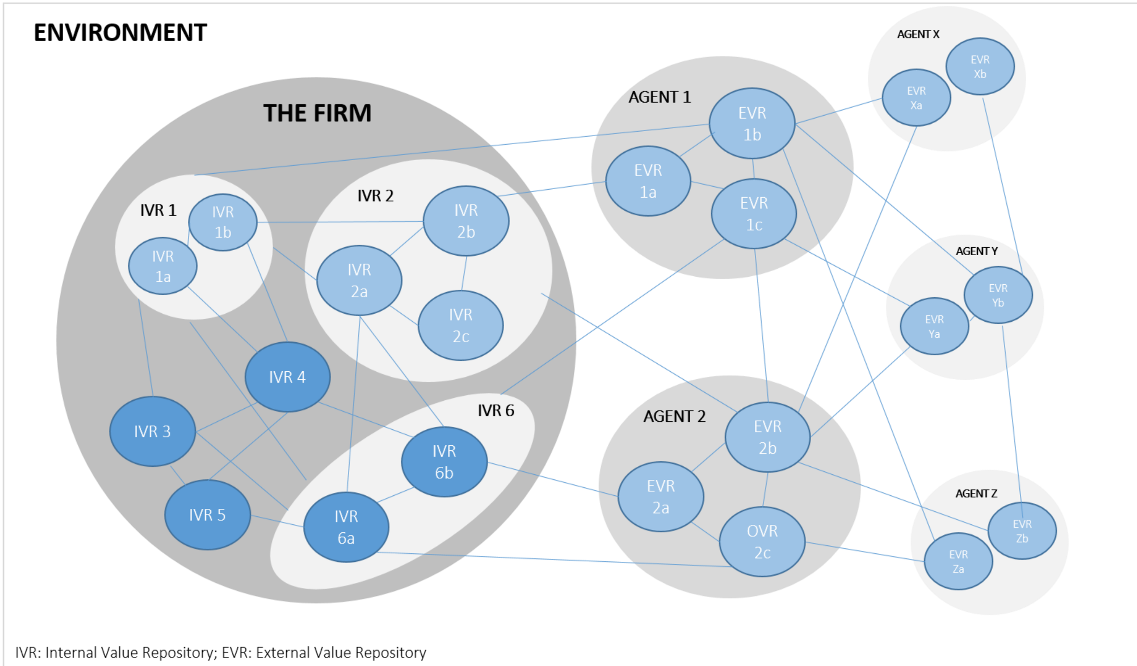


Figure 2. Illustration of the Multi-level Web of VRs
Source: own elaboration

This multi-level network dependency also involves that any change in a VR will be accompanied by changes in the entire network structure, and in all the superordinate and/or subordinate levels (Mella 2009). This in turn may invoke the principle of “co-evolution”, as the individual part (the VR) and the whole (the firm) exist by unfolding one another (Karsten 1990, North 1990, Nelson, Sampat 2001). Co-evolution ultimately implies that the development of VRs mirrors the own evolution of the firm, and vice versa. That is, VRs and the firm evolve together as a whole, with VRs prompting changes in the firm —and vice versa— as a function of time.

Multi-level network dependency is also related to Simon’s “near-decomposability” property of complex systems. According to Simon (1999): *“a much higher frequency and intensity of interaction takes place between components belonging to a single sub-system than between components belonging to different sub-systems; and this principle holds for all levels of the hierarchy”*. From Simon’s proposition we may infer that if a system is disturbed, then all subsystems at the lowest level will come to a steady state before the subsystems at the level above. Consequently, the whole system could be described in terms of the average behavior of the subsystems, and more particularly by their principal eigenvalues.

Furthermore, a nearly decomposable system should allow us to factor the system, which in turn would imply not having to deal with all of the system complexity at once. The above has important practical implications, because as Simon notes: *"having determined the behavior of subunits at one level, we can replace the details of these subunits by a small number of aggregate parameters, and use these to represent the system at the next level above".*

It is likely that Simon's assumptions did not fully considered the networked structure of complex systems, but instead one of boxes-within-boxes, which makes a significant difference when we try to apply it to our CBVF approach. Networks differ greatly from boxes, insofar as complex firms do not seem to follow the quasi-independent behavior attributed by Simon to network components. Remarkably enough, VRs are mutually interconnected with other VRs, from which they depend and obtain continuous feedback.

In this context, what it seems clear is that any attempt to understand the behavior of the firm from a network perspective requires a shift in focus away from the way the firm allocates and structures its internal resources, and towards the way it relates its activities and resources to the other parties constituting the network.

What is more, once a network view of the firm is adopted, considerable changes occur with respect to the basic assumptions made by the conventional theories of the firm, among which it is worth mentioning the own definition of the boundaries of the firm, the assessment of the firm effectiveness, or how we manage the firm (Hakansson, Snehota 2006). Ultimately, a reconsideration of the very essence of the notion of firm would be necessary, although we will leave this discussion aside.

4.2.6 Descriptive-predictive uncertainty

Investigating into the behavior of the firm as a whole, and into the relations between the various VRs, always involves the observer (or researcher) in an essential way. The human observer constitutes the final link in the chain of the observational process, and the complex properties of the firm can only be understood in terms of the interaction between the observer and the firm itself.

This premise, inferred from Heisenberg's uncertainty principle (Heisenberg 1958), would assert the impossibility to describe and, therefore, to predict with entire certainty, how a firm or a particular VR will behave at a particular moment of time and how a particular value dynamic will come to occur. All we can do is to describe the conditions under which a concrete behavior of the firm will most probably come to happen.

The descriptive-predictive uncertainty property would also explain that we cannot know exactly all the properties of the firm, since whenever one property is determined precisely, the other properties will become uncertain or will need to be set as *ceteris paribus* —note that the *ceteris paribus* assumption is a reductionism approach that does not work satisfactorily within the CBVF. In other words, as in the case of complex physics systems, the uncertainty property acts as a limit on the exact and whole knowledge that we can have on the behavior of the firm (Karsten 1990).

This apparent indescribability/unpredictability that characterizes the behavior of the firm may be due either to hidden variables, to our ignorance in understanding the factors accounting for a given structure of value repositories, or to the difficulties to recognize the interrelationships between the VRs dynamics. Consequently, the firm cannot longer be viewed as a deterministic whole system, but instead only be apprehended through complex, most probable, and sometimes paradoxical views.

Furthermore, under our proposed CBVF approach, the firm cannot be disaggregated into simple, isolated, and independent components (VRs) with no relation among them and its environment. As far as the CBVF is concerned, everything in the firm becomes an integrated and an interconnected whole.

4.2.7 Structural homeostasis

The notion of homeostasis is a much debated one in the field of complex systems in a broad variety of scientific disciplines. First originated in physiology, homeostasis was later adapted to the social and economics fields. Hou-Shun definition of homeostasis considers it as the constant act of balancing of two opposing forces to maintain stability in the most developed organism, be it biological or economic (Hou-Shun 1956). Defined in this manner, homeostasis goes well beyond closed (isolated) systems equilibrium to imply open systems dynamics through the description of various self-adjustments (Bailey 1990).

Other authors, such as Simon, define homeostasis as the property of a complex system in which *"by means of feedback mechanisms or by other methods (…), a system may be able to hold the values of some of its important properties within narrow limits, and thereby greatly simplify internal processes that are sensitive to these properties"* (Simon 1999). More recently, other definitions of homeostasis, as the one made by Paradice when describing modern exchange-based societies, denote how societies are able to maintain a relative overall constancy despite complex internal changes (Paradice 2009).

Specifically, our CBVF approach uses the term homeostasis to describe the process by which the firm is able avoid substantial changes of its internal basic structure, despite significant changes in the external environment. According to this definition, both the variability and the unpredictability of the environment impose a need for homeostasis, otherwise the firm would be doomed to vanish every time serious environmental changes take place. In other words, we might say that homeostasis enables the firm to hold up its key hierarchical structure and value system dynamics, despite changes in its environment, thus ensuring its operational continuity.

Although homeostasis is an inherent (an inherited) property of complex natural systems, this is not always the case in the firm. Homeostasis necessarily needs to be instilled into the design of the firm to yield the expected outcomes. This generally involves developing some kind of “layer” that greatly attenuates the transmission of environmental changes into the interior of the firm. The same principle might apply to the way the firm shields the various VRs from each other.

When properly realized, structural homeostasis is a method of reducing the firm’s complexity, though at the cost of some new complexities that may appear in the form of the homeostatic mechanisms themselves. Such mechanisms would include the development of self-learning and auto-adaptive processes within the firm, as well as the transformation of the boundaries of the firm into specialized interfaces.

Note that the presence of structural homeostasis in the characterization of the firm is a convenient but not sufficient condition for the firm to be considered a complex system.

4.2.8 Differentiation by specialization

As seen in the previous sections, VRs are, in essence, specialized subnetworks within the larger firm-system network for the creation and exchange of value. Although at first the VRs configuration of the firm may seem to contribute to simplification of the behavior of the firm, they add new complexities in the form of specialized mechanisms, coordination mechanisms, and exchange interfaces.

Specialization responds to the need of the firm to accomplish very specific value-driven tasks in order to operate successfully and with increased productivity in its environment. In fact, if we assimilate VRs with agents of a social system, we might notice how they become more specialized as the group (firm) size increases and there is too much task choice available (Cockburn, Kobti 2009).

According to Cockburn and Kobti, given a system with a large number of tasks and a small level of connectivity, agents are much less likely to choose tasks not being performed by others. Hence the need to combine a set of VRs highly connected, each capable of performing one —or a few— of the firm's value-related functions, and connect them so that they can cooperate with each other.

The number of VRs and the nature of the interactions among VRs are an approximate measure of complexity of the firm, given that the firms under comparison share the same notion of value and dynamic of interactions. Less complex firms would show just a few VRs and a low number of interactions among them, whereas as the number of VRs increases together with the number of interactions, the complexity of the firm becomes higher.

It should be noted that VRs specialization is mainly a matter of design within the firm. Simon (1999) even contends that *"specialization should be carried out in such a way as to keep the interactions between the specialized components at as low a level as possible".* This certainly should help keep the complexity of the firm within a manageable level. Nonetheless, Simon's recommendation weakens whenever we consider the firm's VRs subject not only to internal design, but also to external factors facilitating or blocking the value dynamics.

As a consequence of the above, even for basic value exchanges, the design of the VRs specialization becomes a rather complex task that requires choices to be made at each level of the hierarchy of the firm. These choices would include identifying which dimensions of specialization are more important, and under which VRs certain tasks should be performed together.

Other elements affecting the specialization of VRs are its boundaries. In fact, understanding VRs boundaries has important practical implications and is key for the characterization of the firm as a complex system, even though they are more blurred and difficult to trace than ever (see Chapter 3). Note that we refer to boundaries in plural, thus presupposing that under the CBVF approach the firm does not feature a single, uniform, all-purpose, high level boundary, but as many boundaries as VRs exist, each specialized in the creation and exchange of a particular type of value.

The importance of the VRs boundaries resides in that they act as specialized agents for exchange of value in and out of VRs, thus affecting the firm's configuration of its own network context. Boundaries differentiation and specialization is essential for an efficient and effective value dynamics. Moreover, specialized boundaries simplify the process of interaction between VRs, as the need to constantly adjust the interaction interface at a VR level is significantly reduced.

Specialization, and the resulting differentiation of VRs, is thus a convenient but not sufficient condition for the firm to be considered a complex system.

4.3 Methodological Framework

The growing interest in the complexity of (living and non-living) systems has proved to be useful in many non-economic disciplines, facilitating some remarkable advances in scientific knowledge and further developing our ability to get through disciplinary boundaries. However, the term “complexity” has entered not only a stage of overuse, but its meaning and utility has started to dilute even before realizing its potential. Some authors even assert that complexity is falling a victim of its own success (Crutchfield 2008).

The times where it was enough to say that this or that was “complex” with hardly any practical consequences for the firm, are now gone. Going one step further has become inevitable, all the more necessary. A step ahead must be taken with the chief intention of operationalizing the notion of complexity in the firm and provide the means to inform professional practice.

In this spirit, this section specifically provides a methodological framework to bridge the gap between the conceptual use of our CBVF and its instrumental adoption. Furthermore, the method of the CBVF shall be concerned with how the firm may be designed to be as simple and efficient as possible —in structure and processes— as to survive in a complex environment, where it interacts continuously in competition with other firms performing a wide range of adaptive functions (Simon 1999).

Accordingly, the methodological framework here presented strives to provide a reliable basis for the systematic analysis of complexity of the firm, and approximate decisions that might be converted into actions. In terms of Gibbon's et al. modes of knowledge production, the practical-oriented solutions provided by our CBVF methodological framework aim at combining the scientific rigour normally associated with Mode 1 knowledge, and the problem solving orientations of Mode 2 (Gibbons, Limoges et al. 1994).

4.3.1 Design

The design of a methodological framework is a crucial step on the path towards incorporating complexity into the investigations of the behavior of the firm. As an essential part of the CBVF general approach, our proposed methodology has been thought to enable researchers and practitioners to tackle complexity from a theoretical-practical perspective, and get a more realistic insight into the behavior of the firm than that provided by other conventional theories of the firm.

The CBVF methodology represents a framework within which particular activities, methods and tools are to be deployed, all of which have been selected among a broad range of different options available in the field of complexity studies.

Originally formulated in response to the need to overcome the serious utilization problem of academic management theory (van Aken 2004) and to tackle the problem of complexity of the firm, the rationale of the CBVF methodology resembles the principles of **design science** (van Aken 2004), pragmatic science (Anderson, Herriot et al. 2001), and action research (Järvinen 2005). Consequently, the methodology focuses on the process to understand, design and experiment actions to be later realized within the scope of the firm, and it is not too much interested in "what is" but in "what can be".

Drawing upon the methodological underpinnings referred above, the resulting product of the CBVF methodology has the character of a "prescriptive scenario" or, in Bunge's words, *"an instruction to perform a finite number of acts in a given order and with a given aim"* (Bunge 1967), rather than a formal causal model where one or more dependent variables are strictly explained in terms of one or more independent variables.

The assembly of a "prescriptive scenario" that can be set out by researchers and/or implemented effectively by practitioners of the firm is thus the raison d'être of the CBVF methodology, which purposefully requires the execution of the following four designs in an iterative way:

1. The **firm design**, or the properties underlying the structure and dynamics of the firm-system and the logic for which we need to know the properties and settings that support the actions to be deployed. This is chiefly achieved by mapping the theoretical constituents that characterize the firm as a complex system (Section 4.2).
2. The **scope design**, or the breadth of the actions to be deployed based on the knowledge of the level of complexity of the firm and of the interrelations among the firm's value repositories. This is mainly accomplished by visualizing the complexity of the firm and, specifically, by characterizing the network representing the firm.

3. The **process design**, or the mechanisms to be used for deploying concrete actions in the real world. This is accomplished by modeling and simulating alternative prescriptive scenarios in a multiple case cycle. By testing artificial scenarios researchers and practitioners might gather further insight into the indications and contra-indications for the application of a particular set of actions (van Aken 2004) and, therefore, decide between different deployment strategies.
4. The **improvement design**, or the re-engineering of the firm's structural, relational and/or dynamical components. This is accomplished by optimizing the firm's operating logic, once the effectiveness of the actions deployed has been simulated in the context of its intended use, and the desired results have been adequately assessed.

As stated above, the main goal of the CBVF methodology is to come up with a "prescriptive scenario" formed through an iterative experimentation process, which develops knowledge to be eventually implemented and refined in successive phases by researchers and practitioners of the firm.

Ultimately, it is worth noting that one of the things that distinguishes the CBVF methodology from other conventional methods is, besides its flexibility, that we need the implication of practitioners. That is, if the CBVF methodology is to bridge the gap between the theory and practice of the firm, as well as translate the study of complexity into practical insights for managerial practice, then research must result from the involvement with the firm and the intention to take action over the basis of specific prescriptive scenarios (van Aken 2004).

4.3.2 Hard vs Soft Approach

In general, complexity scientists have used either a “hard” or “soft” methodological approach (Richardson, Cilliers. 2001). The **hard approach** assumes that reality is determined and, hence, determinable using analytical science. One of the preferred means of investigation within the hard approach is computer simulation, in which complex systems are modeled in an attempt to uncover the conditions that underlie their emergence and to make sense of the new capacities that arise once emergent (Davis, Sumara 2014).

Under this approach, researchers enunciate propositions that are formulated in the language of sophisticated mathematical functions and differential equations, and make every effort to encompass all the variables deemed as relevant to explain the behavior of a complex system as a whole. The hard approach thus tackles complexity heads-on and its main goal is to model the behavior of the firm in a mathematical way by identifying, setting up the relationships, and quantifying as many variables as the researcher’s knowledge of the system allows.

As pervasive as the “hard” approach has been in the history of economic theory, some authors are very critical today of the relevance achieved by the results and the progress made by this approach in crossing the chasm between complexity, reality and the firm (Von Neumann, Morgenstern 1947, Lambertini 2013).

Meanwhile, the **soft approach** draws on the metaphors and principles of hard science to interpret a system rather than to represent a reality (Richardson, Cilliers. 2001). Instead of struggling with complexity, it seeks to avoid complexity by decomposing the complex system into more simple components, provided there is no appreciable relationship among them. The "soft" approach therefore aims to address the behavior of each component individually, using either quantitative or qualitative techniques, or both.

Furthermore, the "soft" approach, as inspired by Simon's reducibility principle, admits that we are quite unable to perform the computations that should help us describe the system as a whole without the aid of some kind of simplification by aggregation at a higher level (Simon 1999). Therefore, whilst the hard approach attempts to integrate as much of complexity as a quantitative model allows; "soft" tactics involves removing as much of complexity as feasible from the system.

The CBVF methodology presupposes a few of the key assumptions made by the soft approach, hence it supports the hypothesis that complexity can only be "defeated" if we are able to modulate the system in a coherent and meaningful way (Ethiraj, Levinthal 2004). In other words, the CBVF methodology assumes that it is always more practical and, generally, delivers better results, if we are able to decompose the firm-system into a (intermediate) level of modularity, which balances between over simplification and excessive breadth that might blind our capacity to comprehend important interactions between system components.

Consequently, the CBVF methodology is mainly a method of descriptive nature which aims at gathering as much knowledge as possible about concrete "burning" questions surrounding the behavior of the firm. Note that in approaching the complexity of the firm there is no reason to assume the existence of shortcuts, and being too impatient to answer the more general behavioral questions of the firm, or approaching the complexity of the firm as a whole, would merely delay progress (Jaynes 1991).

Before going into detail it should be noted that the method of the CBVF is not presumably for every firm. In order to apply the method, firms should exhibit specific properties —those outlined in Section 4.2— or demonstrate specific mechanisms for their development. Furthermore, this author holds reasonable doubts that, at the moment of writing this thesis, the CBVF methodology is appropriate for use in groups of firms, thus noting that further research would be needed before we can assert that the same properties characterizing complexity in a single firm would continue to apply to groups of firms.

4.3.3 Method

Now that we have outlined the main features associated with the design of the CBVF methodology, in this section we sketch a tentative method that might help researchers and practitioners to systematically disentangle complexity and contribute to a more realistic understanding of the behavior of a firm.

Our proposed CBVF methodology is composed of four stages (Fig.3), which outline a framework of different but interrelated tasks where each stage builds upon the outcome of the previous one. The stages should be performed in a sequential order to get as thorough as possible understanding of complexity in the context of the firm. Failure to follow one stage at a time, or the suggested sequence, might result in misconception of complexity and/or a misunderstanding of the behavior of the firm, leading to inaccurate practical consequences.

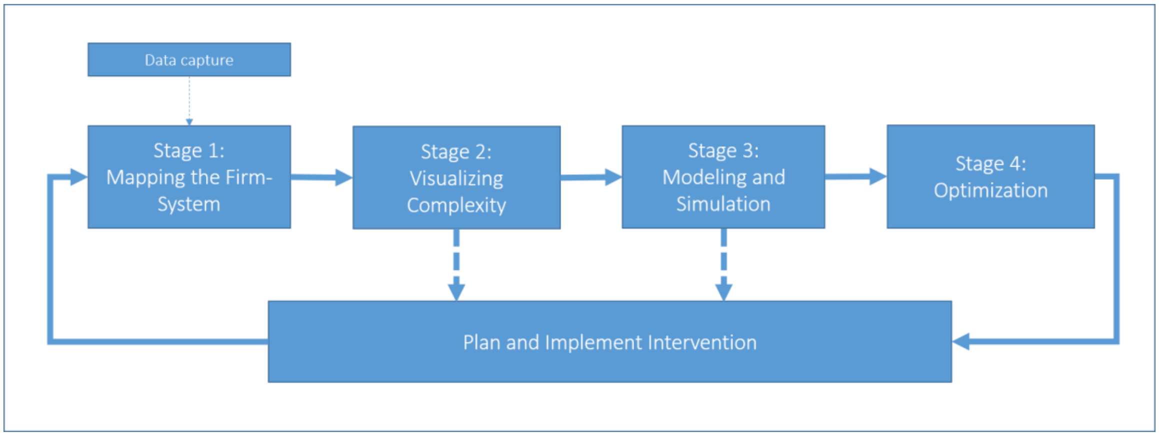


Figure 3. Stages of the CBVF Methodology
Source: own elaboration

It should also be noted that the CBVF methodology is a tentative, elementary, non-all-encompassing set of tasks to help researchers and practitioners tackle complexity of a firm. One of the key advantages being that it is a systematic approach that cater for the most important analytical factors. Needless to say that further research in the methodological field would be required to provide further detail to the stages, or even add new ones.

4.3.4 Data capture

Obtaining meaningful and reliable data to attain the objectives, accomplish the activities, and implement the methods and tools described in the Stages of the CBVF methodology, is a real challenge that every researcher and practitioner will face sooner or later. No matter how robust the firm's actual data are, or how well data support the firm's decision-making processes, most probably the analyst will need to invest time in obtaining the right data to feed the CBVF methodology, and reworking internal numbers —if not to build a new data system.

The CBVF methodology is not easily applicable “as is”. Its implementation requires the availability of extensive (and complex) value-related data, which in turn is likely to be minimal or non-existent in most conventional firms. What further complicates the problem is that, quite often, the dimensions of the actual data are incompatible, and data systems are designed to serve different requirements than those required by the CBVF approach.

The first obstacle emerges when the firm is not organized in VRs and, consequently, the firm’s data systems do not recognize value (and VRs) as a dimension for data collection. In other words, given that conventional data systems mostly accumulate financial data and costs around products and organizational units (Garrison, Noreen et al. 2006), there is no general method thought to map accounting data onto VRs. The resulting lack of correspondence is thus a source of difficulty for the analysts’ attempting to implement the CBVF approach.

Furthermore, the vast majority of real-life firms rarely collect any data on value flows and, when they do, they often use rudimentary tools for modeling interdependencies —i.e. through allocations for services and transfer prices for components or products (Hergert, Morris 1989). Ultimately, if the firm is not structured around VRs much less likely is that it has an in-depth knowledge of its own value system dynamics or assesses value interactions between VRs.

The problems with data do not disappear when we focus our attention on the budget or balance scorecard (BSC), sometimes used as proxies for value-related data. Generally, the budget does not measure value creation activities, nor is it thought to generate any value-related data. Hergert and Morris (1989) suggest two main reasons for this: the first concerns the categories of expense charged to the budget, most often mandated by external reporting authorities; the second, concerns the items of expense included in each category. Therefore, using the cost of an activity as a proxy of value is not trivial and would require substantial reworking of the numbers.

Additionally, the BSC is not particularly helpful either. No matter how sophisticated it is or the refinements involved, the BSC focuses on the strategic implications of performance measures (Barber 2008). The original dimensions enunciated by Kaplan and Norton —financial, customer, internal process, and learning and growth (Kaplan, Norton 1996)— and its later developments in the form of strategic maps (Kaplan, Norton 2004), still remain insufficient for measuring value in the firm.

So, how can we solve the problem with data as far as the CBVF is concerned?

If neither the most frequently models used for organizational design, nor the actual structures of the firm, are consciously designed around a network of VRs —as suggested by our CBVF approach— then the existing firms' data systems are unlikely to provide useful data for its implementation. Actually, there is little more that can be done to solve the way in which value is measured in the firm's conventional data systems.

Upon assuming this situation, the next question that we might ask ourselves is, how can we generate the right data needed to effectively feed the CBVF methodology? To answer this crucial question, the author suggests to develop a value-driven data system, the implementation of which might be based on three subsequent phases (Fig.4):

1. **Phase 1:** the firm would need to develop and share a common understanding of what its key value statements and value drivers are; which of its activities, resources and assets are responsible for creating value; how and who creates value in the firm, and how, why and with whom the firm exchanges value. The firm should them

examine the constituents of customer value and accumulate quantitative and qualitative data —from inside and outside the firm— around these value drivers.

2. **Phase 2 (optional):** Involves reworking the firm's available accounting data to make it usable by the CBVF methodology and its proposed tools and techniques. As there is no universal method for "transforming" cost and accounting data onto value data, the firm would need to internalize the conclusions gained in the previous phase and act upon its findings. Some authors have provided frameworks based on different measures and perspectives that illustrate how to perform this data reworking process (Partridge, Perren 1994, Lieberman, Balasubramanian 2007, Biem, Caswell 2008, Haile, Altmann 2013). However, it is just recently that these methods receive more attention and begin to provide new potential foci for value assessment and measurement.
3. **Phase 3:** This phase is aimed at the longer term, as it builds upon the insights and the lessons learned from phases 1 and 2. Here the firm gets focused on the development of an entirely new value-driven data system to effectively support the implementation of the CBVF methodology. The new information system, which could be called "value scorecard", could serve a two-fold purpose: *i)* it would prevent the firm's current cost and management accounting data from being contaminated by value analysis requirements and, *ii)* it would help to cover the CBVF's data needs without recruiting an army of analysts to continuously rework the accounting data. As shown in Fig.4, it is advisable that phases 2 and 3 run in parallel for some time, prior to making the "value scorecard" available as the firm's primary source of data. All in all, the "value scorecard" would rely on the assumption that

instead of trying to use a universal accounting system for all purposes, the implementation of the CBVF approach requires a data system specifically designed to facilitate a robust value dynamics analysis on the basis of both qualitative and quantitative measures (Town, Kyrillidou 2013).

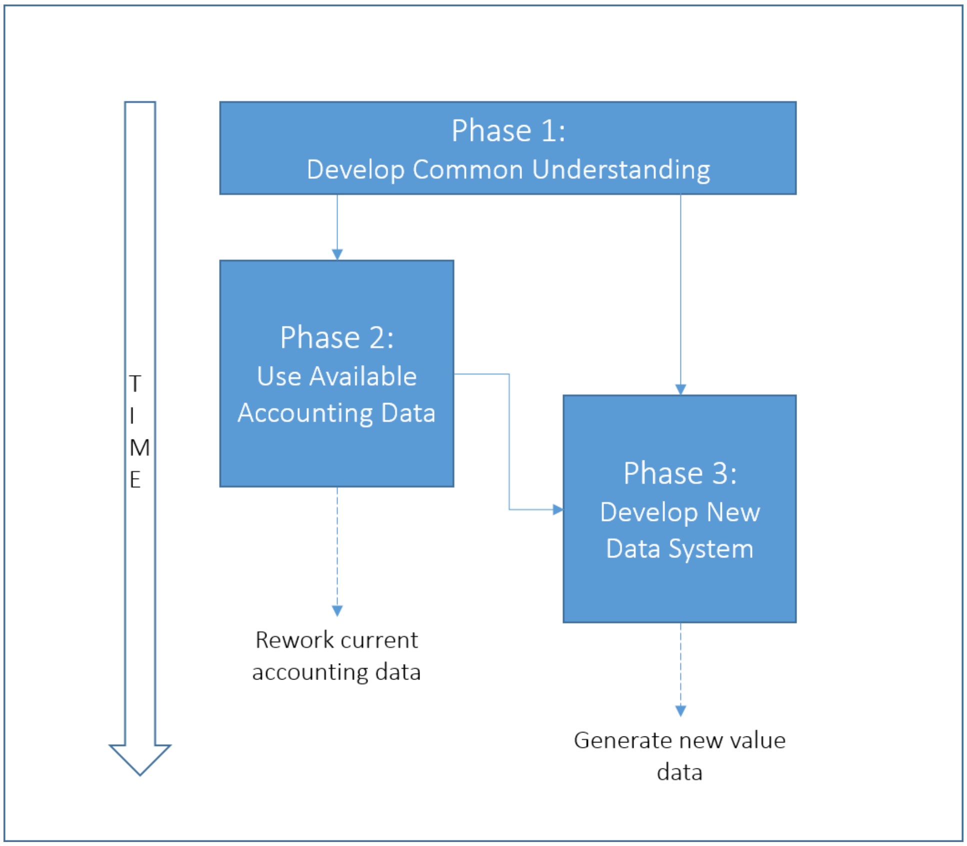


Figure 4. Phased Approach to Resolve the Problem With Data
Source: own elaboration

In the interim of deciding what approach to use and how to build up the resources needed to improve the firm's data system, a relatively rapid and plausible method to obtaining useful data on the firm's value system and start working in the implementation of the CBVF is expert knowledge captured through a Delphi method.

The Delphi method is a versatile research method typically used for futures research in areas where knowledge is incomplete. In fact, it has been satisfactorily used in a wide variety of research areas as a method to develop, identify, forecast and validate data (Skulmoski, Hartman et al. 2007).

The Delphi method involves an iterative survey of experts, where each participant completes a questionnaire and is then given feedback on the whole set of responses. With this information in hand, each participant then fills in the questionnaire again, this time providing explanations for any views (s)he holds that were significantly divergent from the viewpoints of the others participants (Slocum 2005). The explanations serve as useful intelligence for others. In addition, (s)he may change his/her opinion, based upon his/her evaluation of new information provided by other participants. This process is repeated as many times as is thought to be useful. The idea is that the entire Experts' Panel can weigh dissenting views that are based on privileged or rare information.

In general, the Delphi method was invented to overcome some of the following difficulties when carrying out research tasks such as ours (Linstone, Turoff 2002, Slocum 2005, Balasubramanian, Agarwal 2013):

- When there is incomplete knowledge about phenomena and both a quantitative and qualitative research is desired.
- When a problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
- When experts needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.

- When more experts are needed than can effectively interact in a face-to-face exchange.
- When time and cost make frequent experts group meetings infeasible.
- When disagreements among experts are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.
- When heterogeneity of the experts must be preserved to assure validity of the results, i.e. avoidance of domination by quantity or by strength of personality.

Researchers and practitioners should note that no two Delphi studies are the same. As a matter of fact there are many varieties of Delphi, ranging from qualitative to quantitative, as well as mixed methods. Nonetheless, common to all varieties are some design considerations that include deciding on the sample composition, sample size, methodological orientation (qualitative and/or quantitative), the number of rounds, and the mode of interaction. Considering all these choices should add rigor to the method, which in turn shall contribute to a successful Delphi process and, by extension, to a deeper understanding of the firm's value system.

4.3.5 Stage 1: Mapping the Firm-System

As we have seen before in this thesis, most firms in the real world act and behave as open systems embedded in complex environmental settings with which value is exchanged . By adopting this view, firms acknowledge they share a set of characteristics that are definitory of complex adaptive systems (see Section 4.2).

A thorough understanding of the characteristics featuring the firm as a complex system and the extent to which they become apparent in the firm, is thus of paramount importance on starting the path towards incorporating complexity into the practical investigation of the firm.

Mapping the firm-system is the first stage of the CBVF methodological framework and, as such, it strives to provide a characterization of the firm's complexity defining characteristics and how they operate in a particular firm. Ultimately, a systematic mapping of how this theoretical constituents of the CBVF operate and of the firm's value system dynamics should pave the ground for the next stages in the CBVF methodology and for a successful application of the CBVF approach.

A. Objective and scope

Mapping the firm-system fundamentally involves outlining the firm's complexity constituents in a real context. The objective being to obtain a thorough understanding of the role played and the interactions shown by each feature examined in Section 4.2, both individually and in relation to one another.

In particular, given that the firm may be seen as an interface between an "inner" and an "outer" environment (Simon 1996), researchers and practitioners should focus on the relation among three key elements:

- the purpose or goal of the firm.
- the components (value repositories), and
- the environment in which the firm operates.

The purpose or goal shapes the firm's inner environment, which itself is organized as a network of internal value repositories (VRs); namely, a network of nodes that group together activities which create unique and exchangeable value (Section 3.5.1). According to our CBVF approach, complex firms contain a large number of components (or VRs) in continuous interaction with one another, within and outside the firm (Section 4.2.3).

Understanding the firm's VRs architecture, from both a structural and dynamic standpoint, and the conditions set by the outer environment for the firm's goal attainment, is thus a first key step for an effective mapping of the firm-system.

Another important aspect to consider is understand how the outer and inner environment interact and, more particularly, how the firm uses an adaptive behavior —given its limited resources and capabilities— to adjust to its ever-changing outer environment.

Those researchers and practitioners who attempt to accomplish the Stage 1 tasks should note that dividing inner from outer environment when mapping the firm-system may have substantial advantages (Simon 1996):

1. we can assume, up to a certain point, that complexity of the firm is largely a reflection of the complexity of the environment in which it operates.
2. the firm is designed to create and exchange value as a reflection of the environment in which it operates.
3. we can discriminate between internal and external complexity, and assess whether they mismatch or are aligned, and
4. we can more easily come to understand and predict the firm's adaptive behavior from our knowledge of the firm's goals, and its inner and outer environment. In

other words, if we know what the goal of the firm is, we can seek to envision how its behavior will change if we modify a few characteristics of the outer environment, given that we have a reasonable knowledge of the firm's inner environment.

All the above implies that when mapping the firm-system, it is wise to thoroughly characterize the structural components of the firm (VRs) leading to value creation and value exchange first, and thereafter to continue with a comprehensive view of the static and dynamic interactions taking place between components (VRs). This way researchers and practitioners might advance more readily toward realism, filling the gap between the mechanistic view of the firm provided by conventional theories of the firm, and complexity of real-life firms.

B. Activities

The proposed activities covered in Stage 1 (Fig.5) are called to help researchers and practitioners generate a thorough understanding of the firm's complexity constituents, ascertain how they operate and connect, and set the ground for a sound knowledge of complexity:

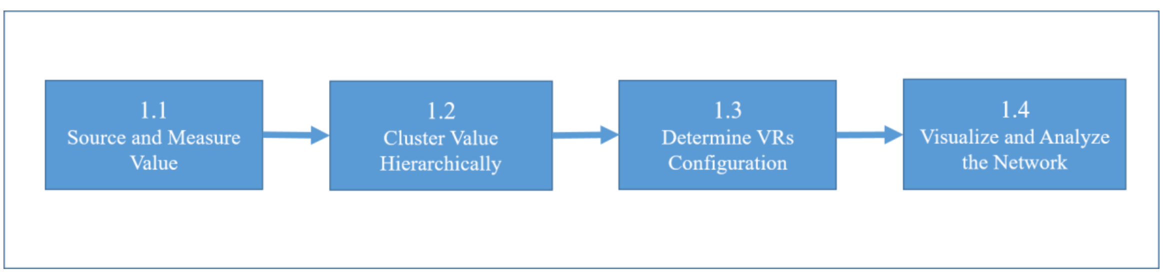


Figure 5. The CBVF Methodology: Stage 1 Activities
Source: own elaboration

B.1 Source and Measure Value

According to the previously defined theoretical constituents of the CBVF (Section 4.2), "value" is the basic building block of the firm and the fundamental element from which the firm's components originate and become cohesive. Furthermore, "value" explains the most inner structure of economic events and substantiates the very nature of firms' life.

However, as crucial as "value" is for our understanding of the firm, it still remains an elusive notion that refers to different phenomena, ranging from the equivalence with "price" to more sophisticated definitions (Haksever, Chaganti et al. 2004). Thus, clarifying the term "value" from the beginning is key when mapping the firm-system. This should be better accomplished not disguised as a theoretical disquisition, but by examining the firm value system dynamics, namely specifying the multidimensional processes through which each particular firm creates and exchanges value (Fig.6).

Usually the first step in any firm's value creation process (VCP) is creating Potential Use Value (PUV), also known as intrinsic value. PUV is created through new combinations of resources motivated by new opportunities detected by the people in the firm to realize value for the customer (Ghoshal, Moran 1997). PUV thus attaches the greatest importance to the customer, as the key driver of value creation, and requires a logic of processes and activities through which the firm directs the transformation of value inputs.

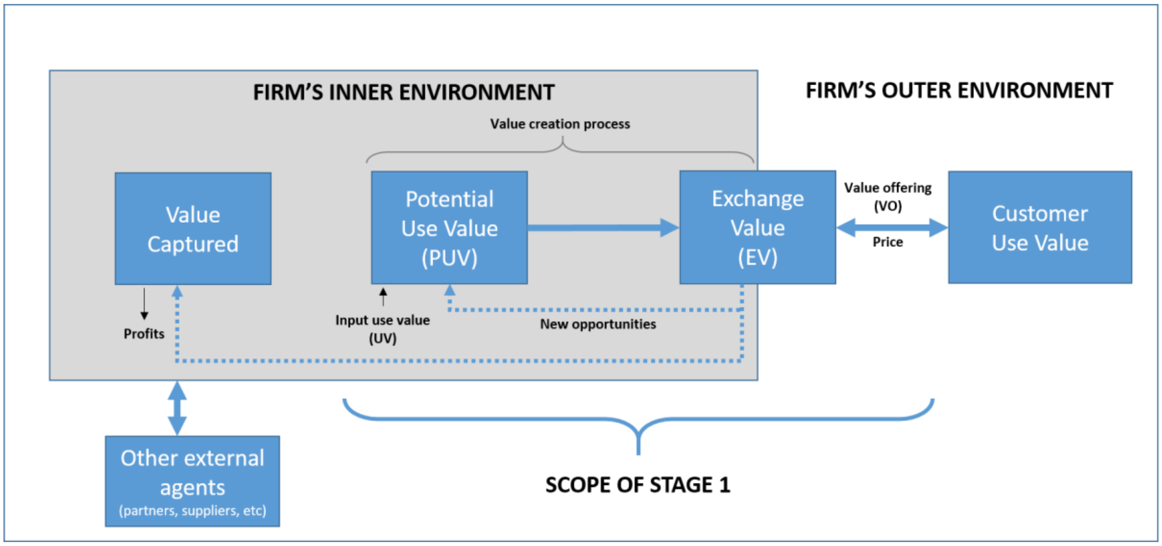


Figure 6. The Multidimensional Value System Dynamics
Source: own elaboration

PUV is value that remains "dormant" or unrealized in the firm until it is exchanged and becomes realized. It is at this moment where Exchange Value (EV) comes into the picture. EV is the monetary amount realized at a certain point in time when the exchange of a new good, product, service, or task takes place —the amount paid by the user to the seller (Lepak, Smith et al. 2007)— or the primary mechanism through which previously created PUV becomes realized.

EV usually substantiates through a Value Offering (VO), namely a bundle of benefits made of goods, services, information, access to systems or infrastructure, and risk-sharing formulae (Ramírez 1999), or a hybrid combination of them, procured either by the firm alone, or in mutual collaboration with the customer. Note that the later would make value sourcing even more complex, because it would need to consider a multiplicity of values in relations with multiple actors that cannot be reduced to a single metric (Dean, Ottensmeyer et al. 1997).

For EV to materialize there must be a coincidence between an opportunity perceived by the firm and a potential demand from a customer. In other words, EV depends on a customer's subjective evaluation of the PUV created by the firm. This is what we call Use Value (UV), which refers to the specific qualities of the VO, as perceived by the customer in relation to his/her needs (Bowman, Ambrosini 2000, Haksever, Chaganti et al. 2004). As such, UV is perceived by the customer and cannot be judged in isolation from the wider needs and economic circumstances of the customer.

In combination, these four dimensions of value —PUV, EV, VO, UV— highlight the subjective and context-specific nature of the value system dynamics. It is worth pointing out to the fact that different customers may arrive at different conclusions about his/her UV, depending on their individual needs or the context in which they are embedded (Lepak, Smith et al. 2007). Consequently, the kind of potential value that is created (PUV), how it is perceived as valuable (UV), how it is realized (EV), and the means through which value is exchanged (VO), are likely to vary considerably depending on the firm and its context.

Altogether mapping the firm-system calls not only for understanding and measuring what the customer is willing to pay for (UV), but also for measuring the multiple dimensions of value which co-exist simultaneously. Note that this process greatly differs from quantifying the financial value of the firm (Koller, Goedhart et al. 2010), or assessing the shareholders' wealth, or the value linked to the stakeholders (Hillman, Keim 2001, Harrison, Wicks 2013).

Ultimately, researchers and practitioners should note that what it really matters most when sourcing and measuring value under the CBVF perspective is to recognize the ability of the firm to create and exchange value on the benefits that are important to the customer (Kothandaraman, Wilson 2001). This shall leave in the background relevant managerial decisions as to what competencies and capabilities are used by the firm, or how the firm captures value.

B.2 Cluster Value Hierarchically

The CBVF approach considers "hierarchy" a central defining constituent of complexity of the firm, capable of offering insight into many complex phenomena (Clauset, Moore et al. 2008). Furthermore, the CBVF assumes that value creation is configured in a hierarchical scale, where top level groups (VRs) divide into secondary groups that further subdivide into lower level groups, and so forth over multiple levels.

Clustering value, by using hierarchical analysis techniques, can be a productive and efficient way that we can use to determine the firm's elemental VRs. This type of analysis is based on the assumption that non-linear interactions take place in the inner and outer environment of the firm, which in turn leads to the formation of different levels that are hierarchically ordered one below another.

Hierarchical levels thus reflect some structural properties that can be very helpful when mapping the firm-system. The following are some good examples (Helbing 2012):

- While changes on the lowest hierarchical levels are fastest, changes on the highest levels are slow.
- On the lowest level, we generally find the strongest interactions among elements; this would explain why the fast changes occur on the lowest hierarchical level.
- Elements do not behave always individually, but form units representing the elements of the next level. The interactions within this units are stronger than the interactions between different units.
- The relatively weak residual interactions between the formed units induce a relatively slow dynamics.

- The highest hierarchy levels usually take a strong influence on the system on a relatively short time scale. This also makes it difficult for the lower, less central levels of the system, to adjust themselves to a changing environment.

As outlined above, a general interdependence between the strength of the interactions, the changing rate, and the formation of hierarchical levels can be found in most complex systems. Moreover, the existence of different hierarchical levels implies a separation of scales (Helbing 2012), which could reasonable be applied to the hierarchical value clustering of the firm.

From a practical perspective, researchers and practitioners should be aware that the hierarchical structure of the firm's value system may help generate meaningful and predictive hypothesis for higher levels without knowing much about the lower levels. This is particularly so in the case of less complex firms, where higher levels VRs can provide reliable explanations of the behavior of the firm, while the analyst only has a broad picture of the VRs below, or no picture at all.

B.3 Determine VRs Configuration

The previous activities covered in Stage 1 shall have provided researchers and practitioners with a general perspective of the fundamental value system dynamics of the firm, and how value is grouped in different levels and dimensions. Now we move one step further and try to decompose the firm's value clusters into authentic VRs.

Specifically, VRs share the properties of symbol systems (Simon 1996), thus having the means to:

a) collect value-related information from the inner and outer environment.
b) encode it into the firm's internal activities, resources and/or processes.
c) arrange the internal structure through a value logic, and
d) create unique and differential value offerings that are exchanged within the firm's inner and outer VRs.

When determining the firm's VRs configuration, the analyst should preferably gather all previous information on the firm's multidimensional value system, as to generate a comprehensive description of where value lies in the firm, and of the network linking the different VRs with the inner and outer environment.

It is important that the analyst is sure about the questions he/she is asking and that he/she focuses on the key variables (Rooke, Molloy et al. 2008). Regardless of the knowledge the analyst may have about how the firm works or is organized, he/she should be aware that what complexity tells us is that patterns can emerge where we least expect them, and that preconceived ideas and personal believes are bad advisors when determining the appropriate firm's VRs configuration. Moreover, different people may have different mental models and, consequently, will view the firm —and its corresponding VRs configuration— in different ways.

Furthermore, the analyst should not forget that he/she stands before a complex system where non-linearity dominates and that "strange" or counter-intuitive behaviors may appear. The later often result from very complicated feedback loops in the system, which can produce errors in our analysis and undesired side effects (Helbing 2012). For example, in large complex firms sometimes large organizational units might not have substantial effect on value creation, while small units might significantly impact value creation. In other occasions, the analyst might be tempted to assimilate VRs to decision-makers or organizational units, which most often would result in fuzzy outcomes.

To avoid these major pitfalls it is important that analysts consider the way in which mapping the firm-system is to be used. Though history and past experience, for instance, can be of great help in identifying VRs, not less important is that the analyst devotes enough time to understand the self-organizing principles of the firm when determining the VRs configuration.

Last but not least, a thorough determination of the VRs configuration should be realized through the assessment of two other important complexity's defining characteristics: structural homeostasis and specialization. The former relates to the mechanisms held by the firm to maintain the state of some important inner properties within narrow limits before changes in the outer environment. The later provides an understanding on the number and different type of unique value related tasks that are accomplished by the firm in its struggle to remain competitive and meet the customer needs. Both properties are key factors for thoroughly mapping the firm-system, the knowledge of which should preferably be captured by the analyst.

B.4 Visualize and Analyze the Network

"Network analysis, as a methodological approach, has been one of the great success stories in the last two decades" (Levinthal 2007). Notwithstanding the foregoing, different authors provide contrasting definitions of the term "network" upon attending to the different purpose of their investigations. For example, a strategic view of networks considers a network as a *"long term purposeful arrangements among distinct but related for-profit organizations that allow those firms in them to gain or sustain competitive advantage"* (Jarvenpaa, Ives 1994); from a business perspective a network could be defined *"a set of two or more connected business*

relationships, in which each exchange relation is between business firms that are conceptualized as collective actors" (Cook, Emerson 1987); still some authors emphasize the differential informational advantages of participants and the control benefits actors can generate by being advantageously positioned within a network (Gulati 1998).

From our CBVF standpoint, what is key is that a "network" presupposes a structure of participants, processes of interaction and exchange, and a unifying purpose among participants. Moreover, the functions of a network are always wide and diverse and they can be characterized not only with respect to its activities (efficiency), actors (self-interest) and resources (leveraging heterogeneity), but also in relation to learning, innovation and resource development (Anderson, Hakansson et al. 1994).

Upon completion of the previous activities in Stage 1, researchers and practitioners should be in a good position to graphically represent the firm's *network context* and *network profile* (Anderson, Hakansson et al. 1994).

The ***network context*** is the part of the network that is relevant for the operation of the firm, and encompasses a *direct network* —where value is directly exchanged between a dyad of VRs— and a *secondary network* —which comprises those VRs that are indirectly connected to the exchange dyad and thus affect the direct network. The ***network profile*** refers to the position of the firm's VRs in the network, based on the intensity and strength of the links, the type of links, the role/s played in the network, and the power relative to other VRs.

A good network representation of the firm should permit researchers and practitioners to answer questions such as: How are VRs organized in the direct and secondary networks? How can I tell what the firm's network looks like when I can't actually look at it? Which VRs in the network prove most crucial to the network's connectivity? What approximate effects might occur if those VRs were removed or failed to create and exchange value? What percentage of VRs or links among VRs need to be removed to substantially affect the network connectivity in some given way?

In addition, greater potential may be derived when we provide a firm's network complexity macro-perspective (Brandes, Raab et al. 2001), which in turn might enable us to:

1. visualize the overall hierarchical structure of the network more intuitively.
2. capture the relative status of the different firm's VRs.
3. analyze what and who causes the firm to be hierarchical.
4. compare between different possible network alternatives.
5. understand the value creation and exchange processes within the inner and outer environment.

Notwithstanding the work involved, analysts should consider the firm's network construction as a serious analytical endeavor that may lead to highly productive, descriptive and normative outcomes. No less important would be the valuable insights for the knowledge of the firm that might be provided with beneficial implications for managerial practice (Gulati 1998).

C. Tools and techniques

Researchers and practitioners seeking to comprehensively map the firm-system need methods and tools that help them accomplish the activities involved accordingly. The linear, mechanistic, causal approaches of the past cannot meet this challenge. Therefore, new methods and tools based on the principles of non-linearity and networks are essentially required to manage the interdependencies of the firm's complexity constituents on which the CBVF approach fundamentally relies.

The proposed methods and tools needed to thoroughly map the firm-system are summarized as follows:

- Classification tools.
- Hierarchical clustering.
- Network visualization techniques.
- Value network construction and analysis tools.

Analysts may choose to use a single tool at a time, or a combination of them, when attempting to accomplish the activities covered in Stage 1. Nonetheless, the use of a specific tool or a combination of them may depend on the particularities of the firm, the past experience with the CBVF approach, and the level of proficiency of the analyst using non-conventional tools.

C.1 Classification techniques

These are tools aimed at identifying, analyzing, and classifying the static and dynamic capabilities of the firm leading to the creation of value in all its four dimensions —potential value, use value, exchange value, and value offerings (see Section 4.3.5, B.1). Through the use of diverse classification criteria, researchers and practitioners should be able to determine how each source of value in the firm:

- integrates into a particular VR.
- requires a unique combination of resources.
- creates new opportunities for further adding new tangible and intangible value.

- is exchanged with other VRs within the firm's network context, and
- converts one type of value to another.

Classifying the sources of value should enable us to assess each value output individually, along with the activities, resources and processes involved. In doing so, the analyst might address three different types of questions aimed at assessing, *i)* the dynamics of the value creation system of the firm, *ii)* the exchange of value within the network context of the firm, and *iii)* the impact that each VR has on the value system of the firm as a whole. The following are some examples of the questions that the analysts should attempt to answer (Peppard, Rylander 2006):

- Questions about the sources of value creation: How does the firm organize, create, and bundle value (either by adding new value, combining value internally or externally, or converting one type of value to another)? Who participates in the value creation process? With what resources?
- Questions about the exchange of value: What is the overall pattern of (internal/ external) value exchange within the firm's network context? What VRs are more critical in the exchange of value? What VRs exchange value above or below expectations?
- Questions about the impact of value: What approximate impact does each source of value have on VRs? How does a VR impact on another VR, and on the firm as a whole?

While conducting such inquiry on the value system of the firm, the analyst might be required to use typical business process re-engineering (BPR) procedures, as well as techniques such as SWOT analysis, flowcharting, mind mapping, brainstorming, cost-to-benefit analysis, Delphi method, data survey techniques, data mining, big data analytics, etc. not to say his/her past experience on the operation of the firm's value system.

Moreover, it is always advisable when performing a value classification field study to log all the data captured into distributed data bases, in order to be of help later when completing the mapping activities. Table 1 below shows an example of a typical outcome obtained from using value classification techniques.

Value output	From		Dimension of value	To	
	Value Repository	Hierarchical level		Value Repository	Hierarchical level
Distribution agreement	Alliances	3	Exchange value	Capacity management	4
Electronic ticketing app	Customer experience	4	Potential value	Innovation	5
…	…	…	…	…	…

Table 1. Value Classification Technique
Source: own elaboration

As for the table above, the first row identifies a distribution agreement as a value output flowing, as exchange value, from the "Alliances" value repository to the "Capacity management" value repository, the later belonging to a hierarchical level 4.

By classifying this multidimensional information of the firm's value system, the firm builds an organized knowledge bank that is key to support later activities within the CBVF methodology. Moreover, analysts might also want to consider drawing a journey map featuring the flow/path followed by each value output individually; for example, depicting the process followed from the moment a value input is received by a VR and processed, to the moment in which a value offering containing that original input is exchanged with an end customer.

Analysts considering using classification techniques should be aware that access to the firm's data systems is required. Upon access to data, the analyst most probably will find a lack of correspondence between the firm's actual data —usually centered on accounting and measuring financial performance— and the data required for true value classification. At this point, the analyst may have no other choice than either to adapt the available data to the dimensions required by the mapping activities, or to develop new sources of data as he/she gains more experience with the CBVF (read more in Section 4.3.4).

C.2 Hierarchical clustering

When mapping the firm-system, researchers and practitioners may want to use different techniques for inferring the hierarchical structure of the firm's value system and, subsequently, translate the resulting knowledge into the topological properties of the firm's value network before getting insight into more complex network phenomena (Clauset, Moore et al. 2008).

In hierarchical clustering the analyst seeks patterns by grouping multivariate data into clusters. The goal is to find an optimal grouping for which the value-related data within each cluster are similar, the rest of the clusters being dissimilar to each other. From a practical perspective, the analyst should try to find the groupings of value that make sense in terms of the firm's actual behavior and past experience. The groupings so detected are the basis of the firm's VRs, on which the next stages of the CBVF methodology heavily rely.

The number of ways of partitioning a set of n items into g clusters is given by (Rencher, Christensen 2012):

$$N(n, g) = \frac{1}{g!} \sum_{k=1}^{g} \binom{g}{k} (-1)^{g-k}\, k^{n}$$

Hence, hierarchical methods permit us to search for a reasonable solution without having to look at all possible arrangements.

Unlike other classification techniques, in hierarchical clustering neither the number of groups, nor the groups themselves are known in advance. The analyst can typically use an agglomerative method, which starts with n clusters, one for each observation, and ends with a single cluster containing all n observations. At each step, an observation or a cluster of observations is absorbed into another cluster (Rencher, Christensen 2012). The reverse process, known as divisive method, might also be plausible in pursuit of our goal.

Whatever the hierarchical clustering method that is finally used, a decision needs to be made as to the optimal number of value clusters found. For this purpose the analyst can generate a dendrogram and select a number of clusters g from the dendrogram, cutting across the branches at a given level of the distance measure used by one of the axes (Clauset, Moore et al. 2008, Rencher, Christensen 2012). When determining the value of g that provides the best fit for the data, one approach might be to look for large changes in distances at which clusters are formed. In this case the analyst should choose the number of clusters with the largest change in distance.

To check the validity of the resulting cluster configuration, the analyst should test the hypothesis either supposing there are no clusters or groups in the population from which the sample was taken, or through a cross-validation approach where data are randomly divided into two subsets A and B, and a cluster analysis is carried out separately on each of A and B. The results should be similar if the clusters are valid.

The general tendency of the firms to form tightly connected clusters could be reflected by using a ***Clustering Coefficient*** $(\boldsymbol{CC})$. This concept is well-known in sociology, where notions such as "cliques" and "transitive triads" have been widely employed. In the case of the firm, a CC might be calculated using the percentage of pairs i's or neighbors that are themselves neighbors (Fagiolo 2007).

Another less visible though no less valuable use of hierarchical clustering may be the prediction of missing interactions. For example, given an observed but incomplete value system, the analyst might want to generate a set of hierarchical random graphs that fits the firm's value system. The analyst might then look for pairs of nodes that have a high average probability of connection within these hierarchical random graphs, but which are unconnected in the observed network. These pairs would most likely be the candidates for missing connections (Clauset, Moore et al. 2008, Jackson 2008).

C.3 Network graph visualization

Visualizing the firm as a network is key in helping researchers and practitioners understand value-related data, facilitate the graphical analysis of data, and communicate that understanding to others (Freeman 2000, Brandes, Raab et al. 2001, Jackson 2008).

Given its relevance for mapping the firm-system, we should first start choosing one among the set of different graph drawing algorithms available —i.e. one based on points and lines, matrices, etc. This is a crucial task, since different visual approaches can lead to different findings that are unlikely to be revealed using non-visual means of analysis. Moreover, different images or graphs can not only emphasize important features of the structure and dynamics of a network and react differently upon possible alterations (Strogatz 2001, Barabási, Bonabeau 2003, Moody, McFarland et al. 2005) —i.e. structural complexity, network evolution, node/connection diversity— but they can significantly affect the scope of the CBVF analysis and its potential outcome.

In view of the above and given the large number of visualization options offered by graph theory today, the analyst should carefully address three main aspects to convey the meaning of the graph quickly and clearly: the content to be visualized, the type of graphical design, and the algorithm realizing it (Brandes, Raab et al. 2001).

This author suggests a network image based on points (nodes) and lines (arcs, edges), where points represent VRs and the lines represent the exchange of value between VRs. Also important is that the analyst takes into consideration a variety of aesthetic criteria; for example, planarity and the display of symmetries are highly desirable, as well as to keep the number of bends and crossings low (Battista, Eades et al. 1999).

The network image should allow the firm to focus on the nonlinear dynamics of the nodes (VRs), without being burdened by additional complexity in the network structure itself. This can be accomplished if the analyst draws a network graph that is static. Given that most graphs do a poor job representing change in networks (Moody, McFarland et al. 2005), this simplification would allow the firm to avoid the issues arising out of structural complexity and to concentrate instead on the network (more interesting) dynamics. The analyst will need to consider the use of a graph drawing algorithm to produce a graph that is easy to understand and reflects all its possible linkages in an appropriate manner.

Notwithstanding the above, as researchers and practitioners gain experience mapping the firm-system, a more realistic approach that combines dynamical and structural complexity of the network should be sought. In this regard, recent media advances should allow analysts to use space to represent distance and movement to represent change over discrete units of time (Moody, McFarland et al. 2005).

With these new tools, the analyst might reflect the rate of change in value exchange, the sequence, or the richness of a value exchange structure. However, as interesting as they might seem, this practical methods for dynamic network visualization —e.g. network flip books, dynamic network movies— remain at a very theoretical stage of development and should only be used by the analyst with great caution.

C.4 Value network construction

Over the years different tools and techniques have been developed by authors trying to extend the analysis of the firm away from the perspective of an isolated unit to looking at how the firm creates value within the context of a network. For some of them, constructing and analyzing the value network has become one of the key guiding forces for determining how a firm should be improved or developed (Peppard, Rylander 2006).

The following list contains a summary of the main tools and techniques used by researchers and practitioners to construct a firm's value network in recent years:

- **Value chain (Porter 1985).** Although Porter's value chain approach has been superseded by more holistic value-based networks, some authors still consider that the value chain can be a valuable analysis tool for the identification of firm-level competitive strengths and weaknesses, especially in industrial organizations (Stabell, Fjeldstad 1998). From a CBVF perspective, the interest of the value chain lays in acknowledging its influence over the more recent value-based analysis frameworks, and as an interim value analysis tool that might be used by firms en-route towards much realistic value networks. Unlike value chain focus on single firm's core processes and sequential activities, value networks address more complex value dynamics and make it possible to see beyond the conventional resource-based boundaries of the firm.
- **Value constellation (Normann, Ramirez 1993)**. The idea of value constellation builds on the idea that the firm is the center of a constellation of services, goods and design; one constellation in which customers are also suppliers, and suppliers are also customers. The value constellation logic presents the firm with three implications according to its authors: (1) value occurs not in sequential chains but in complex constellations, therefore the goal of the firm is not so much to make or do something of value for its customers as is to mobilize customers to create value for themselves; (2) as potential offerings become more complex and varied, so do the relationships necessary to produce them, with the most attractive offerings involving customers and suppliers, allies and business partners in new combinations, instead of the single firm providing everything alone; and (3) if the key to creating value is co-producing value offerings that mobilize customers, then the only true

source of competitive advantage is to make the value-creating system work. Normann and Ramirez value constellation approach implies that the firm must continuously reassess and redesign its competencies and relationships in order to keep its value fresh and responsive.

- **Value Net (Parolini 1996).** Parolini's main focus is on value-creating systems, which she defines as a set of activities creating value for the customers. According to this author, customers not only are the receivers of value, but also play an active role in value creating processes, together with other actors involved. Parolini's Value Net approach aims at identifying all the activities creating value for the customer, and then to analyze them structurally. Only after the first phases are completed, the author suggests to go on and consider who does what. The resulting representation takes the form of nodes and edges, where the nodes represent sets of activities and related resources which are best considered together, and the edges describe relations between nodes that can represent flows of goods, information, or financial resources, depending on which aspect the analyst seeks to develop. In general, the value net approach provides a practical framework which enables the analyst to decompose the firm into a sub-set of activities within a value-creating system, represent the linkages that interconnects them, and guide the implementation of the methodology step-by-step.
- **Other value network frameworks.** Value networks have been studied for a few decades now and many researchers have developed their own models and methods to describe and analyze value creation in networks (Herrala, Pakkala et al. 2011). Although still at a conceptual stage and with empirical work yet to be done,

researchers and practitioners focusing on the CBVF might get insight from the following approaches and use them as a complement to the aforementioned approaches:

- "Value-adding partnerships" (VAP) (Johnston, Lawrence 1988) shows how a set of independent companies work together to manage the flow of goods and services along the entire value-added chain.
- Kothandaraman and Wilson's value-creating networks are mainly focused on firms in a network aimed at delivering value to the final consumer. This model moves beyond VAPs, where firms collaborate to improve their position in the markets, and builds upon the value-creating network whose objective is to create superior customer value. Kothandaraman and Wilson develop a rationale for value-creating networks based on superior customer value, core capabilities and relationships (Kothandaraman, Wilson 2001).
- Allee's approach to the enterprise as a living system (Allee 2002). Given that Porter's value chain model is inadequate to understand the complexities of value, Allee proposes that organizations operate according to the principles of living systems and goes to define three criteria to model businesses and enterprises: pattern of organization, structure, and process or exchanges. From Allee's standpoint, the "molecular level" of economic activity is the exchange, not only material exchanges but also the intangible. At the end, Alle defines organizations as "patterns at exchanges".
- Holweg et al.'s value grid approach describes firms moving beyond conventional linear thinking and suggests a value grid framework with three

dimensions —vertical, horizontal and diagonal— aimed at discovering a variety of new pathways to improve performance (Holweg, Pil 2006). By mapping the value grid and using a complex and dynamic perspective, the authors propose to rethink the organization's value proposition and its associated structures.

- Herrala et al. propose four key building blocks that impact the value chain of a product or service: customer value, core competences, relationships and interactions (Herrala, Pakkala et al. 2011). These building blocks might be re-used by researchers and practitioners to create a method of analysis on value creation in networks.
- Helander's four phases might also be used by researchers and practitioners to assess and understand value creation in a network by determining: (1) who is the customer? what customer considers valuable?; (2) what activities are needed to create the value for the customer?; (3) what resources are needed to carry out the activities?; and (4) who (actors) are able to utilize these resources? (Helander 2004).

Researchers and practitioners should note that the best way to advance in the proper construction of the firm's value network is to build their own hybrid method, which draws on the specificities of the firm. In this regard, the tools described above are a good starting point to reflect on the value creation processes of the firm and might provide some interesting methodological clues as to later on design a comprehensive and readable value network of the firm.

4.3.6 Stage 2: Visualizing Complexity

Having completed the activities referred in Stage 1, researchers and practitioners should now have a well-grounded perspective on the firm as a complex system, as well as a unique understanding of what complexity looks like in a particular firm.

During the previous stage of the CBVF methodology, a detailed knowledge on the constituents of complexity shall have been gathered and, more specifically, on the firm's structural components and interactions. Furthermore, we should now be in a position to visualize the complexity of the network representing the firm, as well as some of the optimization mechanisms developed within the network, such as the specialization and homeostatic mechanisms.

But before we attempt to visualize firm's complexity at once, we may wonder what is that we are interested in visualizing complexity of the firm? And more importantly, what may we get in return?

The advantages of visualizing complexity of the firm are many and varied. Some of the most important are introduced right below:

- Enable researchers and practitioners to conclude whether the firm is really a complex system and, therefore, if the activities, tools and techniques proposed by the CBVF methodology are applicable and can be used.
- Some visualization techniques enable us to assess how complex the firm really is. Eventually, we may want to know how complex the firm is in relation to another firm, thus comparing firm *A* with firm *B* (De Toni, Nardini et al. 2001), or alternatively, compare the complexity of the firm *A* at two different points in time.

- Make it possible to compare different VRs configuration alternatives, and choose the one most suited to improve the performance of the firm (Deshmukh, Talavage et al. 1998).
- Assist planners in managing desired levels of complexity, depending on the changing operating or environmental conditions (Deshmukh, Talavage et al. 1998).
- Help determine the degree of fitness (or degree of adaptation) of the firm with respect to its outer environment, and therefore to plan for managerial guidance if a misfit occurs.

However, developing a measure for visualizing complexity of the firm that considers all different aspects of complexity is challenging, even more to grasp complexity in a single measure or number (Boschetti 2008). In addition, nearly all intended measures of complexity known to this author come from the fields of physics, biology, or computing science, and they hardly seem to capture what we intuitively expect from such measures (Adami 2002), nor do they form part of any theory telling us when or how things get complex (De Toni, Nardini et al. 2001).

Furthermore, the literature usually distinguishes between deterministic and statistical measures of complexity, and if we focus on the methodology, between computation theory (Kolmogorov, Rissanen, Universal Turing Machine-based theories) and information theory (Shannon’s entropy, thermodynamic depth). These approaches are incomplete measures for visualizing complexity of the firm, sometimes because they do not consider the structure of the system, other times because they are simply incomputable or limited by the possibility to get information about the system (De Toni, Nardini et al. 2001). In order to overcome these pitfalls, a set of measures that capture researchers' and practitioners' intuitive ideas about what is meant by complexity (and simplicity) of the firm, would be needed.

If we accept that processes in the firm can be viewed as computations, then complexity of the firm might be regarded as a kind of computational complexity, which would theoretically allow, in turn, to infer complexity from an appropriate "finite state firm" that reproduces the (value creation) logic of the firm —something to a certain extent similar to a "Universal Turing Machine" in the context of the firm.

Aside from such idealization, unachievable in practice, complexity of the firm cannot as yet be captured simply by attempting to characterize its underlying dynamic value creation logic, but we should also consider its underlying structural or functional complexity (Adami 2002). Here again difficulties arise when attempting to count the number of different functions that the firm can perform. Furthermore, it is troublesome to imagine that a "universal" measure for structural or functional complexity can be devised given that firms differ so greatly in form and function.

In this challenging theoretical-practical context, it may be helpful if we first identify the essential characteristics to be considered for visualizing complexity of the firm:

- It should intuitively match researchers' and practitioners' expectations of what complexity is (Adami 2002).
- It should reflect the dynamics of the underlying value creation processes, as well as the firm's structural architecture.
- It should take into account information about the interactions with the environment in which the firm operates.

- It should be inferred from empirical observations (Adami 2002).
- It should make it possible to introduce the use of mathematics.

By making sure that any potential measure of complexity of the firm satisfies the characteristics above, we might be able to narrow the search field to only a few plausible options. Notwithstanding researchers and practitioners should note that the measures that might help them visualize complexity are, to some extent, context-dependent or even subjective (Gell-Mann 1995), and will mostly depend on the firm's own network context and the level of detail achieved when mapping the firm-system.

A. Objective and scope

The main objective of Stage 2 is to address the problematic of visualizing complexity of the firm, thus to determine first whether visualization of complexity is possible and, if appropriate, to establish the most convenient way to depict it.

Such visualization should allow researchers and practitioners to draw conclusions on the structural components of the firm and its dynamic relationships and, at the end, inform managerial practice. For example, a particular visualization of complexity of the firm might allow managers to figure out where "slow" VRs are located, whether there exist inadequate connections/ interactions that make it difficult for the firm to coordinate adaptive responses in a timely manner (Eidelson 1997), or whether there are bottlenecks within the firm's network context.

A particular set of measures well fitted to visualize complexity of the firm has to do with **network complexity**. Network complexity has grown to become the "universal language" to describe dynamic evolutionary systems (Barabási 2002). As such, it opens opportunities for the introduction of new methods for characterizing systems complexity, not as information-based complexity but, most essentially, as topological complexity of the network representing the system.

Information-theoretic and non-information-theoretic network complexity approaches have proven useful to solve many interdisciplinary problems —e.g. problems in biology, computer science, ecology, neuroscience, linguistics, sociology, mathematical psychology (Dehmer 2011), with many authors having contributed various measures of network complexity. Some of these measures offer great potential for analyzing complex networks quantitatively and, by extension, provide researchers and practitioners with an effective way to visualize complexity of the firm.

For a network complexity measure to be deemed as acceptable —and since no measure will never provide an absolute and uncontestable account of complexity— it must be sensitive to changes in one, or a combination of any, of the CBVF's theoretical constituents (Section 4.2). More specifically, it should reflect changes in:

- the number and variety of VRs in the network.
- the hierarchical nestedness of VRs.
- the connectivity of the nodes in the network.
- the interactions required to exchange value.

Consequently, the scope of Stage 2 should not only cover the selection and later calculation of a network complexity measure (or a combination of them), but also cover the study of the results obtained and the subsequent planning for improvement.

Furthermore, it is highly recommended that, as an extension of the later, researchers and practitioners devote time to study the costs associated with higher/lower than expected complexity, the effects of different VRs configurations on the variability of the measures of network complexity, and the relation between such measures and system performance (Deshmukh, Talavage et al. 1998).

B. Activities

The activities proposed in Stage 2 aim at assessing alternative methods of network complexity, quantitatively calculate them, analyze the outcomes, and plan for improvements in the firm-system. The figure below illustrates the order in which these activities might be carried out (Fig.7):

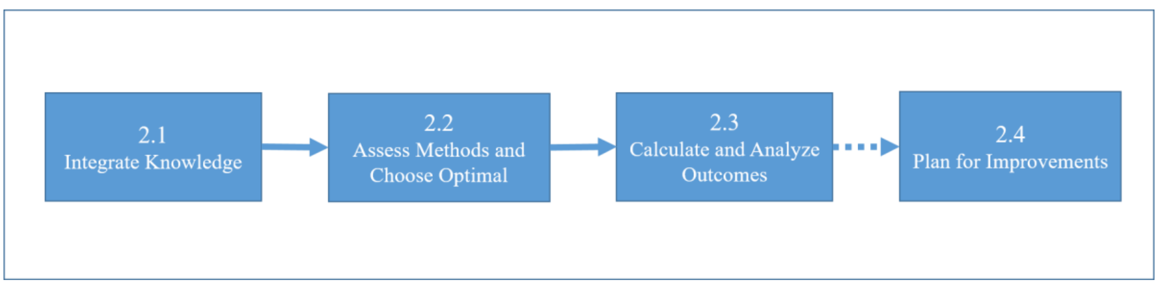


Figure 7. The CBVF Method: Stage 2 Activities
Source: own elaboration

B.1 Integrate Knowledge

Before we start even thinking on what and how to visualize complexity of the firm, it is important that we integrate all the structural and process-based knowledge available from different parts of the firm.

Particularly important is to put together all the knowledge generated in Stage 1, which should allow us to draw the firm's network context, as well as to challenge our understanding of complexity upon testing some preliminary hypotheses about how the firm behaves before particular shocks. The knowledge so gathered should be made available to those members of the firm actively involved in carrying out the Stage 2 activities, as well as those responsible for planning improvement actions.

B.2 Assess Methods and Choose Optimal

Upon having internalized the knowledge on the firm's complexity constituents, researchers and practitioners should undertake a review of the theoretical-practical foundations of the different topological network measures available, with a particular focus on those methods most related to the firm's particular structural and dynamical properties mapped in Stage 1.

Specifically, the analyst should look at the best balance between the set of potentially usable methods of network complexity and its "calculability" in terms of robustness and cost. At this point the analyst should take extra care, because the firm will exhibit very different behaviors in different areas of its "parameter space" (Boschetti 2008), thus significantly affecting our understanding of complexity and the outcomes resulting.

B.3 Calculate and Analyze Outcomes

Analysts should proceed to calculate the set measures chosen in the previous phase, and carefully log the results in a data base for later analysis. A brief description of the equations, the list of parameters, and the values used, should always be provided by the people carrying out the measurements. Once calculations are performed, analysts should work to detect any inconsistencies, bifurcations, or contradictory values within the measurement space, reconfiguring the set of measures if measurements appear incompatible or are unintelligible.

After completion of calculation tasks, a study of the levels of variability and of the tradeoffs between different structure-complexity-performance network setups (Deshmukh, Talavage et al. 1998) should provide a valuable inquiry into complexity of the firm.

A proposal for further enhancement of the network complexity methods and its calculation process, including those concerned with the analysis of the outcomes, the communication patterns and associated costs, are all tasks expected to be carried out during this phase.

B.4 Plan for Improvement Actions

A plan sketching the actions for improving the firm's network value system and firm's performance is a by-product of the activities covered in Stage 2. The Plan should include, at least, the general vision and goals of the firm, together with a detail specification of the scope, calendar time, expected outcome, follow-up metrics, and resources required to successfully implement each individual improvement action.

It is worth noting that although taking improvements into actions is not considered within the scope of the CBVF methodology, the proper implementation and follow-up of each action individually should increase our understanding of complexity of the firm and, therefore, strengthen the feedback between complexity, improvements, and firm's performance.

C. Tools and techniques

Networks have been extensively characterized both structurally and quantitatively by graph theory, which has over 150 years of extensive development and application (Bonchev, Buck 2005). This provides researchers and practitioners with a large number of tools and techniques to substantiate visualization, particularly by using measures of topological complexity of networks representing the firm.

A good starting point may be figuring out whether the firm's network shows the attributes of a small-world or a scale-free network. These well-known graph topologies imply particular dynamic properties (M'Chirgui 2012) which in turn may have important managerial implications in terms of designing better and more robust (value system) networks.

Small-world networks are characterized by shorts paths and high clustering, that is, they show small average path length —or average shortest path between nodes— compared to the number of nodes, and a high degree of clustering compared to a random graph of the same size. Small-world networks display enhanced signal propagation speed —even between distant parts of the system—, synchronizability and computational power (Watts, Strogatz 1998, Strogatz 2001, van Ham, van Wijk 2004), and they can help modeling firms' value systems that are hard to visualize using conventional graph theory techniques.

Scale-free networks are dominated by a relatively small number of nodes that are connected to many other nodes. These highly connected nodes dominate the topology of the network forming hubs. Highly connected hubs become more connected over time and, as a result, the centrality of these nodes functions as an attractive element for new nodes to join the network (Barabási, Bonabeau 2003). What it is interesting about scale-free networks is that they behave in certain predictable ways thoroughly known by researchers. For example, they are remarkably resistant to accidental failures, but somewhat vulnerable to “attacks”.

Finding whether the firm’s network meets the properties of a small-world or a scale-free network would therefore have two important implications (Watts 2004):

1. Very complex networks could be captured by rather simple models, and
2. Well-known/tested metrics and models used to address complex social networks problems might be applied to the firm as well.

Besides the proper characterization of the firm’s network as a small-world or a scale-free network, other network parameters can provide further insight into topological complexity and may be addressed by researchers and practitioners. In this regard, the network analysis literature provides extensive references of metrics that might be conveniently used for a thorough descriptive analysis of topological complexity (Wasserman, Faust 1994, Dean, Ottensmeyer et al. 1997, Jackson 2008, Kolaczyk 2009). Some of the key metrics to be used at this stage may include:

- Nodes characteristics: degree, degree distribution, centrality, including closeness, betweenness, eigenvector.
- Edges characteristics: edge betweenness centrality, hubs, authorities.
- Network cohesion: subgraphs, census of cliques, number of dyads and tryads, coreness, motifs, density, transitivity, reciprocity, connectivity, etc.
- Graph partitioning: modularity, hierarchical clustering, dendrogram.
- Assortativity and mixing.

Additional measures would comprise others based on the idea of graph entropy and graph invariants, including Rashevsky's topological information content (Rashevsky 1955) , Mowshowitz's symmetry index for graphs (Mowshowitz, Dehmer 2010), Bonchev's indices based on the combined use of the adjacency and distance matrix (Bonchev, Buck 2005), and network structural interpretations —e.g. branching in trees, linear tree complexity, cyclicity in graphs, etc. (Jackson 2008).

To provide an idea of inter-component associations in complex networks, measures such as the cycle coefficient and others focused on the distribution of connectivity of nodes (Rao Raghuraj, Lakshminarayanan 2006), may also be useful. This type of measures might even be used to characterize the relationship between the number of cycles and the robustness of the firm's network.

Ultimately, analysts should be aware that all measures mentioned above are useful within the concrete scope in which they are defined and applied. Thus, a given measure featuring different firms might behave differently and even contradictorily. The same might occur if the map of complexity changes, or if we have different observers for the same firm (Tarride 2013).

4.3.7 Stage 3: Modeling and Simulation

Despite their complexity, firms have many structural and functional features in common that can be effectively modeled and simulated using advanced computing techniques and software tools. By performing diverse modeling and simulating tasks, researchers and practitioners can explore the nature of the firm and their dynamical behavior under a range of assumptions. This ability to model and simulate the behavior of the firm is call to have a major influence on studying and understanding firm's complexity.

Modeling (the firm) is central to our very understanding of real-life behavioral phenomena and is probably one of the most consistent approaches to theory construction (Jaccard, Jacoby 2010). However, now that we have gathered knowledge on the fundamental structure and logic underlying the basic behavioral phenomena of the firm in the previous stages of the CBVF methodology, there is still a long way to go until we are able to devise a model. That is precisely the objective pursued in this stage.

In accomplishing the modeling and simulation tasks set forth below, many variables need to be assessed. This in turn requires tools and techniques that enhance the integration of data, and allow interdisciplinary model development, reproducibility of models, and visualization of the results (McGarvey, Hannon et al. 2004).

Upon building a model of the firm, researchers and practitioners should also be able to understand what is fixed and what changes in terms of structure, anticipate how value is created and flows within and outside the components (VRs) of the firm, how and why interactions between VRs occur, as well as how to address the fundamental tradeoffs among efficiency, effectiveness and agility (Rouse 2007). The ultimate objective being to identify potential ways in which to improve the firm's value system design, before acting on improving the performance of the firm.

A. Objective and scope

The main objective of Stage 3 is to create an “imitation” of the structural components (VRs) and interactions shaping the behavior of the firm, as well as to test the imitated system in a variety of simulated environments to get insight into that behavior. Eventually, our goal is to achieve as broad as possible understanding of the behavior of the firm and build a certain predicting capacity.

The activities covered at this stage, as well as the tools and techniques herein suggested, include powerful means of approaching the real-life behavior of the firm. Whereas the earlier stages of the CBVF methodology provide us with key knowledge describing the behavior of the firm, at Stage 3 we aim at building a model in the computer to work out the implications of a large number of VRs —the firm’s network context— continuously interacting one another.

At this point, researchers and practitioners should have accepted the idea that since trying to explain and anticipate the behavior of the firm in all its particularity would be simply inaccessible, we need to work via simplified, and sometimes fuzzy variables. After all, we have no choice but to focus on a few properties abstracted from reality —i.e. the own fuzzy notion of value— and disregard the incommensurable number of internal and external variables that characterize the inner and outer network context of the firm.

Consequently, central to the modeling and simulation activities in Stage 3 of the CBVF methodology is the process of ***design*** itself, which in turn involves carefully delineating the logic of the firm that influences its performance goals. After this logic is made explicit, the analysis and assessment of constraints and alternatives of action becomes key in carrying out our modeling tasks.

At the end, a final design and simulation against a broad range of conditions should complete the scope of Stage 3. The outcomes obtained from the simulation should allow us to corroborate a number of intuitions gathered from previous stages in the CBVF methodology, draw attention to less obvious relationships, and suggest possible lines of empirical research to confirm and expand on the insights gathered (Carrillo-Hermosilla 2015).

B. Activities

The activities covered in Stage 3 are grouped around the ODD protocol —developed by Grimm et al. (2006)— and Helbing's (2012) principles for crafting agent-based models. The reason for settling the activities using a framework specifically designed for use in (ecology and social) agent-based models, is because it is a method for systematically carrying out complex systems modeling and simulation activities and is fully consistent with the goals and method pursued by the CBVF.

The ODD protocol is based on the experience gained by twenty eight experienced modelers from within the complexity modeling community. The protocol is made up of three main blocks, namely: Overview, Design concepts, and Details, which are further divided into seven elements: purpose, state variables and scales, process overview and scheduling, design concepts, initialization, input, and submodels.

The logic behind the ODD sequence is as follows: (1) context and general information is provided first (Overview), (2) followed by strategic considerations (Design concepts), and (3) more technical details are provided (Details) (Grimm, Berger et al. 2006). Building on the ODD logic, listed below are the key activities for modeling and simulation of the firm under our CBVF approach:

1. **Purpose:** This block informs why the firm needs to build a model, what the firm is going to do with the model, and what is the purpose of the simulation. The context and purpose of the model should help researchers and practitioners understand why some aspects of complexity are included while others are ignored.
2. ***Variables and scales:*** The full set of variables is chosen and described at this point. The term variables refers to the properties of the model's key components —i.e. the firm's VRs. Once the analyst knows the full set of variables, he/she would have a clear idea of the model's structure and resolution. Thereafter, the higher-level components should be also described, for example, if a higher cluster of VRs exist. Finally, in addition to the variables, the scales addressed by the model should be also described —i.e. the size of the firm's network context. Choosing the scale is a crucial decision which affects the design of the model itself.
3. ***Process overview and scheduling:*** Consists in providing a description of the underlying processes or fundamental mechanisms leading to the particular firm behavior that needs to be explained, as well as the scheduling of the model processes. Moreover, this refers to the order in which the processes are performed and the subsequent order in which the variables are to be updated.
4. ***Design concepts:*** The design concepts process provides a framework for designing and communicating the model. A short checklist of design concepts would include: emergence, adaptation, fitness, prediction, interaction, observation.

5. ***Initialization:*** This process deals with questions such as: What are the initial values of the variables (or input vector)? Is initialization always the same, or should it vary among simulations? Are the initial values to be chosen arbitrarily or based on specific data?
6. ***Inputs:*** As the dynamics of most complex models are driven by some environmental conditions (inputs or constraints) that change over time and/or space, the analyst needs to know what input data are to be used, how data are generated, and how data can be captured.
7. ***Submodels:*** All submodels representing the processes listed above are presented and explained in detail. The analyst should also provide a description of the mathematical "skeleton" of the model and a full model description where the assumptions are verbally explained. Furthermore, questions such as: What specific assumptions are underlying the model? How are input values chosen? Or, how are the submodels tested?, should be answered now.
8. ***Calibration:*** The analyst compares the results from the computer simulation with the empirical evidence, pointing out what features are correctly reproduced and which not. Moreover, the analyst describes the limitations of the model, as well as its explanatory power. Finally, the analyst should choose the model with the better predictive power, namely the one that better matches the data that have not been used for calibration.

C. Tools and techniques

In this section we propose a set of tools and techniques that support the general objective and scope pursued by the modeling and simulation activities established in Stage 3. These tools and techniques include a number of soft computing techniques consisting of several computing paradigms —including neural networks, fuzzy cognitive maps, agent-based modeling— which in turn can be used to produce hybrid modeling systems for solving firm complexity problems.

The use of one tool or another may depend on one or more of these factors: (1) the analyst's previous knowledge of the firm, (2) the particular goals pursued by the model and the adequacy of abstraction offered by a specific tool, (3) the type, quality and robustness of data available, and (4) the particular skills of the modeler and the type of software technology available.

The use of one tool or another is not exclusive. This means that the modeler may choose to combine several soft computing techniques in order to tackle the complexity and high dimensionality of real-life firm's problems.

Hybrid techniques can have different architectures, each having a different impact on the efficiency and accuracy of the outcomes. For this reason it is very important to optimize the architecture design (Castillo, Melin et al. 2006). For example, the architectures might combine, in different ways, neural networks and/or fuzzy cognitive maps and/or agent-based modeling (Jang, Sun et al. 1997, Panwai, Dia 2005, Rodin, Querrec et al. 2009, Stula, Stipanicev et al. 2010, Song, Miao et al. 2010, Zarandi, Hadavandi et al. 2012, Lee, Lee et al. 2013), in order to achieve the ultimate goal of approaching the behavior of the firm.

It is worth noting that the choice of any particular tool or hybrid technique, not only will determine the level of abstraction and the method to follow by the modeling and simulation activities (Izquierdo, Ordax et al. 2008), but will also affect the breadth and depth of the outcomes to be obtained at Stage 3 of the CBVF methodology.

C.1 Artificial Neural Networks

Artificial Neural Networks (ANN) result from attempts to mimic certain aspects of the information processing and physical structure of the brain through a large number of relatively simple and interconnected neurons (Caudill, Butler 1992, Li 1994, Kriesel 2007). The underlying concept assembles many single simple processors (neurons), which run in parallel, learn from experience, and interact through a dense web of interconnections (Fig.8). These systems are capable of performing tasks that are found to be extremely complex and difficult by today's computing systems (Quaddus, Khan 1999).

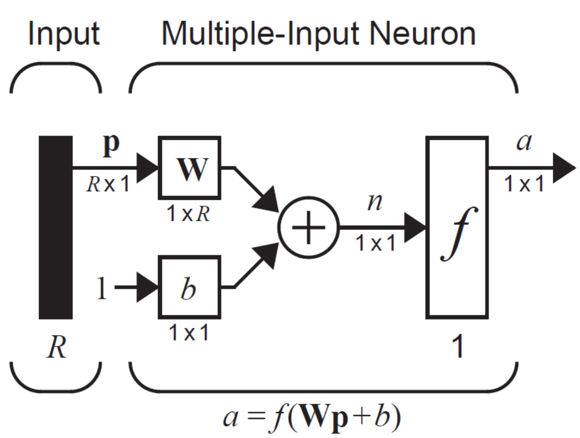


Figure 8. Neuron with R Inputs
Source: Hagan, Demuth et al. 2014

Typically, a neuron has more than one input. The individual inputs $p_1, p_2, \dots, p_R$ are each weighted by corresponding elements $w_{1,1}, w_{1,2}, \dots, w_{1,R}$ of the weight matrix $\boldsymbol{W}$ (Hagan, Demuth et al. 2014).

$$\boldsymbol{W} = \begin{bmatrix} w_{1,1} & w_{1,2} & \dots & w_{1,R} \\ w_{2,1} & w_{2,2} & \dots & w_{2,R} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_{S,1} & w_{S,2} & \dots & w_{S,R} \end{bmatrix}$$

The neuron has a bias b, which is summed with the weighted inputs to form the net input n:

$$n = w_{1,1}\, p_1 + w_{1,2}\, p_2 + \dots + w_{1,R}\, p_R + b$$

This expression can be written in matrix form:

$$n = \boldsymbol{W}\,\boldsymbol{p} + b$$

where the matrix $\boldsymbol{W}$ for the single neuron case has only one row. Now the neuron output can be written as:

$$a = \mathrm{f}\,(\boldsymbol{W}\,\boldsymbol{p} + b)$$

At present there are more than thirty different families of ANN being used in research and/or industry applications (Krycha, Wagner 1999), though most of them can be grouped in two basic network paradigms: the supervised and the unsupervised learning networks. ANN in these two categories differ in their architecture, training, mode of operation, and interpretation of outputs (Lippmann 1987).

Supervised neural networks mainly include the multilayer perceptron (MLP), recurrent associative networks, and Hopfield networks. Unsupervised neural networks cover networks such as adaptive resonance theory models and self-organizing maps. According to numerous field studies (Vellido, Lisboa et al. 1999, Quaddus, Khan 1999) the vast majority of ANN practitioners rely on the use of the feedforward MLP trained by back propagation, with only a few documented investigations opting for unsupervised models.

Over the last decade, and especially in the last few years, ANN have reached into a wide range of applications, which can be divided into the following main categories: pattern classification, forecasting, planning, approximation, generalization, and optimization. The special features of ANN's information processing makes them attractive for solving complex problems in finance, specifically in forecasting, trading, stock performance, and portfolio selection; marketing, including market segmentation, monitoring of customer behavior patterns; retail: forecast of sales, inventory, staffing, pricing; telecommunications: customer churn, win-back, assignment of calls, optimal network design, efficient routing, control of traffic; insurance: detection of fraudulent claims, prediction of claim costs; operations management: scheduling, control, planning; and many other examples (Vellido, Lisboa et al. 1999, Smith, Gupta 2000, Paliwal, Kumar 2009).

The experience gained with ANNs and the large body of research carried out on business and management applications, makes them a sound alternative to conventional statistical models. In fact, much of the comparative literature points out that ANNs can be applied to many problems that are solved conventionally by statistical and management science techniques, and that they outperform, or perform as well as, the conventional statistical models (Vellido, Lisboa et al. 1999, Krycha, Wagner 1999, Paliwal, Kumar 2009).

Authors frequently cite the following advantages of ANNs (Li 1994, Warner, Misra 1996, Paliwal, Kumar 2009):

- Suitability to handle incomplete, missing or noisy data.
- Being a non-parametric method, not requiring any a priori assumptions about the distribution and/or mapping of the data.
- Their parallel processing ability, such that each neuron in the ANN acts a processing element similar to a Boolean logical unit, except that the neuron's function is programmable.
- Their distributed memory, which means that a ANN does not store information in a central memory, thus relying on the collective outputs of all the connected neurons.
- Their learning/training ability, which makes ANNs capable of applying learning rules to develop models while adapting the network to the changing environment.
- Their demonstrated capability to approximate any continuous function.

But ANNs also have some important disadvantages. They are not a general-purpose problem solvers. They are good at solving systems of linear or non-linear equations, organizing data into equivalent classes and adapting the solution model to environmental changes. Therefore, they are not so good at logical inference. ANNs do not use a structured methodology for choosing, developing, training, and verifying an ANN, thus users of ANNs must conduct sensitivity analyses to identify the best possible configuration of the network. Last but not least, most ANNs are not able to explain how they solve problems (Li 1994, Warner, Misra 1996, Vellido, Lisboa et al. 1999, Paliwal, Kumar 2009).

From a CBVF perspective, ANNs are a powerful tool that can be very helpful at the early stages of the CBVF modeling process. They offer an approach to modeling which does not require a complete algorithmic specification. Moreover, ANNs provide inductive means for gathering, storing, and using, experiential knowledge (Schocken, Ariav 1994).

There is a descriptive proximity between ANNs and the firm as an adaptive complex system. For example, real neuron networks are inspired by the architecture and behavior of the brain and tend to “fire” only when its combined input exceeds a certain threshold. Not very differently, the firm under the CBVF approach is comprised of a network of VRs, each of which continuously interacts exchanging value when certain conditions are met.

From a computational perspective, ANNs can be used to extract a set of rules that specify how the firm has structured in the past and exchanged value. Literature shows, for example, that feedforward networks are good at classifying fuzzy objects into concrete categories (Desai, Crook et al. 1996, Setiono, Thong et al. 1998, Atiya 2001, Smith, Gupta 2002, Prevolnik, Škorjanc et al. 2011). Assuming that the analyst has gained access to a large amount of past data and that he/she is able to discern a good set of attributes, ANNs might help him/her minimize classification error when mapping featuring the firm’s VRs and value exchange patterns. Additionally, ANNs would help us avoid falling into the consistency trap of expert knowledge.

The inductive experience gained through ANNs might enable researchers and practitioners to monitor the firm’s value creation and value exchange patterns over time, so that they can detect non-performing VRs or identify outputs which seem to be off-target (Schocken, Ariav 1994). In doing so, ANNs might provide a framework to systematically identify improvement opportunities in the firm and approach the impacts on firm’s performance.

Last but not least, ANNs might also help us bring order to the data management processes needed to successfully implement the CBVF approach in the firm. ANNs would make possible to create a distributed memory organization of data, where data is spread across the network in a distributed format and would allow retrieval of information through inexact or incomplete keys. This flexibility would enable managers and analysts to trace chains of associations and recognize patterns in unpredictable ways (Schocken, Ariav 1994, Smith, Gupta 2002).

Ultimately, ANNs and conventional statistical tools should not be viewed as competing modeling approaches, but rather they should work synergistically, conventional methods providing good starting points for ANNs (Sharda, Wang 1996, Krycha, Wagner 1999). In this regard, literature shows well-performing associations, for example, between feedforward MLPs and discriminant analysis and regression, and between unsupervised networks and cluster analysis (Paliwal, Kumar 2009).

C.2 Self-Organizing Maps

Self-Organizing Maps (SOMs) are a data analysis and visualization technique invented by Finish Professor T. Kohonen designed to provide a way of representing complex, arbitrary multidimensional data in much lower dimensional spaces, usually in one or two dimensions (Kohonen 1998, Kohonen 2013, Bhowmick, Shah 2015). This technique is essentially a data compression process, also known as vector quantization, which creates a network that stores information in such a way that any topological relationships within a training set are maintained.

One of important aspect of SOMs is that they learn to classify data without supervision. Unlike supervised training techniques such as backpropagation, in which the output is compared with a target vector, training a SOM does not require a target vector —no right answers are provided. A SOM learns to classify the training data without any external supervision, making it possible to obtain insight into the topographic relationships of data. An unknown input is classified according to a node of a regular, usually two-dimensional grid, the model of which is most similar with it in some metric used in the construction of the SOM. Every input data item shall then select the model that matches best with the input item, and this model, as well as a subset of its spatial neighbors in the grid, shall be modified for better matching (Kohonen 2013).

According to Mangiameli et al. (1996), if we consider a Kohonen one-dimensional array of neurons, each of which receives the same input vector $\boldsymbol{X}$, the index i measures the dimensionality of the input vector $\boldsymbol{X}$ such that i = 1,2, …, m, and N Kohonen layer neurons are indexed by the numbers j = 1, 2, …, n , then any particular Kohonen neuron j n_j has an input weight vector W_j. The neuron c n_c is the neuron with weight vector W_c that is closest to the input signal vector $\boldsymbol{X}$. This distance is calculated as follows:

$$| X - W_c | = \min_j | X - W_j | \qquad \forall j$$

If we define N_c as the subset of neurons that includes n_c and its adjacent neighbors, the process of self-organization is accomplished as follows (Mangiameli, Chen et al. 1996):

$$\frac{d\,W_j}{dt} = \alpha\,(t)\big(X - W_j\big) \quad for\, j\ \in\ N_c$$

$$\frac{d\,W_j}{dt} = \ 0 \quad for\, j \notin N_c$$

where $0 \ < \ \alpha \ < \ 1$. The magnitude of the learning coefficient $\alpha(t)$ determines how rapidly the system adjusts over time. Typically alpha is decreased as learning proceeds. The neighborhood function that defines N_c starts with a large area and decreases over time.

An example that illustrates the way a SOM works is mapping the three dimensional components of color —red, green and blue— into two dimensions (ai-junkie). The Fig.9 below graphically illustrates how a SOM can be trained to recognize the eight different colors shown on the right. The colors are presented to the network as 3D vectors, one dimension for each of the color components, and the network learns to represent them in the 2D space. In addition to clustering the colors into distinct areas, areas of similar properties are usually found adjacent to each other.

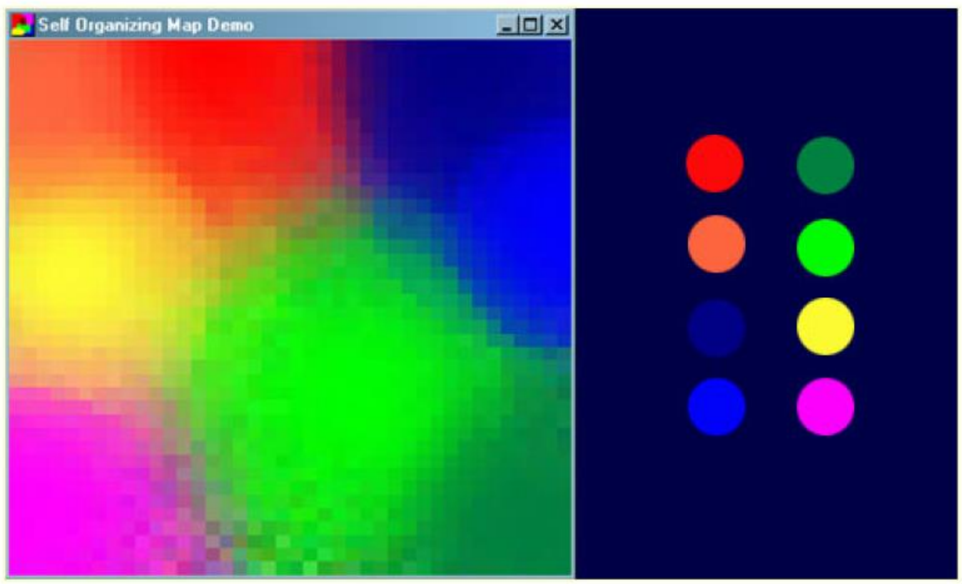


Figure 9. Example of How a SOM works
Source: ai-junkie

SOMs are widely applied to clustering problems and exploratory data analysis in industry analyses, finance, biomedical and telecommunications, with practical applications ranging from industrial process control to the management of very large document collections. Other more specific applications of SOMs found in the literature include profiling of the behavior of criminals, categorization of galaxies, categorization of real estates, and linguistics (Kohonen 2013).

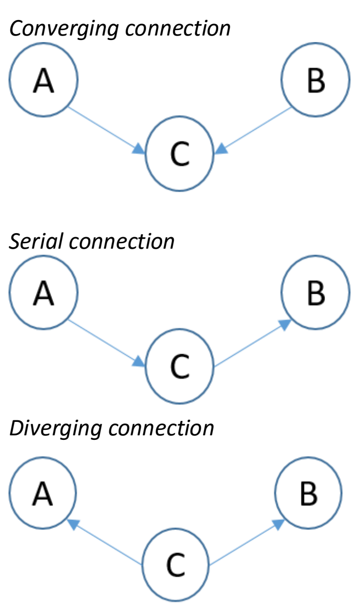
From a CBVF perspective, SOMs might be used as a clustering and data segmentation technique for highly multidimensional firm networks, and as a substitute for hierarchical clustering methods (Mangiameli, Chen et al. 1996). As SOMs compress information while still preserving the most important topological and metric relationships of the primary network data, they make it possible to know which neuron provides output when we are not so much interested in the exact output of the neuron (Serrano-Cinca 1996, Smith, Gupta 2002, Kriesel 2007). For example, firms with a high-dimensional network context or VRs configuration could be mapped onto a SOM, thus generating a two dimensional discrete grid topology that it might be more easily visualized. This way researchers and practitioners might find easier to identify neighborhood relationships and check whether optimal behavioral areas (clusters) develop. In this sense, SOMs might be used as nonparametric similarity graphs, or clustering diagrams.

C.3 Bayesian Networks

Bayesian Networks, also known as belief networks, are a class of graphical models that represent the joint probability distribution between a given set of variables or entities of interest. From the CBVF perspective, these entities of interest can be thought as nodes representing the VRs of the firm's network, the edges featuring their associations (relations), and the Bayesian network showing the joint probability distribution between the entities of interest.

Formally, Bayesian networks are directed acyclic graphs (DAG) whose nodes represent random variables in a Bayesian sense —they may be observable quantities, latent variables, unknown parameters or hypotheses— and edges represent conditional dependencies. Each node is associated with a probability function, whose input is a set of values for the node's parent variables, and the output the probability distribution of the variable represented by the node (Nagarajan, Scutari et al. 2014).

Bayesian networks has its roots in Bayesian statistics and focuses on the computation of posterior probabilities or densities. For a given a set of variables $X = \{X_1, X_2, \ldots, X_p\}$, a Bayesian network thus allows a concise representation of a DAG, $\mathrm{G} = (\mathrm{V}, \mathrm{A})$, where each node $\mathrm{v_i} \in \mathrm{V}$ corresponds to a variable $\mathrm{X_i}$. The correspondence between the graphical separation ($\perp\!\!\!\perp_{\mathrm{G}}$) induced by the absence of a particular edge and probabilistic independence ($\perp\!\!\!\perp_{\mathrm{P}}$) provides a convenient way to represent the dependencies between the variables. Such a correspondence is formally known as an independency map (Pearl 2014). The correspondence between the structure of the DAG G and the conditional independence relationships it represents, is explained by a directed separation criterion, or d-separation (Nielsen, Jensen 2009, Pearl 2014). Fig.10 below illustrates the annotation for the fundamental connections in Bayesian networks.



For A $\not\perp\!\!\!\perp_{\mathrm{G}} B|C$

$$P(A, B, C) = P(C|A, B)P(A)\,P(B)$$

For A $\perp\!\!\!\perp_{\mathrm{G}} B|C$

$$P(A, B, C) = P(B|C)P(C|A)\,P(A)$$
$$= P(A|C)P(B|C)P(C)$$

Figure 10. Fundamental Connections in Bayesian Networks
Source: (Nagarajan, Scutari et al. 2014)

Efficient algorithms exist that perform learning and inference in Bayesian modeling (Ando 2010). The task of fitting a Bayesian network is usually called learning, and it is performed in two different steps, which correspond to model selection and parameter estimation techniques in classic statistical models.

The first step is called *structure learning* and consists in identifying the graph structure of the Bayesian network. Several algorithms have been proposed in the literature, which usually fall under three broad categories: constraint-based, score-based, and hybrid algorithms. As an alternative, the network structure can be built manually from the domain knowledge of a human expert and prior information available on the data.

The second step is called *parameter learning*. As the name suggests, it implements the estimation of the parameters of the global distribution. This task can be performed efficiently by estimating the parameters of the local distributions implied by the structure obtained in the previous step (Nagarajan, Scutari et al. 2014).

Bayesian network has drawn attention across a wide spectrum of disciplines that include biology, medicine, ecology, health care and, more specifically, in causal studies where causal relations are encoded by the structure (or topology) of the network (Steyvers, Tenenbaum et al. 2003). In particular, Bayesian networks are useful abstractions of the underlying biological pathways and signaling mechanisms, where they show the ability to discover new associations in addition to validating known associations between the entities of interest (Grzegorczyk, Husmeier 2009, Nagarajan, Scutari et al. 2014).

From a CBVF perspective, Bayesian networks might be useful when researchers and practitioners attempt to integrate multiple interactions, outcomes, and information from VRs, with large amounts of data coming from different sources, or when there is missing data and uncertainty (Chen, Pollino 2012). In this case, Bayesian networks might provide a good representation of the probabilistic relationships between a concrete VRs configuration and its associated flow (exchange) patterns, thus allowing reasoning under the uncertainties associated with these probabilities.

The inference capabilities provided by Bayesian networks might also help us reveal possible causal relationships between the firm's VRs, based on certain implicit assumptions, uncertain data, or the analyst's prior knowledge on the firm's value system. The strength of these relationships would be established as a conditional probability (CP) attached to each VR (node). CPs would reflect the degree of belief (probability) that a VR is in a particular state given the states of the parent VRs —the nodes that directly affect that VR. Evidence would be entered into the Bayesian network by substituting the *a priori* beliefs of one or more nodes with observation or scenario values (Chen, Pollino 2012). This belief propagation would enable Bayesian networks to be used for diagnostic or explanatory purposes (Castelletti, Soncini-Sessa 2007), as well as for predicting the states of VRs when data is partial or uncertain.

C.4 Fuzzy Cognitive Maps

Fuzzy Cognitive Maps describe the behavior of a complex system by means of graphs consisting of nodes, so-called "concepts", that are connected through arrows that show the direction of influence between concepts. A positive/negative arrow pointing from concept A to concept B indicates that concept A causally increases/decreases concept B. To reflect the strength of causal links, weights are assigned to the arrows. Each concept represents a state or a characteristic of the system, and these concepts interact with each other as to display the dynamics of the system (Stylios, Groumpos 1999).

FCMs are regarded as a simple form of recursive neural networks (Kosko 1987), where concepts are equivalent to neurons, but unlike neurons, they are not either "on" $(=\ 1)$ or "'off" $(=\ 0\ or\ -1)$, but can take states in-between that are considered ''fuzzy''. Fuzzy concepts are non-linear functions that transform the path-weighted activations directed towards them (their ''causes'') into a value in $[0,1]$ or $[-1,1]$.

When a neuron ''fires'' (when a concept changes its state), it affects all concepts that are causally dependent upon it. Depending on the direction and size of this effect, and on the threshold levels of the dependent concepts, the affected concepts may subsequently change their state as well, thus activating further concepts within the network.

Fuzzy Cognitive Maps can be formulated in different ways. Stylios and Groumpos (1999) distinguish three different types. **FCMs of Type I** calculate the value of each component by computing the influence of all other components to the specific components. This is done by calculating the following equation:

$$x_i(t) = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} x_j\,(t-1)\ w_{ji}\right) \tag{1}$$

Where $x_i(t)$ is the value of component C_i at time t, $x_j\,(t-1)$ is the value of component C_j at time $(t-1)$, w_{ji} is the weight of the interconnection between component C_j and component C_i, and f is the sigmoid function:

$$f = \frac{1}{1+e^{-\lambda x}} \tag{2}$$

Other squeezing functions are the $\tanh(x)$ and $\tanh({}^{x}/_{2})$ that convert the result of the multiplication into the fuzzy interval $[0,1]$ or $[-1,1]$.

FCMs of Type II take into account the previous value of each concept, so that the last value of each concept is involved in the determination in the new value of concept and so the values of concepts will have a slight variance after each simulation step. The mathematical formulation of Type II FCMs is as follows (Stylios, Groumpos 1999):

$$x_i(t) = \mathrm{f}\left(k_1 \sum_{\substack{j=1 \\ j\neq i}}^{n} x_j\,(t-1)\ W_{ji} +\ k_2 x_i(t-1)\right) \tag{3}$$

Where x_i is the value of concept C_i at time t, $x_i(t-1)$ is the value of concept C_i at time $t-1$, $x_j\ (t-1)$ is the value of concept C_j at time $t-1$, W_{ji} is the weight of the interconnection from C_j to C_i , and f is a threshold function. The parameter k_2 represents the proportion of the contribution of the previous value of the concept in the computation of the new value and k_1 expresses the influence from the interconnected concepts in the configuration of the new value of the concept x_i. The two parameters k_1 and k_2 satisfy the equation:

$$0\ <\ k_1, k_2\ \leq 1 \tag{4}$$

In **FCMs of Type III**, a concept can take into account its own past value with a weight w_{ii} . Therefore, Type III FCMs are close to Type II and the calculation rule will be similar to the equation (3):

$$x_i(t) = \mathrm{f}\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} x_j\,(t-1)\ W_{ji} +\ W_{ii}\, x_i(t-1)\right) \tag{5}$$

Where x_i is the value of concept C_i at time t, $x_i(t-1)$ is the value of concept C_i at time $t-1$, $x_j\ (t-1)$ is the value of concept C_j at time $t-1$, W_{ji} is the weight of the interconnection from C_j to C_i , W_{ii} is the weight with which the previous value of concepts participate in the calculation of the new, and f is a threshold function.

FCMs have several properties that make them particularly useful for modeling and simulating the firm under the CBVF. FCMs focus on those aspects of a system that are uncertain and not knowable through simple information gathering. For these uncertainties, they provide a limited number of possible states, so-called scenarios, whose main purpose is to challenge prevailing mind-sets and avoid the common problem of over- and under-prediction of change (Jetter, Kok 2014).

To this end, FCM-based scenario approaches put heavy emphasis on integrating knowledge from experts and/or stakeholders and on eliciting and communicating assumptions. The maps so created can be based on interviews, text analysis or group discussions and be easily modified or extended by adding new concepts and/or relations or changing the weights assigned to causal links.

To attenuate some of the limitations and weaknesses of expert-based knowledge, a number of **learning algorithms** have been developed mainly consisting of modifying the FCM weight matrix. These learning techniques have developed on the following three directions (Papageorgiou 2012): (1) the production of weight matrices on the basis of historical data, (2) the adaptation of the cause–effect relationships of the FCM on the basis of experts' intervention, and (3) the production of weight matrices by combining experts' knowledge and data. The learning algorithms resulting from these learning paradigms are Hebbian-based, population based, and hybrid —combines the main aspects of Hebbian-based- and population-based-type learning algorithms. These learning algorithms are the most efficient and widely used to train FCMs.

In addition to the learning algorithms above, several **FCM extensions** have been proposed during the past decade aimed at improving the original formulation of FCM made by Kosko. Some of the extensions reviewed in the literature (Papageorgiou, Salmeron 2013) include: Rule-base Cognitive Maps, Fuzzy Grey Cognitive Maps, Dynamical Cognitive Networks, Fuzzy Cognitive Networks, Evolutionary Fuzzy Cognitive Maps, Fuzzy Rules incorporated in Fuzzy Cognitive Maps, to mention only a few.

Further example of the growing interest that FCMs arouse is the number of application areas in which FCMs are applied. Papageorgiou and Salmeron (2013) study on the most common application domains of FCMs, identify applications in fields such as environmental studies, medicine, engineering, business and management, mathematics, computer science, and some others.

In summary, FCMs allow a quantitative and qualitative analysis of the behavior encoded in FCM models to aid decision making. By means of FCMs, managers can agree on plausible combinations of input values and calculate the states of the dependent variables, thus assessing the impact of input variations —i.e. variations due to particular policies— and/or the impact of alternative system description —i.e. due to different mental models belonging to the same complex problem. The special combination of explanatory and predictive capacity provided by FCMs makes them a particularly well fitted tool to serve the goals pursued by our CBVF approach.

C.5 Agent-Based Modeling

Agent-Based Modeling (ABM) is a modeling and simulating tool that has gained growing attention over the past fifteen years or so, by the increasing number of applications that call for models incorporating complex elements of human and social behavior (Macal, North 2009). Up until now these models were considered too complex to be adequately modeled, however, as our computational power has increased and data is more fine-grained, we are now capable of modeling using agent-based models.

ABM has its roots in complex adaptive systems, and is comprised of autonomous, self-contained, interacting agents, with diverse, heterogeneous, and dynamic attributes and behavioral rules. Moreover, agents are adaptive, which means they can learn from their environment and dynamically change their behavior in response to their experiences (Macal, North 2009).

ABM works best when modeling heterogeneous agents' relationships and agent interactions that are complex, nonlinear, discontinuous, or discrete (Bonabeau 2002). These are models commonly used when mathematical models can be written down but not completely solved, or when writing down equations is not a practical approach (Axtell 2000, Helbing 2012). Hence, ABM tend to be descriptive rather than normative —seeking to optimize and identify optimal behaviors.

Nowadays ABM is being applied to many areas, covering social, physical and biological systems. Applications range from modeling ancient civilizations (Lima, Hadzibeganovic et al. 2009), to modeling customer and market behavior (Twommey, Cadman 2002), population dynamics (Pablo-Martí, Santos et al. 2015), or simulate technological change (Carrillo-Hermosilla, Unruh 2006).

Examples of ABMs found in the literature span from small, minimalist models —with simple rules of behavior and a set of idealized assumptions that can be varied over many simulations— to large-scale decision support systems, designed to answer a broad range of real-world policy questions. Worth noting is how some authors, such as Chang and Harrington, have even used ABM to explore a new approach to organizations. For these authors, an organization can be viewed as a collection of agents, interacting with one another in their pursuit of assigned tasks. The performance of an organization in this framework is determined by the formal and informal structures of interactions among agents, which define the lines of communication, allocation of information processing tasks, distribution of decision-making authorities, and the provision of incentives (Chang, Harrington 2006).

For most researchers and practitioners the main reason for using ABM is because *i)* agent-based models can easily and naturally incorporate the complexity arising from individual behaviors and interactions that exist in the real-world, and *ii)* ABM can capture emergent phenomena and become an effective route to develop a thorough understanding of models with unstable equilibria (Axtell 2000, Bonabeau 2002). Furthermore, since ABM models are “solved” merely by executing it, when a particular agent-based model, call it A, produces result R, one has already established a sufficiency theorem, the formal statement being $R \ if \ A$ (Axtell 2000).

ABM is also well suited for visualizing an organization from the viewpoint not of the business processes but of the activities, which is what most people inside an organization usually do. In addition, ABM is flexible, because it makes it easy to add more agents to a particular model and tune the complexity of the agents. This flexibility allows the analyst to readily change levels of description and aggregation, with different levels of description potentially coexisting in a given model (Bonabeau 2002, Helbing 2012). Another advantage of ABM not very often mentioned is that once a model has been created it provides not only one aspect of the solution —i.e. the equilibria, or the stability— but rather entire solution trajectories (Axtell 2000).

Notwithstanding the foregoing, ABM has one significant disadvantage: despite the fact that each run of the agent-based model yields a sufficiency theorem, a single run does not provide any information on the robustness of such theorem. To address this problem, the analyst must run the model multiple times, systematically varying initial conditions or parameters in order to assess the robustness of the results (Axtell 2000).

In addition, sometimes an idiosyncrasy in the rule code may produce an output that we could erroneously take as a significant result of the model. This might happen, for example, when the agent interaction methods impose some spurious correlation structure on the overall population. Although no real solution exist to this problem, aside from careful programming, one could look for the existence of such artifacts by making many distinct realizations of an agent model, perturbing parameters and rules.

From a CBVF perspective, an agent-based model may be a model that people in the firm would acknowledge as useful, as it aims to explain what the firm does to create and exchange value. This has important implications when it comes to populating, validating, and calibrating the model, since if people connects to the model, they can help to dramatically improve it, and quantify more easily what needs to be quantified.

Conceptually, a CBVF's agent-based model would consist of individual agents (represented as VRs), each with different states and rules of behavior, conveniently represented in software as objects. Building such a model would amount to describe an agent population (the firm's VRs network context), make VRs interact, and monitor what happens. The essential idea would be that VRs only interact at any given time with a limited (small) number of other VRs in the population, thus it is possible to define a local neighborhood with interactions limited to a small number of VRs that happen to be in that neighborhood.

At the simplest level, a CBVF's agent-based model would consist of a firm with just a few VRs and the relationships (exchanges) between them. Even this very simple model could display complex behavioral patterns and provide valuable information about emergent behavior and the dynamics of the real-world firm that it emulates. Further on, VRs might be capable of evolving, allowing unanticipated behaviors to emerge.

For more complex firms, ABM might even incorporate other complementary techniques such as ANN, evolutionary algorithms, and other learning techniques to allow realistic learning and adaptation (Bonabeau 2002). Such a powerful set of modeling and simulation tools might become the first line of attack to the modeling problem on the CBVF approach, with researchers and practitioners resorting to more conventional mathematical modeling techniques only to "tidy up" what the agent-based model had clearly demonstrated to be a robust feature of the problem.

C.6 System Dynamics

System Dynamics (SD) is a general term associated to the study of a variety of complex systems, which explicitly take into account the dynamic behavior that results due to delays and feedbacks in the system (Forrester 1994). Besides a set of conceptual tools that enable us to understand the structure and dynamics of complex systems, SD is also a modeling method to build formal computer simulations of complex systems and use them to design more effective policies and organizations (Sterman 2000).

The method of SD permits the analyst to decompose a complex social or behavioral system into its constituent components and then integrate them into a whole that can be easily visualized and simulated. This process is illustrated in a graphical way, assuming that systems can be represented as a collection of stocks connected by flows (Mendoza, Prabhu 2006, Voinov, Bousquet 2010). Typically, influence diagrams using nodes and directed arrows are used to denote this dynamic behavior. Fig.11 provides an example of a causality loop diagram generated by a focus group (Mendoza, Prabhu 2006).

The principles of SD can be summarized in two major statements:

1. Stocks, flows, and delays determine system behavior.
2. Based on the idea of bounded rationality (Simon 1982), SD does not address all the variables of a problem, rather concentrates on the ones that are key to the problem and its context, neither does it pretend to optimize, but to satisfice our understanding of the problem.

As a modeling tool, SD works best when it is used to develop a model that solves a particular problem, and not a model as a whole or to gain insight. Furthermore, SD considers modeling a feedback process covering constant iteration, continual questioning, testing, and refinement (Sterman 2000), not a linear sequence of steps.

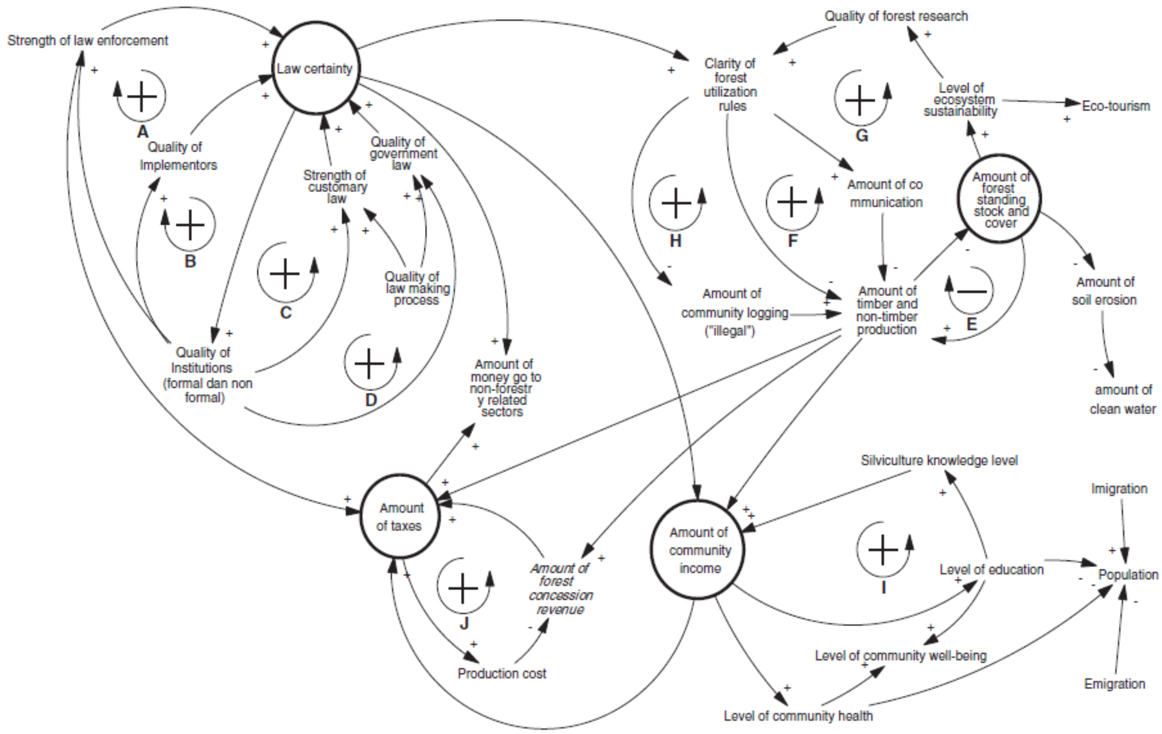


Figure 11. Causal Diagram of Management of a Forest
Source: (Mendoza, Prabhu 2006)

SD is grounded in control theory and the modern theory of nonlinear dynamics, therefore there is a strong mathematical foundation in the theory and models developed under SD (Sterman 2000). SD is also designed to be a practical tool that policy makers can use to help them solve the pressing problems they confront in their organizations and, as such, it has been successfully applied in a wide variety of business and socio-economic fields to understand the problems and gain an insight into various policy interventions.

Among the main **tools used by SD** it is worth mentioning causal loop diagrams —for representing the feedback structure of systems— stocks and flows —for mapping networks of stocks and flows of a system— and integration of flows and differentiation of the stock —to infer the behavior of the flows from the dynamics of the stock (Luenberger 1979, Sterman 2000).

The use of SD might fit the objective and scope of our CBVF modeling and simulation activities under some circumstances, especially when our understanding of the firm's VRs configuration and the interactions between them is sketchy or vague, and not amenable to a formalized representation. When this is the case, soft SD is a valuable tool to use, thus overcoming some limitations of other hard computing models unable to fully represent cause-and-effect relationships.

Furthermore, the method of SD strongly emphasizes the endogenous behavior of the system and evaluates the dynamic behavior implied by feedback loops (Forrester 1987, Izquierdo, Ordax et al. 2008). All the above, combined with the fact that SD focuses on observable variables and provides the modeler with a graphical description language that describes the interdependencies between the attributes of the target system (Gilbert, Troitzsch 2005), suggests that it might be an acceptable modeling and simulation tool to use and that it would meet the goals of our CBVF approach.

4.3.8 Stage 4: Optimization

Given the knowledge gathered so far on complexity of the firm, at this stage of the CBVF methodology we are likely to be in a position to run some optimization process aimed at achieving a more efficient and productive functioning of the firm's network value system.

As we have seen in the previous sections of this chapter, the firm is formed by the interconnection of many value repositories (firm's component) that may have different, or even opposing, optimization goals one another or from the firm as a whole. Consequently, various structural and dynamical properties of the firm can be explicitly involved in the optimization of specific functions (Motter, Toroczkai 2007).

In particular, network optimization has a long research tradition within the field of mathematical programming, and is one of the principal ongoing areas of research in the optimization arena. This is mainly due to the abundance of network applications and the confluence of mathematical theory and computer science research (Meyer 1985).

Examples of real-life network optimization problems include finding shortest paths, finding the vulnerability of networks to disconnection because of link and/or node failure, maximizing the flow in networks, minimum-cost flows, etc. (Khuller, Raghavachari 2013). Correspondingly, there are a large number of methods for achieving optimization, including systems structures and computational methods (Leondes 1998). Last developments in optimization include non-cooperative mathematical games in decision environments, using numerical methods such as steepest decent, fixed point, gap function and computational intelligence algorithms (Friesz, Bernstein 2015).

Given the importance that continuous improvement and optimization presumably have in the adaptive behavior of the firm, the CBVF approach calls network optimization activities to play an important role in shaping the evolution of the firm’s behavior at different scales.

A. Objective and scope

Based on the context of optimization described above, there are probably a good number of behavioral problems of the firm that might be better defined as optimization problems, where optimal behavior is most often connected to a function that the system performs, which is multivariate or multifaceted (Motter, Toroczkai 2007).

Identifying what tendency within the network context improves the behavior of the firm as a result of a selection pressure imposed, for example, by a customer portfolio is the objective of Stage 4. Notwithstanding, this goes beyond the conventional definition of optimization centered on obtaining the solutions that strictly extremize a well-defined functional. Therefore, instead of trying to find “the” best solution, our CBVF approach prefers to find a “good enough solution” or a “better solution”, which in turn is more likely to become a workable alternative for the firm.

According to Motter and Toroczkai (2009), there are fundamentally four major types of optimization problems related to networked systems, in which the CBVF may focus:

1. *Type I: Structural Optimization.* Involves finding a graph $G(V,E)$, where V is the set of nodes and E is the set of edges that extremize a given structural functional $F(G)$.
2. *Type II: Dynamics Optimization on Static Graphs.* For a given graph $G(V,E)$ and a dynamical system Φ on G, such that

$$\Phi(\mathrm{x},\dot{\mathrm{x}},\ldots,\{\alpha\},\mathrm{t})=0 \qquad (1)$$

   we must find the values of the parameters {α} that extremize a global functional $F(\Phi)$.of the dynamics Φ. The variables x are quantities associated with properties of the nodes and edges in the network. This type is useful to study flow optimization problems.
3. *Type III: Structural Optimization for Dynamics.* For a given dynamical system (1), and a set of parameters {α} , we must find a graph $G(V,E)$ for which a global functional

$F(\Phi)$ of the dynamics Φ is extremized. This type is useful in design problems, such as finding the network structure that is optimal for an information outcome.

4. *Type IV: Dynamics-Driven Network Optimization.* If the graph of the network evolves in time $G(V, E) = G(V, E, t)$, we must find the values of the parameters {α} for which a global functional $F(G, \Phi)$ of the dynamics Φ and of the graph $G(V, E, t)$, is extremized. This type is the most difficult to solve because both the structural properties and the dynamics can change.

As we can see, optimization in complex networks has broad significance and may incorporate static and dynamic properties at the same time. The ultimate goal being to serve as an instrument to analyze (and shape) the evolution of the firm and design actions that influence the performance and robustness of the firm.

B. Activities

The network optimization activities covered in our CBVF methodology build on the insights gained from the preceding modeling and simulation tasks performed in Stage 3. From this point, it is suggested that the analyst carries out the following proposed activities (Floudas, Pardalos 2013, Khuller, Raghavachari 2013, Friesz, Bernstein 2015):

1. Define the optimization problem for which a solution is to be sought —e.g. graph theoretic, flow optimization, structural and dynamic optimization.
2. Gather sample data, and choose the parameters to model.
3. Choose a fitness function (or what we want to optimize) and determine when and how the analyst should evaluate the function.

4. Simulate the model several times and assess the results; determine the procedure for further exploration.
5. Assess computation time of the simulation; if the simulation requires much time, use distributed computation.
6. Run the optimization algorithm.
7. Analyze results.
8. Change initial conditions, if required, and run the algorithm as appropriate.
9. Draw final conclusions.
10. Plan for the structural and/or dynamical changes that should improve the network representing the firm.
11. Start a new cycle of the CBVF methodology by updating the map of complexity of the firm (Stage 1, Section 4.3.5).

C. Tools and techniques

Many different tools and techniques allow us to achieve optimization in network-like models, however, not all are thought to deliver the outcomes expected by the CBVF. The following section describes only a selection of those optimization techniques that might better serve the requirements of our CBVF.

C.1 Network flows optimization

Network flows optimization has always been a core problem in almost all industries, including business management. In fact, because network flows optimization problems arise in so many problem contexts (Ahuja, Magnanti et al. 1995), it is sometimes difficult for researchers and practitioners to fully appreciate the benefits and variety of network applications that can bring to the theory of the firm.

Among the wide variety of network flows optimization problems, the **Minimum Cost Flow Problem (MCFP)** is the most fundamental. This problem is generally stated as the *“least cost shipment of a commodity through a network in order to satisfy demands at certain nodes from available supplies in other nodes”* (Ahuja, Magnanti et al. 1993). Special cases of the MCFP are the Shortest Path Problem and the Maximum Flow Problem.

The study of the **Shortest Path Problem (SPP)** is a natural point where we may start optimizing the firm network value system and its underlying VRs configuration. The SPP would thus refer to the best way to traverse the firm’s network to get from one VR (node) to another as cheaply as possible. The SPP might typically adopt one or more of the following forms: (1) finding shortest paths from one VR to all other VRs, when edges lengths are non-negative; (2) finding shortest paths from one VR to all other VRs in the network; and (3) finding shortest paths from every VR to every other VR. Typical algorithms used to solve the SPP include the label-setting and the label-correcting algorithms.

The **Maximum Flow Problem (MFP)** would typically refer to how we can exchange as much value as possible between two VRs without exceeding the (interaction/exchange) capacity of any edge. The generic augmenting path and the pre flow-push algorithms are typically used to solve the MFP (Ahuja, Magnanti et al. 1993).

The MFP and the SPP are complementary approaches, because they both arise as sub problems of the MCFP problem. However, the two problems differ because they capture different aspects of the MCFP: the SPP models edge costs but not edge capacities, meanwhile, the MFP models capacities but not costs.

The MCFP usually combines ingredients from the SPP and MFP, so it is very common that researchers and practitioners end up using linear programing methods to solve MCFP problems. Among the most popular algorithms used for solving the MCFP are the polynomial and network simplex algorithms.

As described above, there is a rich set of algorithms for solving network flows problems, the review of which would be too long for the scope of this thesis. It is therefore part of the analyst's work to choose among the most efficient algorithms available for solving the network flow optimization problem of his/her choice.

C.2 Neural networks global search methods

Neural networks pervasiveness as a tool to approximate unknown functions to any degree of accuracy, makes them *a priori* eligible for modeling complexity of the firm. However, some of the most widely used optimization techniques for training neural networks, such as the back-propagation technique, are shown limited in its ability to find global optimal solutions (Sexton, Dorsey et al. 1999). Instead the literature demonstrates that global search techniques are a far superior technique in providing optimal solutions.

In this section we are going to examine two global search techniques that might serve adequately the CBVF's optimization requirements: Genetic Algorithms and Simulated Annealing.

Genetic Algorithms (GA) are a family of computational methods first described by John Holland in the 1960s and further developed in the 1970s, inspired by the process of biological evolution. GAs exploit the concept of evolution by combining potential solutions to a problem, thus allowing to solve various classes of problems and, more specially, optimization problems (Holland 1975, Mitchell 1998, Calvez, Hutzler 2006, Joyce, Hayasaka et al. 2012).

By means of GAs the potential solution of a problem is encoded on a linear data structure, which is called a chromosome. The algorithm works on a set of several chromosomes, each of which represents a candidate solution to a given problem, called a population. Recombination and mutation operators are then applied to this population.

Intuitively the role of these operators is to pick up the best part of chromosomes to obtain a better chromosome. The suitability of the new resulting chromosomes, as solutions to the given problem, is evaluated by a fitness function. A new population is finally created from the initial population before starting again the whole process (Mitchell 1998, Calvez, Hutzler 2006, Joyce, Hayasaka et al. 2012). The success or failure of a GA resides on the fitness function, as it defines the smoothness or roughness of the solution space —namely, the set of all possible GA chromosomes— and therefore influences the ability of the GA to converge on the best solution.

GAs have been used widely in applications as diverse as medical image processing, modeling crystal formation, functional modeling of the human brain (Joyce, Hayasaka et al. 2012) and, more specifically, in a large number of scientific and engineering problems, including optimization, automatic programming, and machine learning (Mitchell 1998).

In the field of economics, GAs have been used to study evolutionary aspects of social systems, and to model processes of innovation, the development of bidding strategies, and the emergence of economic markets (Amman, Tesfatsion et al. 2006). In these applications, GAs make it possible to explore a far greater range of potential solutions to a problem than do conventional programs (Holland 1975).

From a CBVF perspective, GAs might be used in the context of multi-agent models, such as those specified in Stage 3, as a type of unstructured search method to assist the analyst in the task of variable selection, determining the optimal topology of a network, or fine-tuning the model (Vellido, Lisboa et al. 1999, Amman, Tesfatsion et al. 2006, Calvez, Hutzler 2006). For example, parameter setting in an agent-based model can become long and tedious if the analyst has no accurate, automatic and systematic strategy to explore the parameter space. In this case GAs might be used to explore the parameter space and find the best parameter set with respect to an optimization function. In other cases, GAs might allow the development of new strategies or decisions that had not been considered in the initial model.

Simulated Annealing (SA) draws from the process of annealing, which occurs when physical substances, such as metals, are raised to a high energy level (melted) and then gradually cooled until some solid state is reached to reach the lowest energy state. During this process physical substances usually move from higher energy states to lower ones, so if the cooling process is sufficiently slow minimization naturally occurs (Sexton, Dorsey et al. 1999).

Computational SA basically starts at an initial random point, from which the algorithm takes a step within a range predetermined by the user. The new point's objective function value is then compared to the initial point's value in order to determine if the new value is smaller. If the objective function value decreases, it is automatically accepted and it becomes the point from which the search will continue. The algorithm will then proceed with another step. As the algorithm progresses, the length of the steps declines, closing in on the final solution (Sexton, Dorsey et al. 1999).

SA algorithms are always able to find the optimum or, at least a point very close to it, and they are also less likely to fail on difficult functions. Furthermore, SA is largely independent of the starting values and can escape from local optima and find the global optimum by the uphill and downhill moves (Goffe, Ferrier et al. 1994).

The literature also shows that SA algorithms perform well in the presence of a very high number of variables, and when compared with other conventional algorithms on econometric models, SA algorithms show superior performance (Goffe, Ferrier et al. 1994). Essentially, SA provides more features at the cost of an increase in the execution time for a single run of the algorithm. However, when compared to the multiple runs often used by conventional algorithms to test different starting values, SA are competitive.

Among the frequently mentioned advantages of SA over conventional optimization algorithms, we may refer the following:

1. SA can escape from local maxima by moving both uphill and downhill.
2. the step length gives the analyst valuable information about the function, so that if an element is very large, the function is very flat in that parameter.
3. SA is a better overall measure of flatness than a gradient evaluation at a single point.
4. SA can maximize functions that are difficult or impossible to optimize otherwise. A drawback of SA is the required computational power, but this problem is gradually disappearing.

SA applications include computer and circuit design, the solution of the traveler salesman problem, pollution control, the reconstruction of crystalline structures, image processing, and neural networks (Goffe, Ferrier et al. 1994).

It is worth noting that in the case of neural network optimization, some authors observe that GAs systematically obtain superior solutions than SA (Sexton, Dorsey et al. 1999). Generally, the GA process of moving from one population of points to another enables it to discard potential local solutions and also to achieve superior solutions in a computationally more efficient manner than SA. Furthermore, GAs usually provide researchers and practitioners with superior estimates of interpolation data.

C.3 Agent-based optimization

Optimizing an agent-based network/model can have different connotations. Most commonly it refers to how the analyst can influence a network in order to best achieve some specific goal, while in other contexts optimization may refer to parameters or model design. In this later case, agent-based optimization can still refer to the optimal choice of a sequence of external inputs to achieve a particular goal (Oremland, Laubenbacher 2014).

The stochasticity inherent to ABM means that special care should be taken when attempting to solve optimization problems. As data from individual simulations often vary, careful analysis of ABM dynamics is a prerequisite for the development of any optimization technique (Oremland, Laubenbacher 2014). Furthermore, the increasingly number of variables and complexity of ABM makes it is impossible to enumerate the solution space to find optimal solutions. As a result, heuristic algorithms are the most frequent means of performing optimal control and optimization of agent-based models, thus providing a means for searching the solution space in an effective manner and in a reasonable timeframe.

Optimization algorithms usually begin with a user's choice of the control input values and employ various methods to refine (decrease) the value of the associated cost function, until no better solution can be found. In addition to the already described GA and SA algorithms, other potentially useful optimization algorithms include the Tabu search algorithm (Glover 1989), the GRASP Greedy Randomized Adaptive Search Procedures (Feo, Resende 1995), and Hinkelmann et al.'s method for translating an agent-based model into a polynomial dynamical system (Hinkelmann, Murrugarra et al. 2010).

4.3.9 Summary

Stage	Activities	Tools and Techniques
1. Mapping the Firm-System	1. Source and Measure Value 2. Cluster Value Hierarchically 3. Determine the VRs Configuration 4. Visualize and Analyze the Network	• Classification techniques • Hierarchical clustering • Network graph theory • Value network construction
2. Visualizing Complexity	1. Integrate knowledge 2. Assess Methods and Choose Optimal 3. Calculate and Analyze 4. Plan for Improvement	• Topological characteristics: Nodes characteristics, Edges characteristics, Network cohesion, Graph partitioning, Assortativity and mixing. • Rashevsky`s topological information content • Mowshowitz`s symmetry • Bonchev`s indices • Others (Raghuraj et al. 2006, Jackson 2008)
3. Modeling and Simulation	• ODD protocol (Grimm et al. 2006) • Principles for crafting agent-based models (Helbing 2012)	• Artificial neural networks • Self-organizing maps • Bayesian networks • Fuzzy Cognitive Maps • Agent-based modeling • System Dynamics
4. Optimization	1. Assess results from simulation 2. Run optimization algorithm 3. Analyze results 4. Plan for structural and/or dynamical changes 5. Start new cycle	• Network flows optimization • Global search methods • Agent-based optimization

Table 2. Summary of the CBVF Methodological Framework
Source: own elaboration

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CHAPTER 5.

TESTING THE THEORY AND METHOD: AIRLINES FIELD RESEARCH

5.1 Introduction

Up to this point in the thesis we have been concerned with formulating a complexity-based theory of the firm and a practical methodology to bring the theory into practice. Nonetheless, *"in social research, generating theory goes hand in hand with verifying it"* (Glaser, Strauss 2009), thus we must make sure that the CBVF is readily understandable and can be operationalized by researchers and practitioners of the firm.

In accomplishing this key task of our theory building process, the CBVF must provide clear assumptions that are verifiable in present and future research. This involves that the CBVF should "fit" the situation being researched, and make it "work" when put into use. By "fit" we mean that the assumptions made by the CBVF must be applicable to real data; by "work" we mean that the CBVF must be meaningfully relevant to, or be able to, approach the behavior of the firm (Glaser, Strauss 2009).

In this chapter we provide a test case for verifying the applicability of the CBVF theory and method, using field research in network airlines. Field research differs significantly from other research methods in that it involves various levels of observation, interaction and participation with members of real firms. This in turn should provide the researcher with data against which to confront the CBVF main assumptions and insight to test the theory, which might not be obtained using other research methods (Young 1999). Furthermore, by examining the data captured through field research we expect to provide feedback that improves the CBVF theory and discloses its limitations.

5.2 Field Research Design

5.2.1 Purpose

The purpose of the present field research is to validate the propositions made by the CBVF theory and to ascertain the coherence and practicality of the procedures established in its methodological framework. Note that the validation of these propositions must not be confused with quantitative hypothesis testing; the purpose of field research is to gather and describe enough data as to verify the applicability of the CBVF theory and method, and not to prove it statistically.

Based on the data and insights gathered from this empirical fieldwork, verification of our CBVF theory and method is expected. By iteratively confronting our analytical generalizations in the form of CBVF propositions with the empirical insights in the form of validated propositions, internal validity of the CBVF is to be established.

5.2.2 Research questions

The following questions are of particular importance for the present field research:

- RQ1: What are the key value repositories comprising the airlines’ value system?
- RQ2: What are the key constraints affecting value creation in network airlines?
- RQ3: What is the impact of value repositories and constraints on airlines’ Operating Margin?
- RQ4: What actions help create value in network airlines and affect performance positively?

Therefore this field research dives into the essence of the airlines’ value system dynamics with a dual purpose: (1) to offer researchers and practitioners a broad picture of the external variables and structural components that shape network airlines’ value creation system, and (2) to address the question of what actions could be more appropriate to increase value creation in airlines and stay competitive. The main goal pursued by this research is thus of a qualitative and practical nature, with a particular focus in providing new insights that support managers in the process of improving value creation and anticipating performance.

It is worth noting that this field research generates novel data from experts on the constraints and value dynamics within the firm’s network context. Furthermore, we study the relationships of these elements with a key performance indicator, Operating Margin, as to build a network model of the firm on the basis of soft computational techniques.

The resulting model, and the outcomes obtained from the subsequent simulation scenarios, are not a concluding step to solve all the critical competitive issues in the airline industry. They only provide a proof of concept and set the ground for a novel complexity-based view of the firm, the generalization of which should open new opportunities to all firm researchers and practitioners. Hence our intention becomes the exploration, identification and description of multiple relationships regarding complexity in airlines, rather than the quantification of a single consensus or framework.

5.2.3 Why network airlines?

Contrary to the trend of many research studies in the literature, which selectively choose examples for its confirming power, this author chose network airlines —also known as hub-and-spoke airlines— in a non-aprioristic way and without theoretical control. The only criteria used was past professional background of the author and the fact that the airline industry is a conspicuous paradigm of a rapidly changing firm, whose many challenges and opportunities make it one of the most competitive and complex industries of all.

Leading and managing an airline, or one of its operational units, is not an easy job. Airlines' managers are invariably compelled to readapt their policies to the customer preferences as few other industries do, and the ever-changing "external factors" in the industry impose severe constraints to growth and competitiveness. Complexity has unequivocally seized an industry that is key for economic growth and progress, where value is increasingly more difficult to create and where taking the benefits of it, a question of survival (International Air Transport Association 2011). To make things even more intricate, no magic formula seems plausible to cope with this complex panorama.

However, among the management options implemented by the airline industry in history, some pathways seem more likely to succeed than others in the struggle for competitiveness. One of the pathways that have traditionally yielded better results is when airlines attempt to solve the competitiveness equation from inside the organization, no matter how convoluted the environment becomes. In following this course of action, value creation seems to become key.

Notwithstanding the foregoing, the notions of “value” and “value creation” are rather ambiguous and inconclusive, not to say they are full of misconceptions; a kind of slippery floor for airline managers. With such problematic characterizing the airline industry, the CBVF seems a natural approach that may help tackle such complex issues and draw conclusions of practical order.

5.2.4 Method

The method used in this field research follows the stages established in our CBVF methodological framework, as enunciated in Chapter 4: (1) data capture, (2) mapping the firm-system, (3) visualizing complexity, (4) modeling and simulation, and (5) optimization.

The author carried out extensive fieldwork in order to capture relevant data on value creation dynamics from airlines’ experts that could be used to fulfil the goals of the thesis field research. It should be noted that despite the limited domain of the research (airline industry), this does not constrain our ability to verify the applicability of our complexity-based theoretical-practical approach in a real case scenario.

The above involved launching a Delphi process and setting up an Experts’ Panel. After data were collected, an exploratory data analysis was conducted that contributed to map the firm-system. Then a network graph of airlines was drawn, the topological complexity of which was appropriately assessed. Finally, the author undertook specific soft computing modeling and simulation work, as a step towards reproducing the impact of key variables on the airlines’ value system and performance. No optimization work was undertaken as part of the field research as this exceeded the scope of our field research and the commitment gained from the members of the Experts' Panel.

Two more factors characterize the method used in our field research: (1) all inputs, analysis and modeling tasks performed, as well as the outcomes obtained, are built on the knowledge and experience provided by an international group of airlines' practitioners/experts, and (2) the qualitative and quantitative techniques used are of non-conventional type. The latter meaning that this author intended to surpass the conventional, cause-and-effect mindset, and instead applied an approach based on fuzzy elements from reality.

5.2.5 Data collection

As stated before, data on value creation and exchange is key in carrying out our field research, and a critical asset to make our CBVF theory and methodology both robust and reliable. However, airlines —and firms in general— do not generate value-driven data and, if available, experience shows that managers are typically hesitant to share this information with others given the "strategic" nature of it. Hence, our first concern in this field research has to do with how to collect this type of data, and from whom.

In examining the key characteristics of the Delphi method as a survey and knowledge extraction procedure (Chapter 4), it becomes clear that its philosophy and procedures match well with our research intentions. First, the Delphi method fits well our research focus on future actions. Second, it is a method that systematically delivers when relatively little is known about these actions. Third, our research questions lend themselves to making use of a wide range of experts geographically dispersed internationally, an area where Delphi excels. Last but not least, the Delphi method works especially well when the research consists of an iterative process where each question builds on the answer to the previous question, and some kind of consensus is sought (Skulmoski, Hartman et al. 2007, Amos, Pearse 2008). For all these reasons, the Delphi method was the author’s choice for capturing data.

A. The Delphi process

The broad range of expertise and layering of questions required in this field research involved a phased approach of four Delphi rounds, each with its own objective yet relevant to the subsequent Delphi rounds.

Owing to limited access to concrete airlines executives and industry experts, the author chose to conduct the Delphi process on an online basis, on the belief that our topic of interest would attract the interest of experts not reachable by other means. This basically involved launching a Delphi process aimed at attracting worldwide experts to participate; experts who belonged to many different airlines, held different positions of responsibility, and performed in various functional areas.

Similar research findings indicate that a Delphi so conducted not only increases the efficiency of the process, but accommodates experts availability and reduces drop-out-rates. Moreover, when the online/computer-based Delphi format is compared with a conventional Delphi, no significant differences between the two are really observed and final survey results are not seriously affected by changes in the survey procedure (Gnatzy, Warth et al. 2011).

As the Delphi process has been reviewed elsewhere in this thesis (Chapter 4) and extensively studied in the literature (Adler, Ziglio 1996, Linstone, Turoff 2002), we exhibit below an overview of how this author used it in the field research (Fig.12).

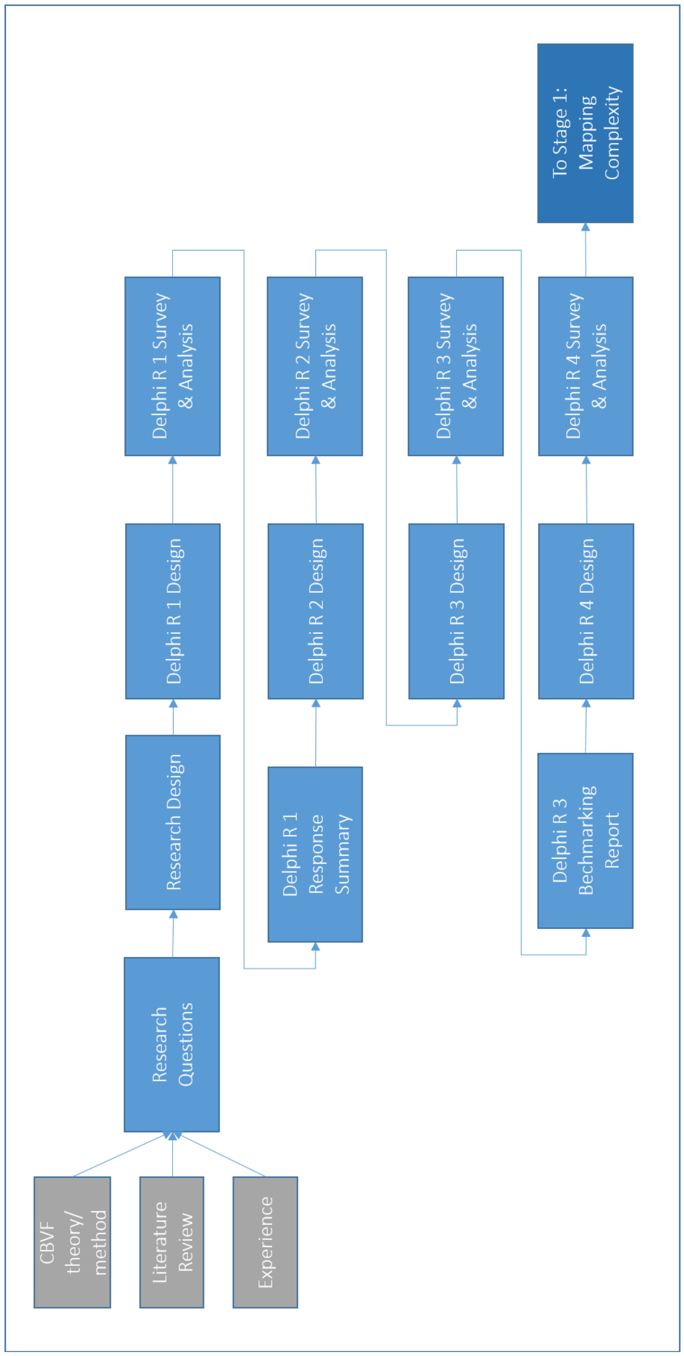


Figure 12. The Delphi Process
Source: own elaboration

- *Research Questions.* These are the research questions derived from the need to verify the applicability of the CBVF theory and methodology. Previously to the formulation of the questions, the author considered his own experience in the industry and the conclusions obtained in Chapter 4 of the thesis. Also a review of the literature was conducted to determine if a theoretical gap existed.
- *Research Design.* After formulating the research questions, we proceed to select the research participants, choose a survey and communication system, and draft a working plan. Participants are a critical component of Delphi research, since it is their expert opinion upon which the output of the Delphi is based. So a careful selection of participants was carried out by the author (see Appendix C). The survey and communication system is also a critical tool in the process, from which an effective and efficient implementation of the Delphi depends (see Appendix H.3). The system chosen by the author guaranteed a service level and automated delivery of questionnaires, thus accelerating the monitoring and reporting of participants generated data. The working plan is also an essential part of the Delphi process, as it contains the specification of the roles of researchers and participants, sets the timeline, and assigns the resources needed to implement the entire Delphi process.
- *Delphi Round 1.* Consisted of a divergent thinking process focused on the identification by participants of as many value constraints and key firm's components as possible.
- *Delphi Round 2*. Aimed at building "experts consensus" on the top ten constraints to value creation and the top fifteen value repositories identified in the previous round. This limiting numbers were set to forestall excessive analytical work for

participants, as well as to avoid an overly too complex network graph and subsequent model and simulation overload.

- *Delphi Round 3.* Having got an idea of the key structural components making up the airlines' value creation system, the focus shifted in *Round 3* to the identification of the connections between the constraints and the value repositories, the connections among the value repositories themselves, and between the value repositories and Operating Margin.
- *Delphi Round 4*. Aimed at building "experts consensus" on the questions asked in Round 3, adding a novel question about the sign of the relationships previously identified by the experts.

The Delphi process was supported by a website, http://www.valueinairlines.com, created and hosted by the author to serve as main communication channel with participants, and which included information about the purpose and method of the research, the research information sheet file, and introductory resources for participants. Screenshots of the website can be found in Appendix G.

B. Panel questions

Much of the outcomes in the field research depend on the type of questions posed to Panel members. The Delphi process used a series of questionnaires interspersed with feedback (Appendix D), designed to identify the firm's key components and its relationships. Each questionnaire in subsequent rounds of the process was drafted based on the results of the previous questionnaire. The process stopped when sufficient information had been exchanged and group stability —defined as the consistency of responses between successive rounds— had been reached (Skulmoski, Hartman et al. 2007, von der Gracht 2012). For sake of clarity, and in order to avoid being too deterministic in the research, specific academic parlance was deliberately avoided in the questionnaires.

The questions posed to Panel members in Round 1 were twofold: *"What do you think are the main external constraints to value creation in airlines?"* and *"What are the key value repositories in airlines that affect airlines' Operating Margin?"* An explanation of what a Value Repository was provided in the questionnaire along with a link to an author's introductory paper on the basics of our complexity-based view of the firm.

Individual answers from Round 1 —individually compared with the aggregated Panel answers— were later distributed to each participant in Round 2, and they were asked to agree on the top ten constraints and the top fifteen value repositories previously identified. Specifically, the questions posed were: *"What do you think are the 10 key constraints to value creation in network airlines?"*, and *"What do you think are the key 15 value repositories affecting performance in network airlines?"*

The questions posed in Round 3 pursued to gain insight into the interconnectedness of the constraints, value repositories and Operating Margin, captured in rounds 1 and 2. In particular, the questions in Round 3 were threefold: *"How do the 10 consensus value constraints impact on the 15 consensus value repositories?"*, *"How are the 15 consensus value repositories interlinked and how they impact on each other?"*, and *"How do the 15 consensus value repositories impact on airlines' Operating Margin?"* The questionnaire consisted of several matrix-type questions, where experts could mark whether or not a particular relationship existed and provide the weight (strength) of a particular relationship by choosing one among five levels —zero, very weak, weak, strong and very strong— in a Likert-type scale.

Finally, in Round 4, an individual report containing the answers from Round 3 and a benchmarking of the personal responses against the aggregate responses from the Experts' Panel was distributed to the members (Appendix B). Upon the analysis of the report, Panel members were asked to accomplish the following three types of tasks:

- To set the final strength and sign of the links between the 10 consensus value constraints and the 15 consensus value repositories.
- To set the final strength and sign of the links between the 15 consensus value repositories.
- To set the final strength and sign of the links between the 15 consensus value repositories and airline's Operating Margin.

Similarly as in Round 3, the questionnaire in Round 4 consisted of several matrix-type questions where experts provided their insight into the strength and sign of the interconnections among constraints, value repositories and Operating Margin.

All Delphi questionnaires in the field study were conducted using an online Qualtrics-created survey (Appendix H.3). Copy of the questionnaires used in the Delphi process are found in Appendix D.

C. Participants selection

The Delphi process required participants to be experts on the phenomenon under investigation. Therefore, an important practical consideration in the field research design had to do with who might serve as a qualified expert in the Delphi Experts' Panel.

The answer to this question was influenced by the particular research questions posed in the study, and the following eligibility criteria was set for meeting “expertise”: (1) knowledge and experience with the issues under investigation; (2) position of responsibility held in the organization, considering that expert competency is usually higher for participants whose positions are closely associated with the investigated topic; (3) capacity and willingness to participate, and (4) effective communication skills (Adler, Ziglio 1996).

To decide on the candidates for the Experts’ Panel, the author’s own professional LinkedIn online network served as the tool used to review candidates’ curricula, and as main channel of communication with candidates (see Appendix C for a list of Panel members).

On invitation, selected candidates were kindly requested to accept participation in the research project before starting to provide their insights through the Delphi questionnaires.

D. Criteria for consensus

As described before, the Delphi process used in this field research gathers a heterogeneous number of international experts from the airline industry, the objective being to include all diverse opinions and expertise, as to verify the applicability of the CBVF theory and methodology in airlines. This means that although consensus among participants might be an outcome of the process, this was not the primary intention of the process (Rauch 1979). Instead, all the viewpoints were captured with the intention to creatively explore complexity in airlines according to our CBVF approach.

It should be pointed out that when we say that "consensus" among participants is reached, what this author means is that a sufficient clarification and definition of the different opinions and viewpoints among Panel members was effectively reached.

5.3 Results Obtained

5.3.1 Data analysis

In this section we provide an analysis of the data captured throughout the four rounds comprising the Delphi process, as well as an analysis of data on participation. For sake of clarity, we divide this section into five subsections: one providing an overall analysis of Panel members' profile and participation, and one for the analysis of the data captured in each Delphi round.

A. Data on profiles and participation

The total number of participants providing a response at any round of the Delphi process is thirty three. Notwithstanding that number of participants, we must note that not all of them produced a response considered technically valid. Consequently, if we focus strictly on the number of participants providing a valid response —either complete or incomplete— then we must adjust the total number of participants to twenty eight.

A.1 Participants by functional area

The professional profile of the participants in the Experts' Panel is mixed and varied, covering a broad spectrum of functional areas within their own organizations. Table 3 below shows the distribution of the Panel members according to the functional areas where they perform their responsibilities.

Functional area	No. Participants
Commercial	9
Network & Revenue	7
Sales & Distribution	5
Corporate	4
Engineering	3
TOTAL	**28**

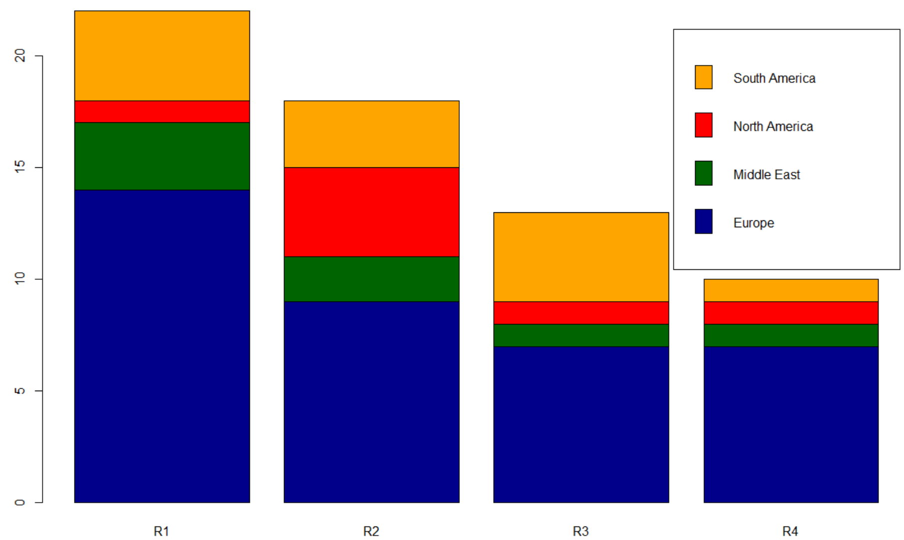
Table 3. Delphi Survey, Distribution of Panel Members by Functional Area
Source: own elaboration

As we can see in the table above, Panel members perform their responsibilities within a wide range of functional areas, with the participants from the commercial area being the most numerous, followed by those participants performing in the network and revenue areas. This not only reveals a high functional diversity among participating members, but it also helps us prevent bias in the field research.

A.2 Members by geography

Geography is another key factor that allows us to characterize Panel members' profiles. In this regard, the presence of a broad number of different geographies in the field research should be a good indicator that reflects consistency and move us away from research bias.

As Fig.13 indicates, participants from Europe are the largest group, followed by participants from South America, North America and Middle East in this order. Note that this geographical distribution pattern remains virtually unchanged across the four rounds of the Delphi process.



(*) R1: round 1, R2: round 2; R3: round 3; R4: round 4

Figure 13. Distribution of Participants by Geography
Source: own elaboration

Such varied distribution of geographies fulfils a good practice in similar field research studies, consisting of having a wide geographic coverage of participants to avoid bias. An explanation for the decrease of participation across the four Delphi rounds (Fig.13) is provided in the next sections.

A.3 Members by organic position

When analyzing the positions held by Panel members in their respective organizations, we should take into consideration the heterogeneity existing in the way airlines refer to organic positions. This sometimes makes it difficult to compare positions or levels of responsibilities in different airlines, particularly when members are from different companies and/or geographies.

That said, we synthesize the different positions held by Panel members according to the levels of responsibility stated in their curricula and seeking homogeneity in the description (Table 4).

Position	No. Participants
Senior Vice-President	2
Vice-President	15
Director	8
Manager	3
TOTAL	**28**

Table 4. Distribution of Panel Members by Organic Position
Source: own elaboration

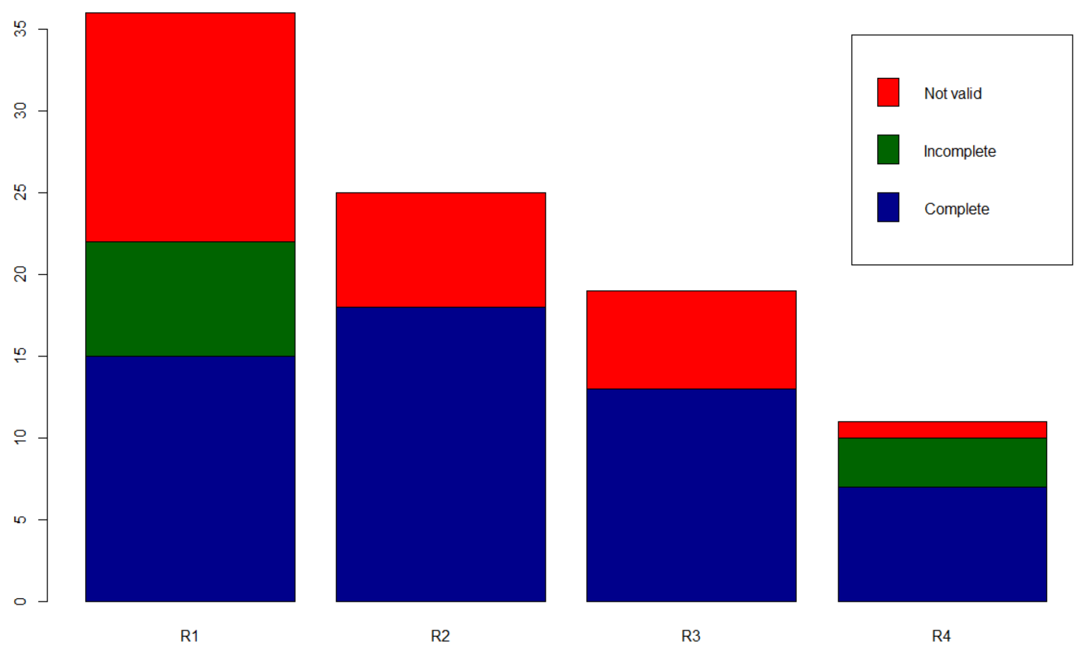
The table above shows that the group of Vice-presidents is the largest among Panel members, followed by Directors, Managers and Senior Vice-Presidents in this order. This distribution of organic positions ensures that all data captured in the Delphi process come from experts with the greatest knowledge and highest experience within the airline industry, as was originally intended in the design of the Delphi process.

A.4 Type of responses

Panel members provided different types of responses to the questions posed in the Delphi process, which basically fell into two broad categories: valid and not valid responses.

Valid responses were those responses that could be satisfactorily processed and analyzed to the effects of the field research, and thus incorporated to the stream of research. Valid responses were themselves either "complete" —whenever Panel members provided a response to the entire questionnaire— or "incomplete" —when members responded partially to the questionnaire.

Not Valid responses refer to those members' submissions lacking the possibility to be processed and analyzed by the author, the reason being an incomplete submission process or a technical failure occurring during submission. Not valid responses were excluded for the purpose of the field research. Fig.14 shows the distribution of the different types of responses provided by Panel members along the four rounds of the Delphi process.



(*) R1: round 1, R2: round 2; R3: round 3; R4: round 4

Figure 14. Type of Responses Provided by Panel Members
Source: own elaboration

As we can observe in the figure above, the proportion of "complete" responses mostly increased across the four rounds of Delphi, at the same time as the proportion of "not valid" and "incomplete" responses decreased. This trend is consistent with the fact that some Panel members at the initial stages of the Delphi process might have been hesitant to participate in the research, thus preferring to peer into the content of the questionnaires before deciding a valid submission. This fact might explain most of the “not valid” responses.

Furthermore, the decrease in the number of total valid responses, and of Panel members’ participation, is consistent with the author’s past experience and numerous Delphi-based research projects shown in the literature (Linstone, Turoff 2002, Skulmoski, Hartman et al. 2007). From a mere methodological perspective, the total number of valid responses achieved along the field research is significant enough for an online Delphi process, and ensures a high level of reliability in the data collected.

B. Delphi round 1

In Round 1 of the Delphi process, Panel members were asked two main questions:

- Q1: *What do you think are the main external constraints to value creation in airlines?*
- Q2: *What are the key value repositories in airlines?*

Both questions were open-ended, which means that Panel members were free to write down whatever constraint and value repository they thought were key for real-life airlines. This process, known as “group visioning” or “divergent thought”, sought to carry out a scattered creative process where Panel members provided as many different responses as possible.

Given the heterogeneity in the responses obtained from Panel members, this author synthesized the complete list of constraints and value repositories into a reduced number of common, non-overlapping categories.

Table 5 below shows the frequencies of the main constraints provided by Panel members. Note that the top four constraints —*Labor costs, Competition from other airlines, Government regulation, Fuel cost*— amount together to more than 50% of all responses given by Panel members.

Constraints	Frequency	Percentage
Labor costs	18	15
Competition from other airlines	16	13
Government regulation	15	12
Fuel cost	14	12
Airport fees	8	7
GDS feed	6	5
Leisure travel demand	5	4
Business travel demand	5	3
ATC fees	3	2
IT systems costs and complexity	2	2
Other cited constraints	30	25
TOTAL	**121**	**100**

Table 5. Delphi Round 1: Summary of Top Cited Constraints
Source: own elaboration

On the other hand, responses to the question *"What are the key value repositories in airlines?"* reveal a very different pattern. As we might expect given the novelty of the term *Value Repository*, members' responses appear much less grouped than in the case of constraints, with the top four value repositories amounting barely to a 26% of the total number of responses. Not surprisingly, we also find an evident high level of dispersion in the responses

(Table 6), which might be due to the broad idea of "value" dominating among Panel members and their different contexts and backgrounds.

Value Repositories	Frequency	Percentage
Capacity management	6	7.9
Information management	5	6.6
Network	5	6.6
Customer experience	4	5.3
Scheduling	3	3.9
Sales	3	3.9
Procurement	3	3.9
Operations management	3	3.9
Relationships with stakeholders	3	3.9
Corporate culture	3	3.9
Products and services	3	3.9
People and talent	3	3.9
Process and cost optimization	3	3.9
Digital channels	2	2.6
Alliances	2	2.6
Other cited value repositories	25	32.9
TOTAL	**76**	**100**

Table 6. Delphi Round 1: Summary of Top Cited Value Repositories
Source: own elaboration

C. Delphi round 2

With the aggregated information from top constraints and top value repositories gathered in Round 1 in their hands, Panel members were asked in Round 2 to reach consensus on the key top ten constraints and top fifteen value repositories making up an airline's value system. Specifically, the questions asked in Round 2 were the following:

- Q1: *What do you think are the 10 key constraints to value creation in network airlines?*
- Q2: *What do you think are the key 15 value repositories affecting performance in network airlines?*

The analysis of the responses to Q1 and the comparison with the responses given in Round 1, show how the triad of constraints comprising *Government regulation*, *Fuel cost,* and *Competition from other airlines*, remain at the top of the list (Table 7). This give us a general idea of the high degree of consensus reached by Panel members with respect to the key constraints.

Top 10 Constraints	Frequencies	
	Round 1	Round 2
Government regulation	15	15
Fuel cost	14	11
Competition from other airlines	16	11
Commoditized product offering	1	11
Power of unions/labour force	1	10
Labor costs	18	10
Slot availability	1	8
Excess capacity	1	7
Capital intensity	1	7
Business travel demand	5	7

Table 7. Comparison of Top 10 Constraints, Round 1 vs Round 2
Source: own elaboration

The consensus reached in Round 2 becomes self-evident when we observe the number of constraints with hardly any significance in Round 1 that now appear at the top of the table in Round 2 —e.g. *Commoditized product offering*, *Power of unions/labour force*, *Slot availability*, *Excess capacity*, *Business travel demand*. An analogous process, but in the opposite direction, occurs with constraints such as *Labor costs*, whose frequency drops to the middle of the table despite being the most cited constraint of all in Round 1.

Meanwhile, the analysis of responses to Q2 and the comparison of the top 15 value repositories in rounds 1 and 2 (Table 8) reflects a somewhat similar underlying process of consensus. In this case, some of the most cited value repositories in Round 1 —e.g. *Network, Capacity management, Customer experience, Information management*— remain at the top of the list in Round 2, despite the large number of different value repositories provided by Panel members.

Round 2 also shows new entries to the list of top 15 value repositories —e.g. *Brand, Innovation, Safety and security, Alliances*— and the drop of other previously top labelled value repositories —e.g. *Scheduling, Procurement, Relationships with stakeholders, Digital channels*. This process of entries/exits is a typical characteristic of Delphi groups sharing aggregated knowledge and building consensus.

Finally, yet importantly, let us recall that the top 10 constraints and the top 15 value repositories are the only elements that qualify for the next rounds of the Delphi process. All others, although important, remain excluded from further analysis in the field research.

Value Repositories	Frequencies	
	Round 1	Round 2
Network	5	17
People and talent	3	16
Revenue management	2	16
Management/Leadership	2	15
Capacity management	6	14
Corporate culture	3	14
Customer experience	4	13
Alliances	2	12
Brand	2	12
Innovation	1	12
Distribution strategy	2	11
Safety and security	1	11
Customer-centric proposition	2	10
Information management	5	10
Process and cost optimization	3	10

Table 8. Comparison of Top 15 Value Repositories, Round 1 vs Round 2
Source: own elaboration

D. Delphi round 3

On the basis of the top 10 constraints and top 15 value repositories determined in Round 2, the Delphi process continued on to ask Panel members the following questions:

- Q1: *How do the 10 consensus value constraints impact on the 15 consensus value repositories?*

- Q2: *How are the 15 consensus value repositories interlinked and how they impact on each other?*
- Q3: *How do the 15 consensus value repositories impact on airlines' Operating Margin?*

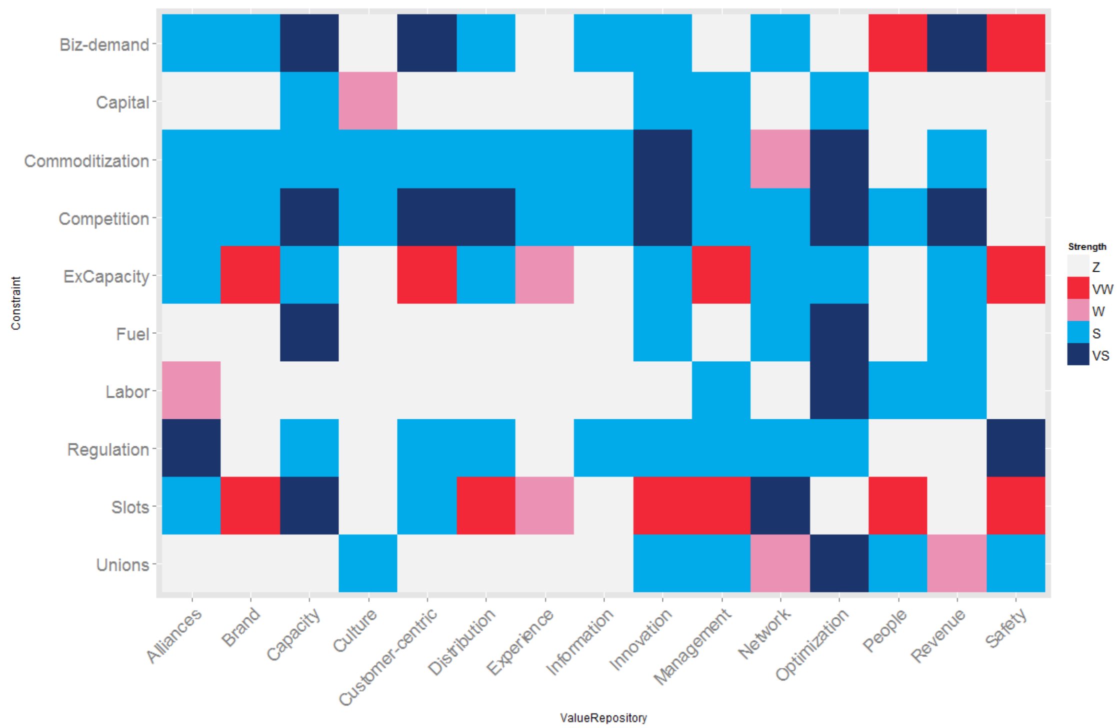
What follows below is the analysis of the responses given by Panel members to these questions. For sake of clarity, we have used a heat-map like plot to graphically display the most cited levels of strength of interconnectedness between components.

Note that the term "interconnectedness" is divided into five levels of strength, each represented by a color in the heat-map plot: *i)* dark blue for "Very Strong" interconnectedness, *ii)* light blue for "Strong", *iii)* pink for "Weak", *iv)* red for "Very Weak", and *v)* white for "Zero" interconnectedness. For example, interconnectedness between the *Biz-demand* constraint and the *Safety and security* value repository is most frequently labelled by Panel members as "Very Weak", thus this interconnection appears in the heat map plot in red color.

D.1 Interconnectedness between constraints and value repositories

The analysis of responses to Q1 shows a wide dispersion in the strength of most cited interconnections existing between constraints and value repositories. This is visually apparent by the fact that no color —representing the strength of interconnectedness— dominates the heat-map plot (Fig.15).

Some constraints such as *Fuel cost, Capital intensity and Labor costs*, although were labelled key by Panel members in previous rounds, are now labelled as weakly interconnected with value repositories, exception made for some value repositories —i.e. *Process and cost* *optimization, Capacity management*— for which strength of interconnectedness is mainly labelled as strong or very strong.



(*) Z: Zero, VW: Very Weak, W: Weak, S: Strong, VS: Very Strong

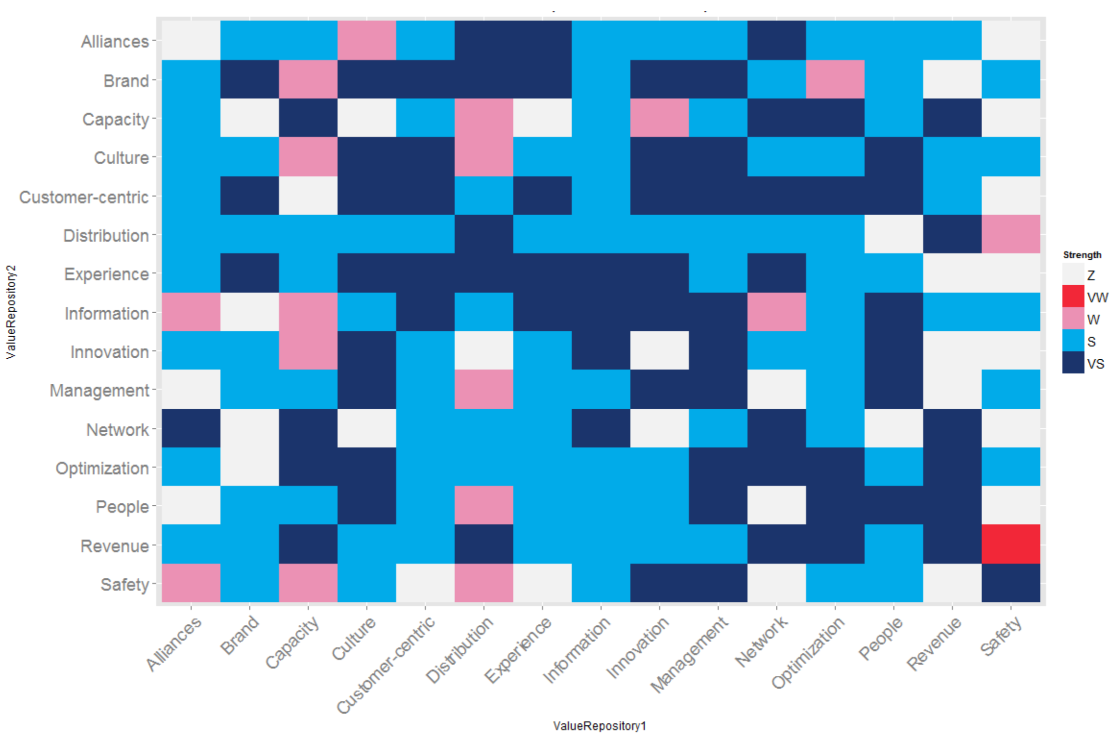
Figure 15. Strength of Interconnectedness: Constraints-Value Repositories (Round 3)
Source: own elaboration

This observation contrasts with the (mainly) "Strong" interconnectedness shown by other constraints, such as *Commoditized product offering* and *Competition from other airlines*. At the same time, *Slot availability* and *Excess capacity* are the constraints with the weakest interconnectedness of all.

The analysis from the value repositories side shows that only *Process and cost optimization* has mainly "Very Strong" interconnectedness with constraints. On the contrary, *Safety and security* is the value repository with the weakest interconnectedness of all.

D.2 Interconnectedness among value repositories

The most frequently labelled strength of interconnectedness among value repositories is summarized in the heat-map plot presented in Fig.16. The visual observation of the plot suggests an almost total lack of red color, or "Very Weak" interconnections, with the exception of the interconnectedness between *Safety and Security* and *Revenue Management*. This contrasts with the fact that dark blue ("Very Strong") and light blue ("Strong") interconnections are the predominant in the plot.



(*) Z: Zero, VW: Very Weak, W: Weak, S: Strong, VS: Very Strong

Figure 16. Strength of Interconnectedness: Value Repositories (Round 3)
Source: own elaboration

Some value repositories are particularly worth noting for their high strength of interconnectedness. This is particularly the case of the *Customer Experience* and *Customer-centric proposition* value repositories, which mainly present "Very Strong" interconnectedness with other value repositories. Others, such as *Distribution Management*, *Process and cost optimization*, and *People and talent*, also stand out for its “Strong” level of interconnectedness.

D.3 Interconnectedness between value repositories and Operating Margin

Panel members’ responses to the question of interconnectedness between value repositories and Operating Margin mostly reflect either a “Very Strong” (VS) or “Strong” (S) interconnectedness. This can be visually evidenced by observing Fig.17, where interconnections of green (“Strong”) and blue color (“Very Strong”) dominate.

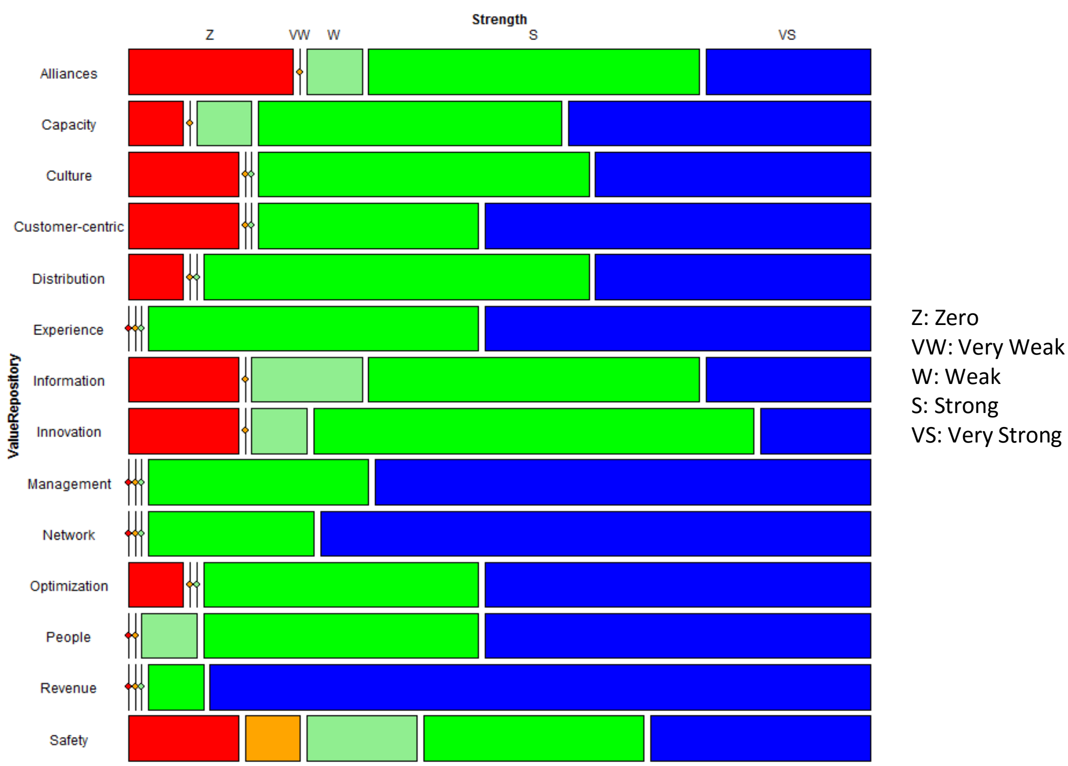


Figure 17. Strength of Interconnectedness: Value Repositories-Op. Margin (Round 3)
Source: own elaboration

It is worth highlighting the “Very strong” interconnectedness that Panel members assign to value repositories such as *Revenue Management*, *Network* and *Management/Leadership*, not to mention the "Strong" interconnectedness given to *Innovation*, *Alliances*, and *Distribution Management*, to name just a few examples.

E. Delphi round 4

Upon completion of Round 3, a report containing an individual benchmarking of the responses given by each member of the Experts' Panel with respect to the aggregated responses of the Panel was drafted and handed out to the members (see example in Appendix B). The report allowed Panel members to know the differences existing between their responses and those of the Panel, so that they could be taken into account in Round 4 questionnaire.

Specifically, Round 4 questionnaire asked Panel members to reach consensus on the interconnectedness among components, in addition to their strength and sign. These were the questions made to Panel members:

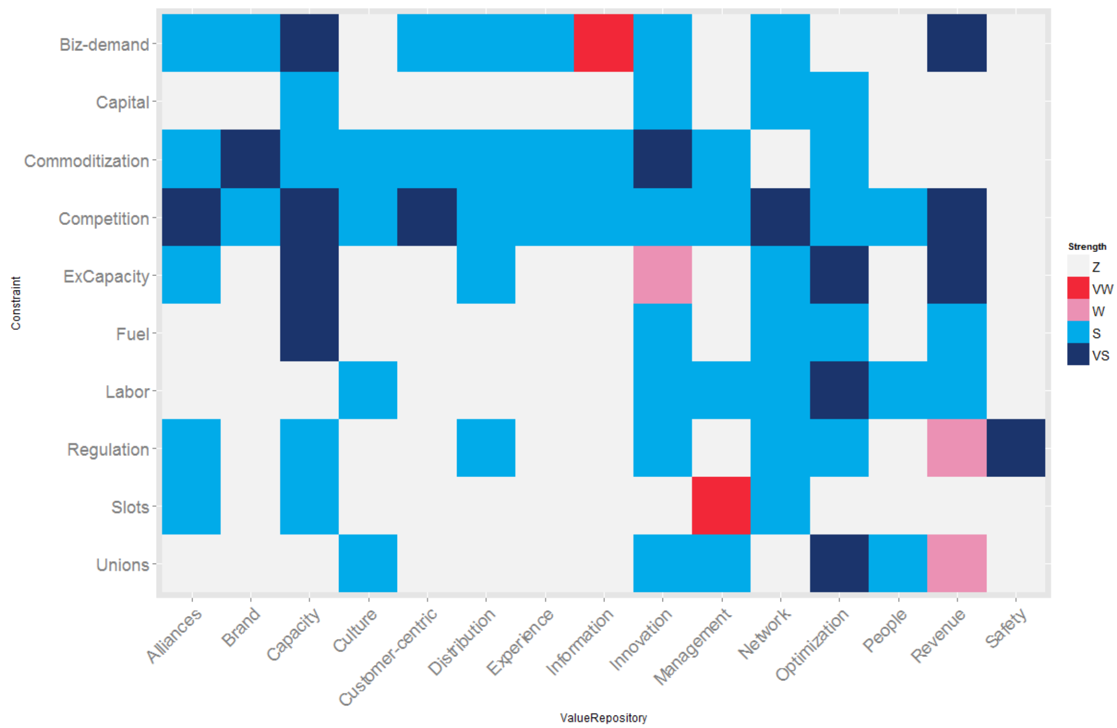
- Q1: *Set the final strength and sign of the links between the 10 consensus value constraints and the 15 consensus value repositories.*
- Q2: *Set the final strength and sign of the links between the 15 consensus value repositories.*
- Q3: *Set the final strength and sign of the links between the 15 consensus value repositories and airline's operating margin.*

E.1 Interconnectedness between constraints and value repositories

The comparative analysis of Panel members' responses on the interconnectedness between constraints and value repositories in rounds 3 and 4, leads us to conclude the following:

- There is a decrease in the interconnectedness mainly labelled as "Very Weak"; this is visually reflected by the lower number of red interconnections shown in the heat-map plot (Fig.18).
- The interconnectedness labelled as "Zero" moderately increases from Round 3 to Round 4, therefore many of the interconnections previously identified seem to lose momentum.
- The interconnectedness labelled as "Strong" and "Very Strong" by Panel members in Round 3 practically keeps the same level of strength in Round 4.

By comparing the results gathered in rounds 3 and 4, we may conclude that Panel members have fundamentally reached a broad consensus on the strength of the interconnections labelled as "Strong" and "Very Strong". Similarly, Panel members have opted to reduce the strength of a good number of the interconnections mostly labelled as "Weak " and "Very Weak" in Round 3, changing them to a "Zero" level of interconnectedness in Round 4. This should be no surprise, as this is part of a typical "experts consensus" building process driven the Delphi process.



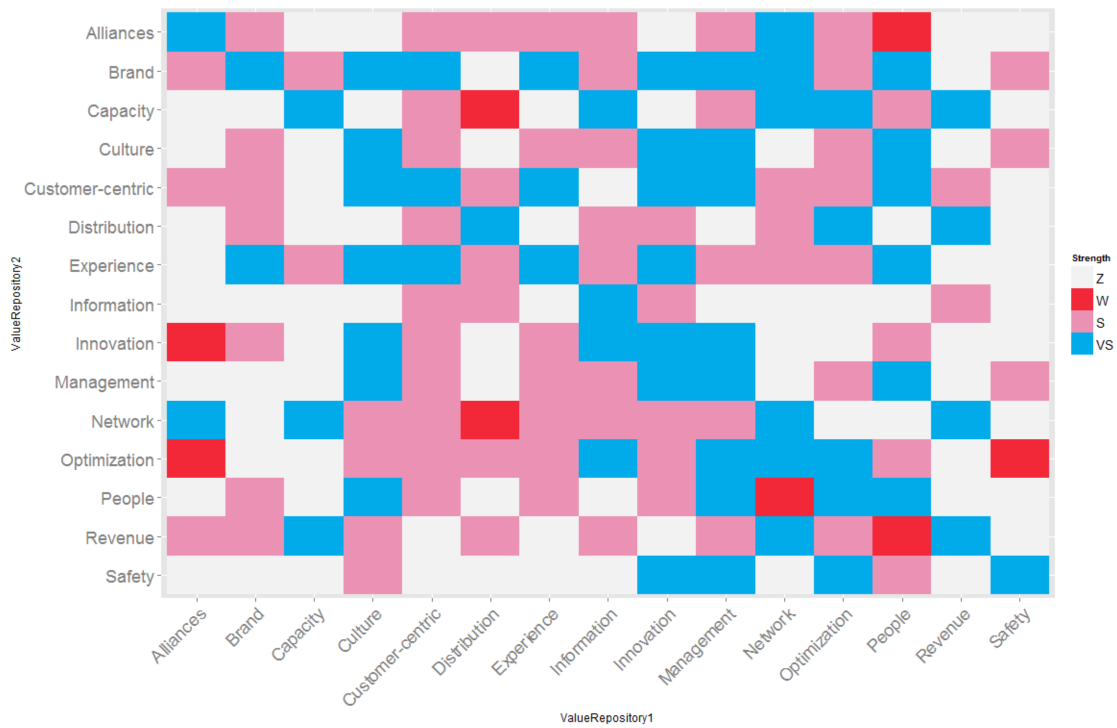
(*) Z: Zero, VW: Very Weak, W: Weak, S: Strong, VS: Very Strong

Figure 18. Strength of Interconnectedness: Constraints-Value Repositories (Round 4)
Source: own elaboration

E.2 Interconnectedness among value repositories

The analysis of the responses on the interconnectedness among value repositories in Delphi Round 4 reflects noteworthy changes with respect to Round 3. Most significant examples of such changes is the disappearance of the interconnections mostly labelled as "Very Strong" (dark blue color), whereas the predominant strength now becomes "Strong" (pink color), as we can see in Fig.19.

Also worth noting is the growth in the number of (mainly) "Zero" (non-existent) interconnections among value repositories with respect to Round 3, in addition to the increase in the interconnections mainly labelled as "Very Weak".



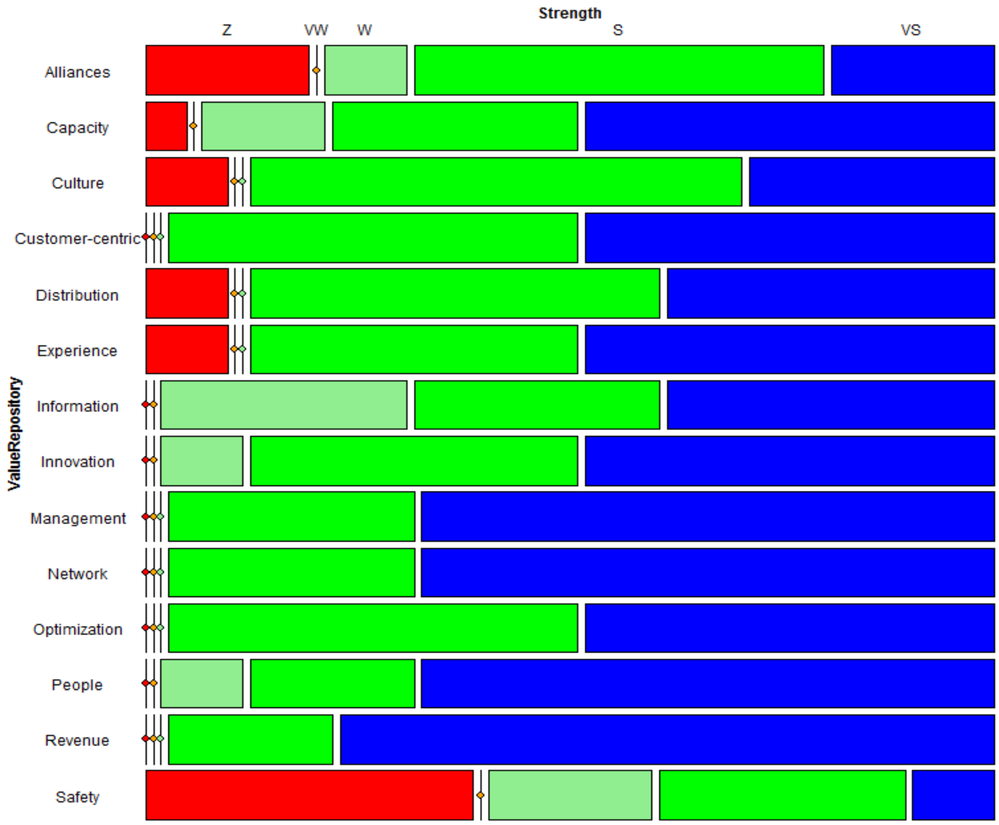
(*) Z: Zero, VW: Very Weak, W: Weak, S: Strong, VS: Very Strong

Figure 19. Strength of Interconnectedness: Value Repositories (Round 4)
Source: own elaboration

E.3 Interconnectedness between value repositories and Operating Margin

Round 4 responses on the interconnectedness between value repositories and Operating Margin mostly reveal an increase in the strength of these interconnections with respect to Round 3.

As we can observe in Fig.20, the proportion of mostly labelled “Very Strong” (VS) interconnections has increased in almost all value repositories, the only exceptions being the interconnections of *Alliances*, which maintains the same strength as in Round 3, and *Safety and Security*, which is now mostly labelled as a “non-existent” by Panel members.



(*) Z: Zero, VW: Very Weak, W: Weak, S: Strong, VS: Very Strong

Figure 20. Strength of Interconnectedness: Value Repositories-Op. Margin (Round 4)
Source: own elaboration

5.3.2 Mapping the firm-system and Visualizing complexity

Once data on the key components of airlines and its interconnectedness has been captured, it is time to map the firm-system and visualize the firm's network complexity. For sake of brevity, we have merged both the mapping and visualizing stages together (see Chapter 4), which would otherwise be separated stages were this field research a detailed firm-specific application of the CBVF methodology.

Key for our purposes at this point is to gather a thorough understanding of the airlines value system dynamics. To achieve this goal, the image of a network is a natural one to use, especially as we gather knowledge to better understand the behavior of the components of the firm and their interconnectedness (Kolaczyk 2009). Notwithstanding the foregoing, the term “network” is one used ambiguously and in a variety of ways —e.g. as a graph, as a collection of interconnected things. In this field research we use the term “network” in its most general form to refer to a graph representing a network, or simply a “network graph”.

Among the many methods provided by modern “state-of-the-art” network analysis, the one used by the author has to do with descriptive analysis of data. This approach primarily involves the visualization and numerical characterization of the airlines’ value creation network. Specifically, the author constructs a visual summary of the airlines’ value creation network, which in turn enables us to combine the data collected in the Delphi process into one single digraph from where we can compute diverse topological complexity methods.

Under this approach, a graph made of three different types of vertices —representing the constraints, value repositories, and Operating Margin— and edges —representing the interconnection between pairs of vertices— is used to represent the firm’s network.

A. Visualizing the Airlines’ Value Creation Network (AVCN)

In this section we address the task of visualizing the airlines’ value creation network (AVCN). In other words, we focus on drawing a graph that can help us visualize the AVCN and appraise key topological complexity methods.

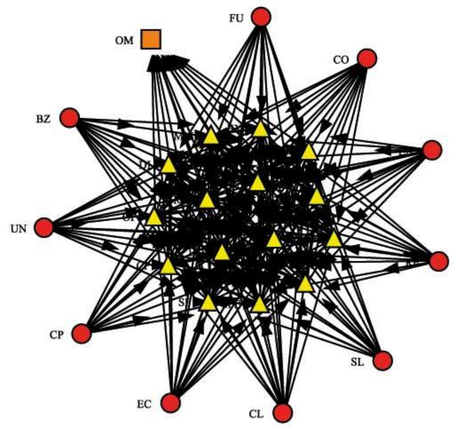
We start by assessing different ways to lay out the AVCN graph, followed by some ways to decorate such layout using a combination of mathematics, human aesthetics, and algorithms.

Fig.21 offers a first approach to the graph of the AVCN, considering different levels of strength of interconnectedness between constraints, value repositories and Operating Margin.

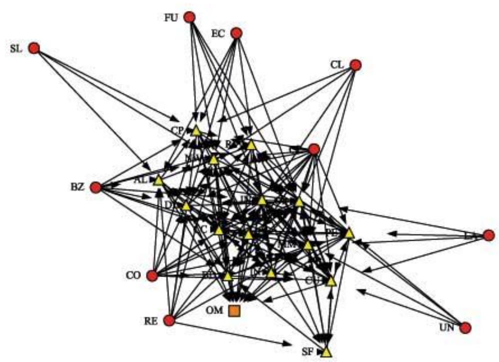
A first impression that we form when we observe the AVCN graph at the top of Fig.21 is that of a heavily connected graph, where everything seems highly connected to everything else. This is certainly a “clogged” graph that makes it visually difficult for an observer’s eye to discern between links. It is needless to say that the AVCN graph at the top does not help much if we seek clarity, nor does it allow us to infer valuable conclusions from a visual standpoint, other than the AVCN is inherently complex.

To appraise key topological complexity methods and draw meaningful conclusions at this stage of the CBVF methodology, such as what are the key nodes or key interconnections in the AVCN, one possible solution is to discriminate the number of interconnections by strength. Following this method, the graphs in the middle and at the bottom of Fig.21 display only the links of higher strength, with the graph at the bottom showing only those links labelled as “Very Strong” by Panel members. As we note, this latter graph is made up of the same 26 nodes as the graph at the top, but with only 77 of the 319 links; likewise the network degree distribution —which gives us an idea of the distribution of connections in the network— noticeably decreases from 29.99 to 5.92. Now the AVCN appears much more tidy and clear to our eyes.

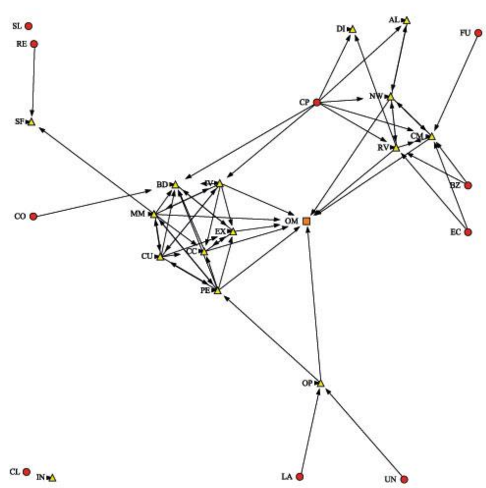
This progressive reduction in the number of links in the AVCN graph enables us to infer the following valuable observations:



Type: directed-weighted
Layout: Fruchterman-Reingold
Colors: Red-circle: constraints, Yellow-triangle: value repositories, Orange-square: Operating Margin
Nodes: 26
Edges: 390
15 self-loops
Degree: 29.99
All existing interconnections are displayed



Type: directed-weighted
Layout: Fruchterman-Reingold
Colors: Red-circle: constraints, Yellow-triangle: value repositories, Orange-square: Operating Margin
Nodes: 26
Edges: 238
15 self-loops
Degree: 18.31
Only Strong & Very Strong interconnections are displayed



Type: directed-weighted
Layout: Fruchterman-Reingold
Colors: Red-circle: constraints, Yellow-triangle: value repositories, Orange-square: Operating Margin
Nodes: 26
Edges: 77
15 self-loops
2 isolated nodes
Degree: 5.92
Only Very Strong interconnections are displayed

Figure 21. Airlines' Value Creation Network (AVCN)
Source: own elaboration, based on Pablo-Martí, Muñoz-Yebra et al. 2014

- Some value repositories are more critical than others when it comes to value creation —e.g. *Revenue management*, *Capacity management*, *Customer experience*, *Customer-centric proposition*, *Innovation*.
- Some value repositories are much more influenced by constraints than others —e.g. *Process and cost optimization, Brand, Revenue management, Capacity management.*
- Some constraints are much less relevant to value creation than we might have initially thought from experience —e.g. *Slots availability* and *Capital intensity.*
- Only nine value repositories significantly affect Operating Margin.

Using a network scaling method is of great help at this point to address the above observations in more detail and gather an in-depth knowledge on the underlying structural architecture of the AVCN and its building process.

Specifically, the author used a Pathfinder Network Scaling method. This method relies on the so-called triangle inequality to eliminate redundant or counter-intuitive links. Given two links or paths in a network that connect two nodes, the link/path preserved is the one with a greater weight defined via the *Minkowski* metric. It is assumed that the link/path with the greater weight better captures the interrelationship between the two nodes and that the alternative link/path with less weight is redundant or even counter-intuitive and should be pruned from the network (Indiana 2005).

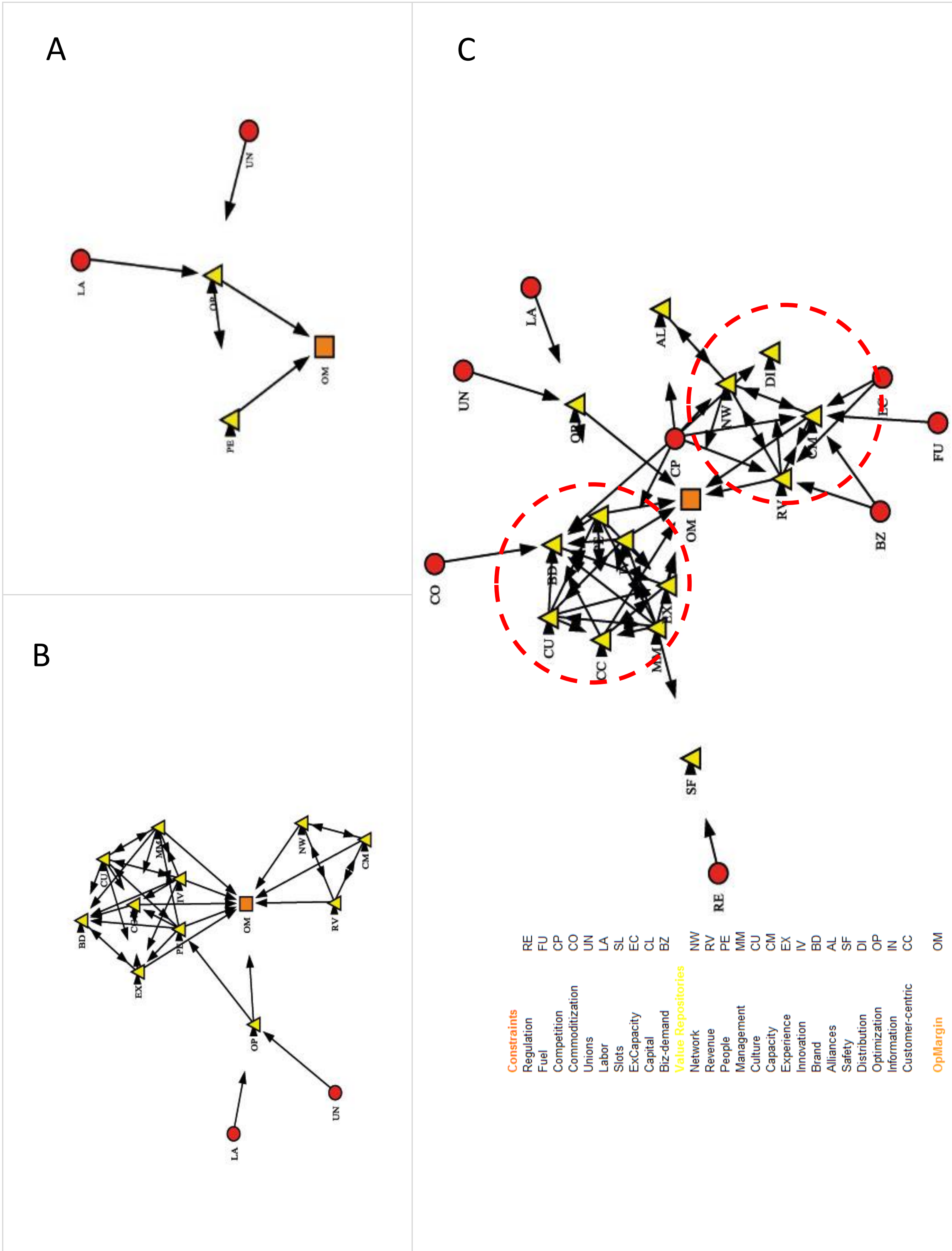


Figure 22. AVCN Pathfinder Network Scaling
Source: own elaboration

Two parameters r and q influence the topology of a pathfinder network. The $r-parameter$ influences the weight of a path based on the *Minkowski* metric. The $q-parameter$ defines the number of links in alternative paths, up to which the triangle inequality must be maintained. A network of N nodes can have a maximum path length of $q = N - 1$. With $q = N - 1$ the triangle inequality is maintained throughout the entire network (Schvaneveldt, 1990).

Fig.22 contains three graphs (A, B and C) simulating the transition of the AVCN through three different stages of its building process. Each graph incrementally assigns higher distances or dissimilarities among the set of links and the set of nodes upon their relative positions. The graphs so created enable us to explain the underlying organization of the AVCN in a highly schematic way, as well as to visually determine its key components and interconnectedness with Operating Margin (OM). Furthermore, we are able to graphically visualize the clustering processes growing around the airlines' Operating Margin in the form of two incipient groups of value repositories marked by two red circles (C).

The analysis of the AVCN graph can be taken one step further by using Hierarchical Clustering (HC) and a tree-like dendrogram (Figs. 23 and 24). The HC algorithm produces, as the name indicates, an entire hierarchy of nested partitions in the structure of value repositories, comprising the following clusters when the strength of the interconnections is "Strong" or "Very Strong":

- *Cluster 1* (Red), contains only two value repositories: *Information management* and *Process and cost optimization*.

- *Cluster 2* (Green), contains six value repositories: *Network, Revenue management, Capacity management, Alliances, Distribution management,* and *Customer-centric proposition*.
- *Cluster 3* (Blue), contains seven value repositories: *People and talent, Management-Leadership, Safety and security, Corporate culture, Innovation, Brand,* and *Customer experience*.

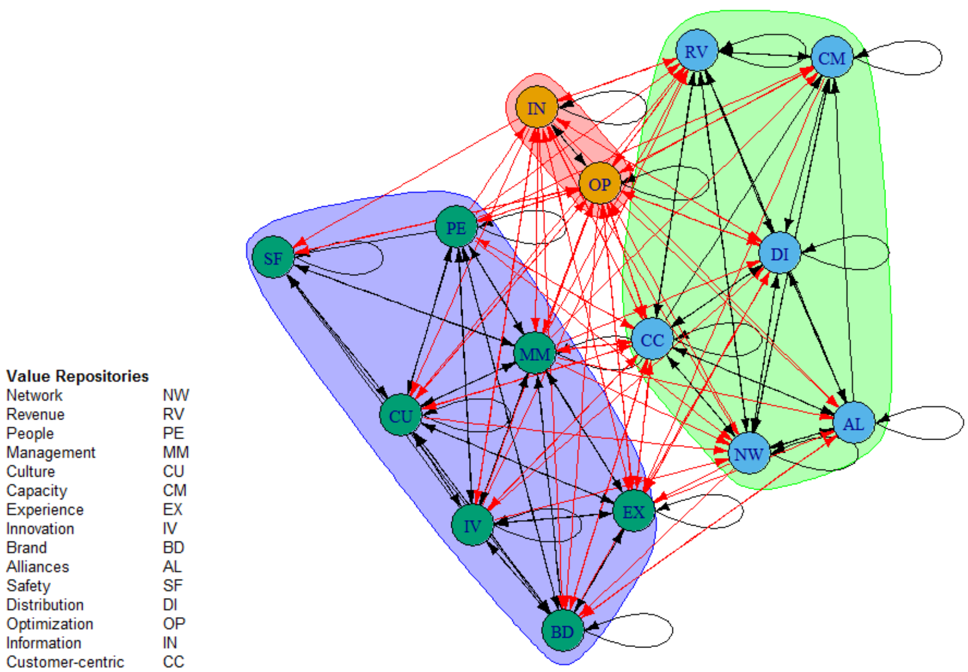


Figure 23. Clusters in the AVCN
Source: own elaboration

The HC algorithm takes the distance information —dissimilarity— between the value repositories, and links the pairs of them that are close together. This process is repeated linking these newly formed clusters to each other and to other value repositories in order to create bigger clusters, until all of them are linked together in a hierarchical tree or tree-like dendrogram (Fig.24). The height of the links indicates the distance between the value repositories.

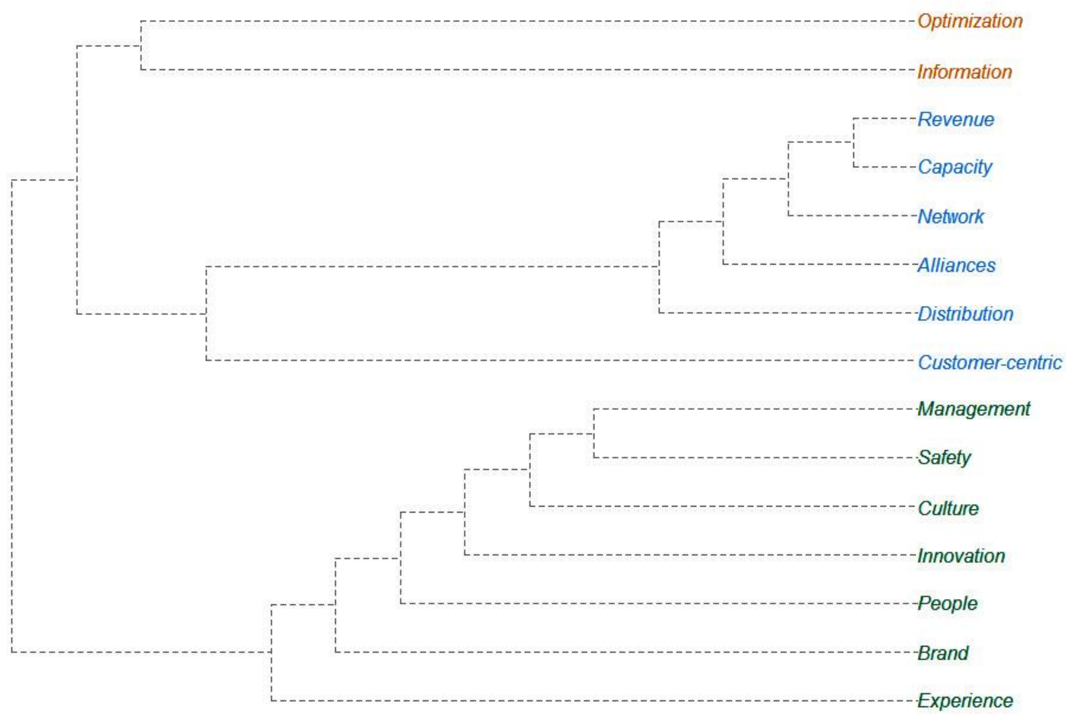


Figure 24. AVCN Tree-like Dendrogram
Source: own elaboration

B. Descriptive methods of AVCN complexity

A summary of some key topological methods available to comprehend complexity of the AVCN is presented in Appendix F, subsection 2.4. These methods mostly derive from areas outside mainstream statistics and have traditionally been used for descriptive purposes (Kolaczyk, Csárdi 2014).

An overwhelming proportion of these methods are graph-theoretic in nature, and have their origins in mathematics and computer science. More recently, the field of physics has also been an important contributor, with many methods often motivated by analogues in statistical mechanics.

The topological network complexity methods presented in Appendix F include vertex and edge characteristics, measures of network cohesion, and assortativity and mixing.

C. What value repositories are most important?

To determine the most important or influential value repositories within the AVCN, we use a network centrality measure known as *Eigenvector centrality*. This measure is based on the notion of “status” or “rank” of the value repositories specified, and seeks to capture the idea that the more central the neighbors of a value repository are, the more central that value repository itself becomes (Kolaczyk, Csárdi 2014). The *Eigenvector centrality* is therefore an approximate measure of the importance of each value repository within the AVCN.

As we can see in Table 9, upon computing Eigenvector centrality for the AVCN we can conclude that *Customer-centric proposition* is the most influential/important value repository of all. Based on this first outcome, we continue to assign a maximum score of one to the importance of *Customer-centric proposition* and compute the importance of each subsequent value repository with respect to the former.

Value Repository	Importance
Customer-centric proposition	100
Brand	98
Customer experience	95
Revenue management	94
Network	88

Value Repository	Importance
Process and cost optimization	87
Distribution management	86
Corporate culture	80
Alliances	79
Management (Leadership)	79
Capacity management	78
People and talent	78
Information management	73
Innovation	70
Safety and security	50

Table 9. Most Important/Influential Value Repositories in the AVCN
Source: own elaboration

It is worth noting that customer-related value repositories —e.g. *Brand, Customer experience*— are among the most important/relevant value repositories in the AVCN, whereas *Safety and security* is the least important/relevant among the top fifteen value repositories.

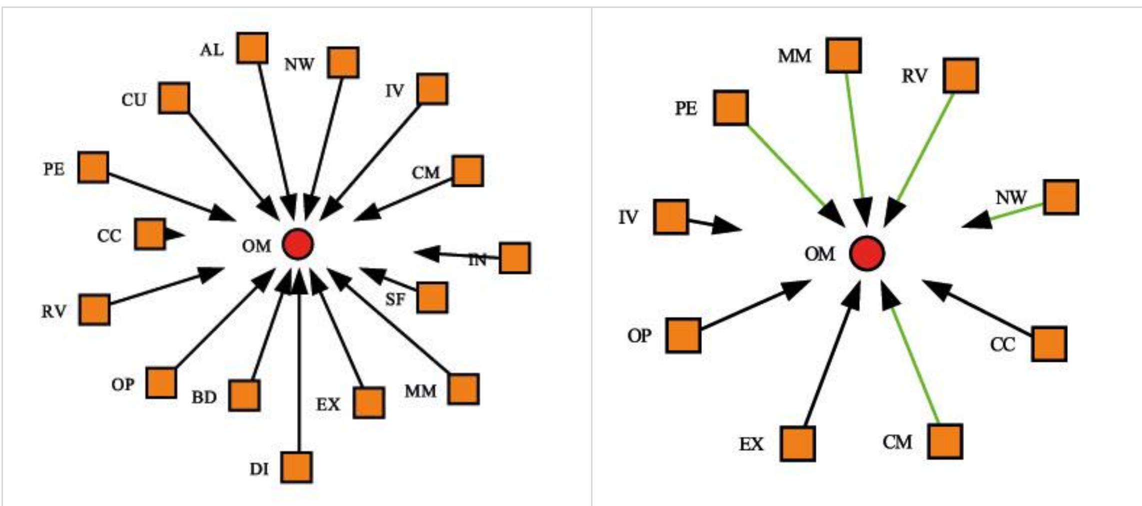
D. What affects most the Operating Margin?

Up to this point we have identified nine value repositories that affect airlines' Operating Margin. Now we are interested in finding out further details on what those value repositories are, and what the strength of the interconnections between each value repository and Operating Margin is.

We resort to the AVCN graph to visually determine the interconnections having an impact on the airlines' Operating Margin. As we can see in the graph on the left in Fig.25, all top fifteen value repositories identified by Panel members have some kind of interconnection with

Operating Margin. What varies from one value repository to another is the strength of interconnectedness.

In contrast, the graph on the right shows that only five value repositories have a "Very Strong" interconnectedness with Operating Margin: *Network, Capacity management, Revenue management, Management/Leadership,* and *People and talent*; whereas those with a "Strong" interconnectedness are four: *Innovation, Process and cost optimization, Customer experience,* and *Customer-centric proposition.*



Network (NW), Revenue management (RV), People and talent (PE), Management/Leadership (MM), Corporate culture (CU), Capacity management (CM), Customer experience (EX), Innovation (IV), Brand (BD), Alliances (AL), Safety and security (SF), Distribution management (DI), Process and cost optimization (OP), Information management (IN), Customer-centric proposition (CC), Operating Margin (OM)

Left: All Value Repositories connecting with Operating Margin. *Right:* Value Repositories with "Strong" (black arrows) and "Very Strong" (green arrows) interconnectedness.

Figure 25. Interconnectedness of Value Repositories and Operating Margin
Source: own elaboration

5.3.3 Modeling and simulation

Previous stages in this thesis field research have provided us with the data needed to build the airlines' value creation network (AVCN), to map the interconnectedness between the different AVCN components, and between these and Operating Margin. Now according to the CBVF methodology (Chapter 4), it is time to address the question on how to convert the AVCN into a practical model that enables airlines' managers simulate future scenarios and anticipate the impact on performance.

The technique chosen by the author for modeling and simulation consists of a **Fuzzy Cognitive Map (FCM)**. The FCM is a soft-computing technique that enables researchers and practitioners to model the properties of the AVCN from expert knowledge and determine possible future states and instabilities of the firm's network (see Chapter 4, Section 4.3.7, for a detailed description on FCMs). The FCM is not the only technique available to approach the CBVF, there are of other methods and tools that could have been used in this field research, such as those described in Chapter 4. However, the scope and method of our field research made this technique specially suitable for the goals pursued.

In particular, FCMs are most useful when other more refined quantitative methods fail. This usually occurs in broad knowledge domains with only partial experts, in situations with little or no relevant historic data, and in cases where most information is qualitative and fuzzy. FCM models use a mix of qualitative and quantitative approaches, consider multivariate interactions leading to nonlinearities, and aim to make implicit assumptions (or mental models) explicit (Jetter, Kok 2014). These properties of FCMs meet altogether our field research modeling and simulation needs.

Once the AVCN-FCM model has been formulated, the subsequent simulation tasks are performed by studying how uncertainty in the outcome variable —Operating Margin— can be attributed to different changes in the source of inputs —i.e. value repositories and constraints. This simulation technique, known as **Sensitivity Analysis (SA)**, aims at analyzing the behavior of the firm response locally around the interconnectedness of the AVCN components and Operating Margin.

The importance and usefulness of SA is widely recognized in the literature (Saltelli 2002, Cacuci, Ionescu-Bujor et al. 2005, Carrillo-Hermosilla 2015), where we can find a good number of reviews and applications of SA in the various areas of applied economics —i.e. decision making, communication, increased understanding of systems, and model development, among others. For some authors a sensitivity analysis should be a prerequisite for model building and *"an integral part of any solution methodology"* (Pannell 1997), without which the status of a solution could not be understood. In this field research, the SA is a method used for the corroboration, quality assurance, and demonstrability of our AVCN-FCM based analysis (Saltelli 2002).

It is worth noting that the ultimate goal of the FCM is not to create a ‘‘true’’ model of the AVCN, but a useful and formalized description of the perception of a group of experts in the airline industry. A benchmark that gauges the validity of the FCM should thereafter assess whether the FCM adequately describes what the Panel members know about value creation in airlines. This in turn would require Panel members to take an active role in practical model testing.

A. The AVCN-FCM model

Construction of our AVCN-FCM model consists of a multi-step process that captures knowledge from experts in the form of a network or map, formally describes the AVCN as an adjacency matrix, and applies neural network computation to refine the model and analyze the results.

For the purpose of this field research, the FCM model construction framework consisted of three steps (Jetter, Kok 2014):

1. Knowledge capture (Step 1). This process step included all the elicitation activities that led to formulate one individual weighted causal cognitive map describing the AVCN for each Panel member.
2. Detailed design of the FCM inference model (Step 2). Included the aggregation of the individual causal cognitive maps of Step 1 into one single relational adjacency matrix, and the design and implementation of the FCM inference engine.
3. Simulation and interpretation of results (Step 3). This was accomplished by choosing the input vectors and carrying out a SA on the basis of real-life airlines scenarios.

A.1 Step 1: Knowledge capture

As seen in previous sections, the Delphi process is the technique used in this field research to capture knowledge from Panel members. Therefore, the Delphi process itself encompasses all the elicitation activities needed to produce the members' individual cognitive maps, prior to the construction of the final (aggregated) AVCN-FCM model.

Furthermore, as far as the analysis of the data captured through the Delphi process is complemented with the mapping of the firm-system and visualization of complexity activities (Section 5.3.2), we end up having a precise idea on how the AVCN-FCM looks like and what the critical structural and relational parameters for the construction of the FCM model must be.

A.2 Step 2: Design of FCM model

In Step 2 we mathematically aggregate the individual cognitive maps gathered from the Panel members into a single integrated cognitive map. This is accomplished by first translating each individual map into square adjacency matrices of the same size. This operation results in a new matrix, the entries of which are the average of the weights of the interconnections assigned by the members.

Weights in the matrix are based on a Likert scale with five different levels of strength, expressed as: *zero* (0), *very weak* (0.25), *weak* (0.5), *strong* (0.75), and *very strong* (1). Note that the numerical values of the weights indicate the degree of influence between component (or concept) A and component (or concept) B.

Also incorporated into the adjacency matrix are the signs of the causal relations between the components of the AVCN, ranging from *positive* (+1) to *negative* (-1). A positive causality between component A and component B means that an increase of the value of component A will cause an increase in the value of component B, likewise a decrease of the value of component A will cause a decrease in the value of component B. Negative causality between components means that an increase in the first component will cause a decrease in the value of the second component, or that a decrease of the first component will cause the increase of the second. When no relationship exists between two components, the weight assigned by Panel members is zero.

The aggregated AVCN-FCM adjacency matrix used in our field research is shown in Table 10.

Nodes	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Regulation	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.75	0.5	0.00	0.63	0.00	0.75	0.00	-0.75	0.00	-0.75	1.00	-0.75	0.75	0.25	-0.5	0.00
Fuel	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.75	0.63	0.00	0.00	0.00	1.00	-0.13	0.75	0.00	0.00	0.00	0.13	0.75	0.13	0.5	0.00
Competition	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	-1.00	0.75	0.75	0.75	1.00	0.75	0.88	0.88	1.00	0.00	0.88	0.75	0.75	0.75	0.00
Commoditization	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5	0.5	0.13	0.75	0.63	0.75	-0.75	0.75	0.88	0.75	0.00	0.75	0.75	0.75	0.75	0.00
Unions	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.5	0.38	-0.75	-0.75	-0.75	-0.13	0.13	-0.5	0.25	0.25	0.38	0.00	-1.00	0.13	0.00	0.00
Labor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.5	0.5	0.75	0.75	0.75	-0.38	-0.25	-0.38	0.00	0.5	0.00	0.00	-0.88	0.00	0.00	0.00
Slots	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.13	0.13	0.25	0.13	0.75	0.25	0.25	0.00	0.63	0.00	0.25	0.25	0.00	0.25	0.00
ExCapacity	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.75	-1.00	0.00	0.38	0.25	-1.00	0.38	0.5	0.13	0.75	0.00	0.63	0.75	0.00	0.13	0.00
Capital	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.75	0.00	0.00	0.63	0.13	0.75	0.13	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
Biz-demand	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	1.00	0.00	0.13	0.38	1.00	0.75	0.75	0.75	0.75	0.00	0.75	0.25	0.38	0.75	0.00
Network	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.5	0.00	0.25	1.00	0.75	0.5	0.75	1.00	0.00	0.75	0.75	0.5	0.75	1.00
Revenue	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.5	0.5	0.25	1.00	0.00	0.00	0.00	0.75	0.00	1.00	0.75	0.75	0.75	1.00
People	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	1.00	1.00	1.00	0.75	1.00	0.75	1.00	0.5	0.75	0.00	0.75	0.75	1.00	1.00
Management	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	1.00	1.00	1.00	0.75	0.75	1.00	1.00	0.75	1.00	0.75	0.75	0.75	1.00	1.00
Culture	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	0.75	0.25	0.75	0.5	1.00	0.75
Capacity	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.25	0.00	0.00	1.00	0.75	0.00	0.5	0.00	0.25	0.75	0.75	0.00	0.00	1.00
Experience	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5	0.5	0.75	0.75	0.75	0.00	1.00	0.75	1.00	0.75	0.00	0.75	-0.75	0.75	1.00	0.88
Innovation	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.75	1.00	1.00	0.5	1.00	1.00	1.00	0.5	0.75	0.75	0.75	0.75	1.00	0.88
Brand	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5	0.75	0.75	0.75	0.5	1.00	0.75	1.00	0.75	0.5	0.75	0.00	0.00	0.75	0.75
Alliances	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.75	0.00	0.00	0.5	0.75	0.5	0.5	0.75	1.00	0.00	0.75	0.5	0.5	0.75	0.75
Safety	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.75	0.75	0.5	0.00	0.00	0.75	0.00	1.00	0.25	0.75	0.00	0.5	0.5
Distribution	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.25	0.5	0.25	0.5	0.75	0.5	0.5	0.75	0.00	1.00	0.75	0.75	0.75	0.75
Optimization	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5	0.75	1.00	0.75	0.75	0.75	0.75	0.00	0.75	0.75	0.75	0.75	1.00	0.75	0.75	0.88
Information	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.5	0.75	0.75	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.75
Customer-centric	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.75	0.75	0.75	0.75	1.00	0.75	1.00	0.75	0.00	0.75	0.75	0.75	1.00	0.88
OpMargin	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. AVCN-FCM Adjacency Matrix
Source: own elaboration

A.3 Step 3: Simulation and interpretation of results

Step 3 is the stage where the AVCN-FCM model is initialized; in other words, this is the stage where we set the initial vector value that feeds the model. Once the initial vector has been fed in, the AVCN-FCM model can start performing simulations in a series of iterations.

Input vectors can be chosen to reflect any specific constraint setting, value creation scenario, or policy choice made by the firm. For the purpose of this research, the author used a random input vector as a **Base scenario**, against which different variant scenarios were later compared.

At each running step, the value of the components is recalculated according to equation (1).

$$x_i(t) = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} x_j\,(t-1)\ w_{ji}\right) \qquad (1)$$

Where $x_i(t)$ is the value of component C_i at time t, $x_j\,(t-1)$ is the value of component C_j at time $(t-1)$, w_{ji} is the weight of the interconnection between component C_j and component C_i, and f is the sigmoid function:

$$\mathrm{f} = \frac{1}{1 + e^{-\lambda x}} \qquad (2)$$

In FCM terminology, a running step is defined as the time step during which the values of the components are calculated. As seen in (1), the value of each component is defined by taking all the causal linkage weights pointing to this component and multiplying each weight by the value of the component that causes the linkage. Then, the sigmoid function is applied and an outcome results in the range $[0,1]$.

A Hebbian-based learning algorithm, known as **Differential Hebbian Learning (DHL)** is used for learning the adjacency matrix. The DHL algorithm assumes that, if two concepts on the opposite side of an edge change simultaneously, then the weight of that edge is increased. The difference ΔA_i for every ith concept is computed as $\Delta A_i = A_i(t) - A_i(t-1)$, if the activation of the concept changes. If $\Delta A_i \neq 0$, then the weight between concepts i (cause) and j (effect) is also changed, therefore $w_{ij}(t+1) = w_{ij}(t) + \gamma(t)\big[\Delta A_i \Delta A_j - w_{ij}(t)\big]$. If $\Delta A_i = 0$, then the corresponding weight does not change, therefore $w_{ij}(t+1) = w_{ij}(t)$.

During DHL learning, the values of weights are iteratively updated until the desired structure is found. The weights of outgoing edges for each concept in the adjacency matrix are modified only when the corresponding concept value changes (Papageorgiou 2012).

B. Scenario simulation

Scenario simulation using the AVCN-FCM model can take place in a variety of ways. For example, we might use a structural assessment simulation to compare the AVCN structure with that of a real-life airline, or we might want to conduct an extreme conditions test, namely to test if extreme constraints and/or value repositories values lead to unmanageable airline behavior. Yet, despite how revealing these techniques might be, they would involve a significant amount of airline-specific knowledge, the capture of which lies outside of the scope and method of this field research.

As we have previously explained, the simulation technique chosen in this field research is based on Sensitivity Analysis (SA). SA specifically examines firm's components influence on Operating Margin upon simultaneously changing input parameters. Note importantly that SA is initiated by feeding a random input vector into equation (1), thus obtaining an outcome state vector of reference. A random initialization of the model is required as no absolute valuation of the airlines' components was practicable within the scope of the field research.

Table 11 summarizes the three exemplary scenarios simulated in this stage:

Scenario #	Goal	Related AVCN Components/Constraints
1	Assess the impact of a tougher business environment	Regulation Fuel cost Competition from other airlines Labor cost Business travel demand

Scenario #	Goal	Related AVCN Components/Constraints
2	Assess the impact of better customer-oriented processes	Process and cost optimization Customer-centric proposition Innovation Information management Customer experience
3	Assess the impact of more productive asset management	Network Distribution management Capacity management

Table 11. AVCN-FCM Simulation Scenarios
Source: own elaboration

B.1 Base scenario

A Base scenario is formulated on the basis of a **random input vector**, which is fed into the AVCN-FCM model to generate an outcome state vector of reference. From this Base scenario, new variant scenarios (Table 11) are formulated by simply varying the values of the random input vector. Once these variant input vectors are fed themselves into the model, the deviations between the variant scenario outcomes and the Base scenario outcome are measured and interpreted.

The inference outcome for the Base scenario is shown in Fig.26. As we can see, after performing the iterative inference process for fifty steps, the model reaches an equilibrium point at which the AVCN state vector becomes stable and does not change anymore.

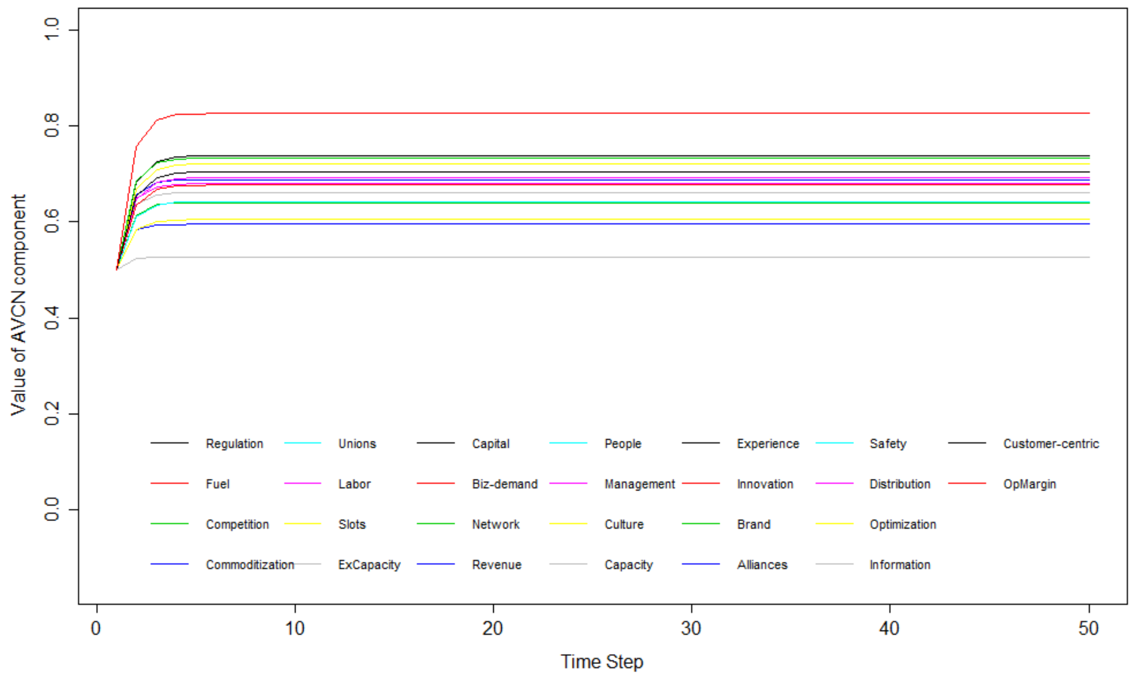


Figure 26. Base Scenario Inference Outcome
Source: own elaboration

Table 12 contains the **outcome state vector** resulting from the Base scenario, to which we will next compare our three scenarios variants.

Base scenario- AVCN Outcome State Vector					
Network	0.64	Capacity	0.66	Safety	0.64
Revenue	0.69	Experience	0.74	Distribution	0.68
People	0.72	Innovation	0.68	Optimization	0.61
Management	0.69	Brand	0.73	Information	0.53
Culture	0.72	Alliances	0.60	Customer-centric	0.70

Operating Margin	
Op. Margin	0.83

Table 12. Base Scenario Outcome State Vector
Source: own elaboration

B.2 Scenario #1: tougher business environment

This simulation was conducted to assess the impact of a tougher business environment on the AVCN components and Operating Margin. In particular, a tougher business environment was defined as one with a more strict regulatory framework, higher resources costs, higher competition from other airlines, and lower business travel demand.

For the purpose of the model inference, we used as input values those contained in Table 13. Note that all values of the input vector not contained in this table remain the same as in the Base scenario.

AVCN Component	Input value
Regulation	-0.9
Fuel	-0.9
Competition from other airlines	-0.9
Labor	-0.9
Business travel demand	-0.9

Table 13. Scenario #1 Input Vector
Source: own elaboration

The inference outcome for Scenario #1 is displayed in Fig.27. The model reaches equilibrium after performing a number of iterations, which means that outcome stability is achieved.

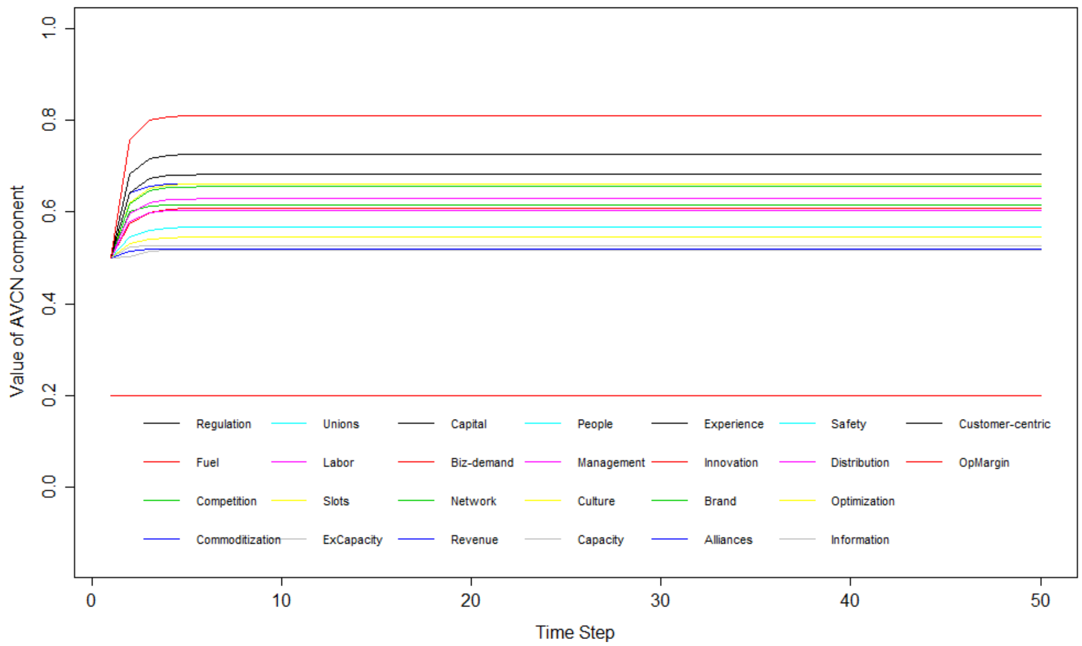


Figure 27. Scenario #1 Inference Outcome
Source: own elaboration

Table 14 below contains the values of the final state vector for Scenario #1 and shows the differences with respect to the Base scenario outcome.

Scenario #1- AVCN Outcome State Vector & Differences with Base scenario								
Network	0.56	-12.3%	**Capacity**	0.46	-30.5 %	**Safety**	0.57	-11.8%
Revenue	0.60	-12.7%	**Experience**	0.72	-2.4%	**Distribution**	0.55	-18.6%
People	0.70	-8.5%	**Innovation**	0.61	-10.5%	**Optimization**	0.54	-10.0%
Management	0.63	-9.4%	**Brand**	0.61	-17.0%	**Information**	0.53	0.0%
Culture	0.66	-8.5%	**Alliances**	0.47	-20.3%	**Customer-centric**	0.64	-9.3%

Operating Margin		
Op. Margin	0.80	-3.0%

Table 14. Scenario #1 Outcome State Vector
Source: own elaboration

We can see that as result of the simulation, the Operating Margin is expected to decrease before a tougher business environment in accordance with airlines' business reality. Also worth noting is the drop in the *Capacity management* value repository, which is the most negatively affected of all firm's components. This, in turn, significantly affects the revenue, distribution and resource related value repositories and, very specifically, those related to people —most probably due to corporate layoffs.

Moreover, according to our simulation, a tougher business environment would lead to a negative impact on the customer-centered value repositories —e.g. *Brand*, *Customer experience* and *Customer-centric proposition*—, as well as those dedicated to organizational improvement —e.g. *Innovation, Information management* and *Process and cost optimization*. In summary, our simulation of a tougher business environment would generate a shock on the viability of the airline itself.

B.3 Scenario #2: implementation of better customer-oriented processes

Our next simulation was conducted to assess the impact of better customer-oriented processes on the AVCN components and the Operating Margin. To perform this simulation, we considered an increase of the input values of the following value repositories:

- Process and cost optimization.
- Innovation.
- Customer experience.
- Information management.
- Customer-centric proposition.

For the purpose of the model inference, these changes translated in the following input values to the AVCN-FCM model, all other values of the input vector remaining the same as in the Base scenario (Table 15).

AVCN Component	Input value
Process and cost optimization	0.9
Innovation	0.9
Customer experience	0.9
Information management	0.9
Customer-centric	0.9

Table 15. Scenario #2 Input Vector
Source: own elaboration

The inference outcome for Scenario #2 appears in Fig.28, where we can observe how outcome stability is reached after a number of inference iterations.

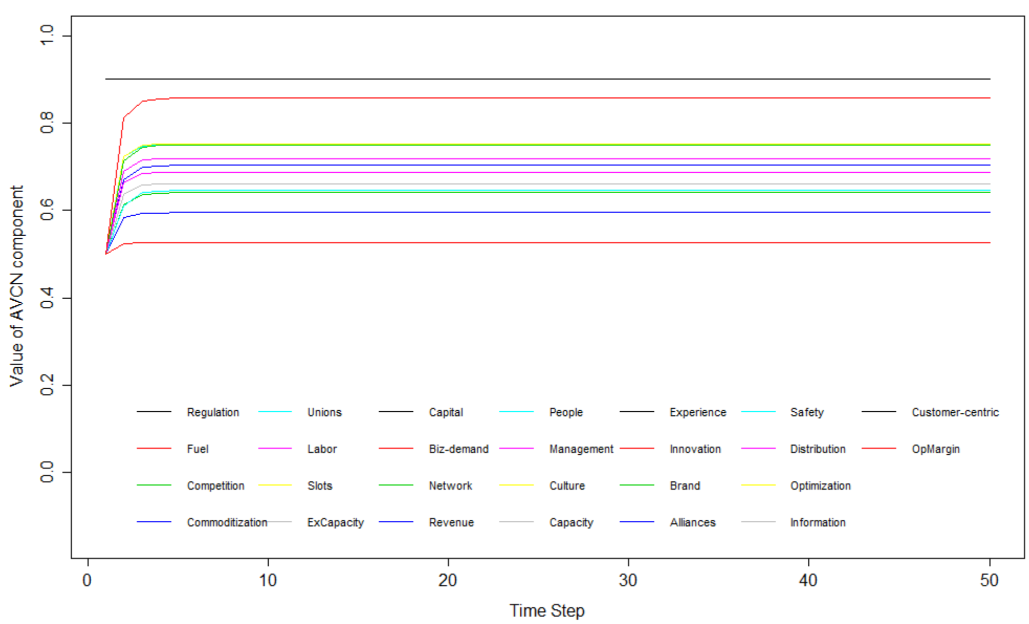


Figure 28. Scenario #2 Inference Outcome
Source: own elaboration

The resulting outcome state vector from Scenario #2, together with the deviations from the Base scenario, is shown in Table 16.

Scenario #2- AVCN Outcome State Vector & Differences with Base scenario								
Network	0.64	0.1%	**Capacity**	0.66	0.1%	**Safety**	0.64	0.6%
Revenue	0.70	2.2%	**Experience**	0.90	NA	**Distribution**	0.68	1.2%
People	0.75	4.3%	**Innovation**	0.90	NA	**Optimization**	0.90	NA
Management	0.72	4.0%	**Brand**	0.75	2.4%	**Information**	0.90	NA
Culture	0.75	4.3%	**Alliances**	0.59	0.0%	**Customer-centric**	0.90	NA

Operating Margin		
Op. Margin	0.86	4.0%

Table 16. Scenario #2 Outcome State Vector
Source: own elaboration

The outcomes derived from the implementation of better customer-oriented processes indicate that a significant increase on the airline's Operating Margin is to be expected. Moreover, this scenario would affect positively people-related value repositories —e.g. *People and talent, Management/Leadership* and *Corporate culture*—, in line with what real-life airline managers would expect. This would help explain the key role of people in firms carrying out customer-oriented policies.

Last but not least, Scenario #2 would also affect positively the perception of the brand by consumers, as well as the *Revenue management* and *Distribution management* value repositories, most probably due to the increased business activity generated by more loyal customers.

B.4 Scenario #3: more productive asset management

Our third simulation was conducted to assess the impact of higher values in those value repositories associated with airlines' asset management, namely *Network, Revenue management, Capacity management,* and *Distribution management*.

For the purpose of the model inference, we used as input values those contained in Table 17, all remaining values of the input vector remaining the same as in the Base scenario.

AVCN Component	Input value
Network	0.9
Revenue management	0.9
Capacity management	0.9
Distribution management	0.9

Table 17. Scenario #3 Input Vector
Source: own elaboration

The analysis of the simulation inference outcome (Fig.29), and of the final AVCN state vector (Table 18), shows the positive impact that this simulation has on the airline's Operating Margin. This outcome is therefore in line with what airline's managers would expect in real-life business. Also note that stability of the outcome is reached after a number of iterations, as can be observed in Fig.29.

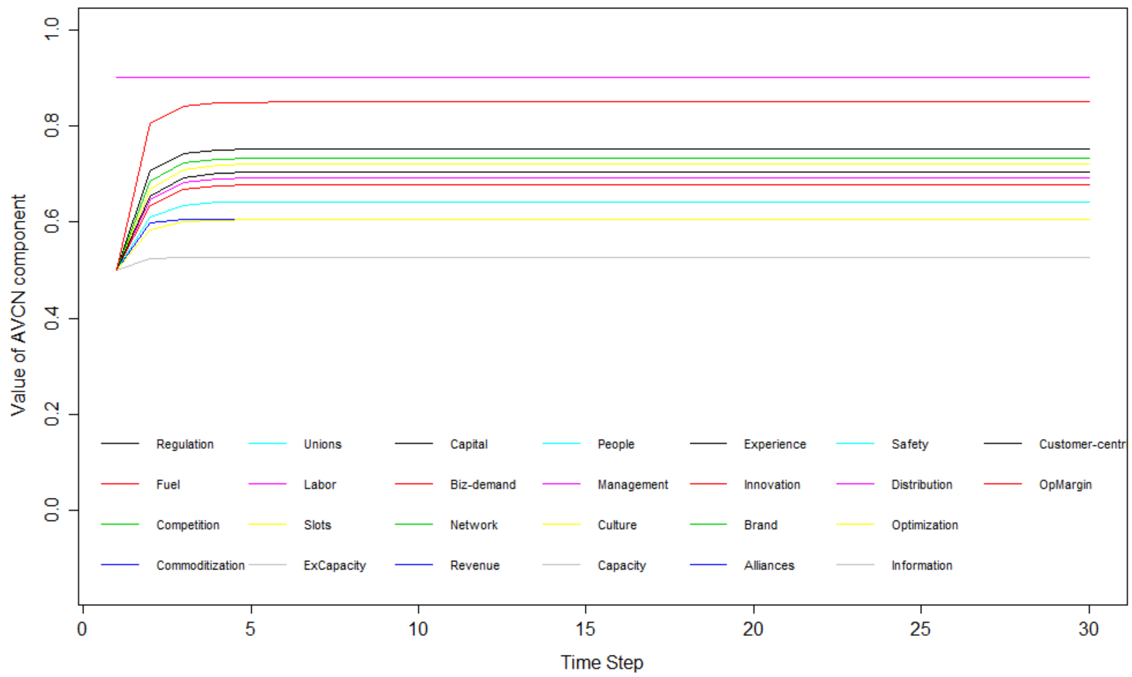


Figure 29. Scenario #3 Inference Outcome
Source: own elaboration

Scenario #3- AVCN Outcome State Vector & Differences with Base scenario								
Network	0.90	NA	**Capacity**	0.90	NA	**Safety**	0.64	0.0%
Revenue	0.90	NA	**Experience**	0.75	1.9%	**Distribution**	0.90	NA
People	0.72	0.1%	**Innovation**	0.68	0.0%	**Optimization**	0.61	0.0%
Management	0.69	0.0%	**Brand**	0.73	0.0%	**Information**	0.53	0.0%
Culture	0.72	0.1%	**Alliances**	0.61	1.7%	**Customer-centric**	0.70	0.1%

Operating Margin		
Op. Margin	0.85	2.9%

Table 18. Scenario #3 Outcome State Vector
Source: own elaboration

It is worth noting that the impact of Scenario #3 on most value repositories is rather limited if compared to the effects of Scenario #2. As we can see in Table 18, Scenario #3 final state vector shows many value repositories not being really affected by the changes in the values of the input vector, which is otherwise consistent with airlines' business reality.

5.4 Discussion and implications

The empirical findings from our field research show certain trends that are useful for understanding complexity in airlines and lead to the generation of **10 tentative propositions** that summarize some of the most important aspects of the CBVF theoretical narrative:

1. Some value repositories are more critical than others when it comes to value creation; some are much more influenced by constraints than others; and some constraints are much less relevant to value creation than we might have initially thought.
2. The strongest impact on value repositories is expected from only four different constraints —e.g. *Competition from other airlines, Business travel demand,* and *Commoditized product offering.*
3. The value repository most affected by constraints is *Process and cost optimization*. On the contrary, *Safety and security* is the value repository least affected by constraints.
4. Interconnectedness among value repositories is mostly built around strong interconnections, with no interconnections mainly labelled as "very strong" by Panel members.

5. Interconnectedness between value repositories and Operating Margin is mostly revealed as "strong" and "very strong". The only exceptions being the interconnections of the *Alliances* and *Safety and Security* value repositories.
6. The strongest impact on airlines' Operating Margin comes from only five value repositories, with four more value repositories having a moderate impact.
7. *Customer-centric proposition* is the most influential value repository of all, with other customer-centered value repositories, such as *Brand* and *Customer experience*, closely following in importance.
8. AVCN topological complexity measures feature the airlines' network context as a multi-layered clustered network embedded in a highly dimensional space, in accordance with CBVF features.
9. The AVCN is built around three closely interconnected clusters, which themselves are linked to create bigger clusters and form a hierarchical nested tree structure.
10. Outcomes from the AVCN-FCM model simulations are consistent with airlines' business reality and they have been proven to have significant management implications.

Furthermore, the above propositions indicate the applicability of the main **theoretical constituents of the CBVF**, as stated in Chapter 4. Decomposition of the firm's architecture into a network of unique, differentiated, and autonomous value repositories has not only been a conceptualization accepted by airlines' experts, but also a valid construct that matches complexity of the firm.

Moreover, the high level of participation achieved from Panel members, the positive feedback received from them, and the quality of the contributions made, endorse our assumption that the CBVF approach allows for a flexible and realistic understanding of the firm and of the interactions that shape its behavior. And the theoretical constituents of the CBVF, such as emergence, nonlinearity, hierarchical structure, homeostasis, and differentiation/specialization, have been proven fully consistent with the findings of our testing exercise of the theory and method of the CBVF in the airline industry.

More particularly, the AVCN-FCM model seems well suited to study emergent behavior and feedbacks, and to test unintended side effects of various firm policy interventions. The various scenarios tested during our Sensitivity Analysis prove, for example, how firm's value repositories reflect a value creation-exchange duality, and differentiation by specialization, thus confirming our original theoretical assumptions. This is also true for the homeostasis property, which becomes apparent when airlines achieve relative performance stability —as reflected by Operating Margin— before significant shocks from the outer environment (see Scenario #1 in Section 5.3.3).

Our testing exercise also reveals that the application of the **CBVF methodological framework** can potentially offer a wide range of possibilities for better approaching complexity of the firm; from extracting relevant data that can be used to model the firm's network context, to simulate real-life scenarios that support competitiveness analysis and decision-making.

The FCM-based model has shown that it can be a key method for scenario generation in firms struggling to assess its own value creation policies and anticipate performance. The resulting scenarios might be used as a standalone output, or as an input for the generation of more detailed value creation roadmaps or corporate strategies. Furthermore, the AVCN-FCM model might help create the basis for further discussion on complexity between C-level executives, management teams and stakeholders, enabling them to contrast simulations against opinions, or comparing them to already existing scenarios.

Nevertheless, this author is well aware of the **limitations** that this testing exercise has. For example, according to frequent criticism found in the literature, some authors might point out as a limitation the difficulty in generalizing the results to a wider population of firms due to sample size (Schmidt, Lyytinen et al. 2001) or the author's own agenda (Nambisan, Agarwal et al. 1999). These authors would most probably recommend further study to refine and verify the results, or to investigate related sets of research questions (Skulmoski, Hartman et al. 2007).

Certainly, a more careful selection of cases according to the CBVF theoretical constituents and the use of a cross-case analysis could alleviate this issue (Helper 2000). Whilst we may agree with this reasoning, the author designed this testing experiment trying to prevent bias throughout the field research. Rather than concentrating on a single airline and a small number of experts, he stayed focused on a broad and diversified group of experts from different network airlines across the word, holding a wide range of positions and performing in different functional areas. Notwithstanding the foregoing, it should be borne in mind that no methodology is perfect —even regressions have serious problems of generalizability and subjectivity— and that further verification study of the CBVF theory and method might provide new and rich results.

This author is also aware that the FCM-based model, formulated as part of the modeling stage of the field research, is contingent on the experts participating, the questions made throughout the Delphi process, and the method used to aggregate the data captured. Had other experts taken part in the field research, or had the questions been different or been made in another moment of time, the results obtained may have also been different. Consequently, not only the structural specification of the firm is contingent on the method used and the moment in time, but also the type and strength of the interactions reflected among firm's components. That said, the above considerations should not jeopardize the usefulness of the CBVF approach to tackle complexity of the firm, nor should its outcomes be neglected. Quite the contrary, all the potentially different representations of the firm that we could obtain under the CBVF shall be considered robust enough so as to deem the CBVF a valid theoretical-practical approach.

Other authors might allude to limitations inherent to the Delphi process, which in turn would have several design and implementation implications. These might include *i)* the somewhat "subjective" consensus method used in the field research (von der Gracht 2012), *ii)* the higher/lower relevance given to response rates, and the suitability of the profile of the participants, *iii)* the consideration that the iterative characteristics of the Delphi process can potentially enable investigator to mold opinions, *iv)* the restrictions posed by the author to the number of constraints (10) and value repositories (15) that might have contributed to the stream of this field research, so that important minority issues may have been missed due to nonconformity of general opinion, and *v)* the loss of objectivity and researcher bias in analyzing findings and generating questions (Balasubramanian, Agarwal 2013). Although this author agrees that some of the aforementioned limitations associated to the Delphi process might certainly need further attention in future research, he contends that the Delphi process is a key research method that has proven to be valid for extracting knowledge, which would not otherwise have been obtainable by other means.

Still other authors might remain skeptical of this field research fearing that it is not replicable; in other words, that it is difficult for other researchers to replicate this study by interviewing the same people. Notwithstanding, the author has attempted to facilitate replicability of this field research by providing all the data captured, the questionnaires, and “R” code transcripts, so as to enable other researchers to replicate this research elsewhere. Nevertheless, it is worth recalling that the CBVF method is not about presenting the subjective experience of experts *per se*, but about abstracting it into a set of tentative theoretical propositions. In the CBVF methodology this conceptual abstraction is achieved through constant comparison — i.e. constant iteration between data collection and analysis— until the stage of theoretical verification is achieved.

CONCLUSIONS

This thesis is an attempt to establish the foundations of both a complexity-based theory of the firm and a practical method to enable researchers and practitioners to approach complexity systematically and with confidence, through a more realistic understanding of the behavior of the firm. The final aim being to foster an open discussion in the social research community on the need to embed complexity awareness in the theory of the firm, as well as to test innovative research that contributes to accelerate the implementation of a CBVF paradigm.

It is in pursuit of the above objectives that we have built our key assumptions on top of propositions that are familiar to conventional theories of the firm, from where we have made further progress at the theoretical, as well as the methodological and empirical level. Our main contribution is thus not of a "breakthrough" nature, but innovative in the way we have *i)* reordered valuable propositions that were developed in conventional theories of the firm over the last decades, *ii)* drawn upon and integrated concepts from a broad range of disciplines —biology, physics, ecology— with competences more advanced in the field of complexity science than social sciences, *iii)* combined the above theoretical-practical propositions and place them in a methodological sequence to bring the resulting framework to practice, *iv)* proven the applicability of the proposed CBVF approach by providing empirical support from real life firms.

In addition to the aforementioned contributions, this thesis harnesses the convergence of two distinct but interrelated lines of inquiry: theoretical and methodological, which combined together form a comprehensive approach to tackle complexity in the firm. Such convergence had shown challenging so far in most literature, due to the lack of a coherent conceptual framework of complexity focused on behavioral phenomena and sufficient experimental data for modeling complexity. Meanwhile, our CBVF approach integrates into a single theoretical-practical framework old and new concepts from otherwise dispersed disciplines, works hands-on on firms' behavioral phenomena that is readily tractable, and enables researchers and practitioners to model and simulate the firm as a complex system, as indicates the empirical evidence presented in the thesis.

In setting the foundations for the CBVF approach, the author has sought to overcome some of the epistemological constraints of traditional economic theory —mainly those based on the analogy of mechanics, equilibrium and linear behavior— and attempted to explain firms' behavioral phenomena in a more realistic way than the average conventional theories of the firm. For example, unlike the conventional approaches of Porter's Value Chain (Section 4.3.5), or Penrose's Resource-based view of the firm (Appendix A), the CBVF introduces a firm-as-a-system approach that enables researchers and practitioners a greater degree of flexibility in representing the firm. At the same time, the CBVF incorporates a greater number of elements from reality into the approach, and it is accompanied by a method that makes the transition to the practical application of the CBVF smoother and focused on continuously feeding the assumptions made.

Whilst in the CBVF theory building process, the author has observed how nowadays factors such as new and more sophisticated computing tools and our increased capacity to address complexity are dramatically altering our understanding of the behavior of the firm. This has made us realize that current conventional theories of the firm are at best insufficient and, at worst, obsolete.

As a result, this author submits that if the heterogeneous body of conventional theories of the firm is to make further progress in the future, they should essentially get rid of some of its most conservative assumptions and start to internalize the type of assumptions and methods covered by a complexity-based approach, such as those presented by the CBVF in this thesis. What this fundamentally entails for the theory of the firm is, paraphrasing Kauffman's assertion, that poised coherence, precarious, subject to avalanches of change in the world of the firm is inevitable (Kauffman 1990).

To support this undergoing complexity-led change of paradigm, this thesis has presented and proved the applicability of a tentative complexity-based theory that addresses in a more realistic way key firm's behavioral phenomena. The following are some of the main theoretical conclusions obtained:

1. The firm is an open complex system embedded in an environment from which it receives and to which it transfers value. No firm exists in isolation from its environment, but only connected to the outside world. From a complexity point of view, understanding this principle is a prerequisite to achieve a truly effective and realistic understanding of the structural and behavioral nature of the firm.
2. Although the open complex system approach challenges some conceptual conservatism grounded in well-established theories of the firm (Oberheim, Hoyningen-Huene 2013), it is not totally incompatible with the findings and insights that we can gather from them. Actually, what the open complex system approach does is weighing the same content and context differently, in such a way that the CBVF cannot be divorced from the experimental process by which it is generated (Glaser, Strauss 2009).

3. *Value* is considered the basic building block of the firm and, as such, it provides the brick-and-mortar that shapes *value repositories* as the firm's elementary functional components. *Value repositories* dynamically interact with one another as nodes within the firm's network context, continuously creating and exchanging value with other value repositories from inside and outside the boundaries of the firm. Not less importantly, the introduction of *value repositories* as the fundamental component within the CBVF approach may provide one workable solution to the problem of modularity and the problem of designing, coordinating, and managing complex systems (Ethiraj, Levinthal 2004).
4. The number of *value repositories* continuously interacting within the firm's network context is large, provided that our goal is to attain a thorough understanding of the behavior of the firm. Empirical complexity thus becomes something inherent to the nature of the firm, thus making it impossible to assess all the behavioral properties of the firm at once.
5. The firm operates in a hierarchical (network) context. The emphasis on the linking of value repositories as a primary task of the firm suggests that the firm should be conceived as a exchanging function rather than a resource-centered or production function under the CBVF. Such a concept of the firm should lead to a shift in focus, away from the control of resources or production towards the integration of knowledge and the creation of value.
6. Deciphering the firm's network context and the relationships and interactions between components is a process that, though intricate, can be satisfactorily accomplished by using expert-based knowledge and soft computing modeling and

simulation techniques. This basically involves carrying out an iterative process consisting of measuring-modeling-simulation tasks, which helps discerning between weak and strong interactions among value repositories.

7. The heterogeneous body of theories of the firm is experiencing increasing integration of mixed theoretical and methodological paradigms coming from disciplines other than economics. Consequently, finding a balance between economical and non-economical explanations of structural complexity, relationships and interactions among components is the new normal.
8. The integration of qualitative and quantitative analytical tools into hybrid techniques is likely to be a much more productive course of action for the advancement of the theory of the firm, rather than continue to sustain the dominance of hard quantitative methods. Moreover, researchers should be fully aware that the use of highly sophisticated quantitative methods alone does not always mean that they are applicable to all research questions (Hoskisson, Hitt et al. 1999).
9. The CBVF is fundamentally a reality-prone approach to understanding the structural and behavioral dimension of the firm. As such, it produces knowledge about unobservables and considers legitimate to derive rules from them that can guide managerial action. It is thus worth noting that this attitude inherent of the CBVF contrasts with logical positivists who rejects this position (Godfrey, Hill 1995).
10. By further exploring and proving new practical applications of the CBVF approach, it is expected that researchers and practitioners shall be able to provide better

guidance to real-life firms, without them having to resort to cumbersome and over-simplifying theoretical frameworks.

Considering the theory building nature of this thesis, the author deliberately has not engaged in any particular quantitative analysis other than that contained in Chapter 5. The induction of relationships between the key propositions of the CBVF theory was instead centered on the understanding of the content and context of the constituents characterizing complexity in the firm. Thus, it was sufficient that a proposition had an importance rating above medium to be subject of our analytical interest (Binder, Edwards 2010). The canon for judging the usefulness of the CBVF theory should therefore be focused on how it has been generated, as well as its logical consistency, clarity, scope, integration and fit and ability to work (Glaser, Strauss 2009).

In addition to the theoretical conclusions discussed above, the author considers that the methodological framework proposed in this thesis is a first attempt aimed at developing a comprehensive framework for researchers and practitioners to effectively bring the CBVF into practice. As such, the CBVF methodology requires continuous feedback from practical outcomes, which in turn stresses the importance of continuously advancing in the development of a robust and flexible methodology designed to have some form of impact on managerial actions.

Particularly noteworthy is the flexibility and usability that the CBVF methodology has demonstrated. Its five consecutive stages, each of which builds on the knowledge gathered by the preceding stage, confers researchers and practitioners the ability to readily become aware of complexity and prevent them from falling overwhelmed by full-blown complexity of the firm. Furthermore, the empirical evidence provided in the thesis stresses the importance of replicability of the CBVF methodology, thus making it a reliable method for firms of almost any size operating in any industry, and easily trainable.

Notwithstanding the robustness and soundness shown by the CBVF approach, the author is well aware of long-standing difficulties to bring complexity into practice, which taken together, have made the adoption of a complexity-based approach by theorists of the firm fall behind other developments. The ever-lasting challenge to set a theoretical-practical conception of *complexity* being one of the more obvious examples.

In this bewildering situation, the author acknowledges that we should not expect to see the CBVF integrated into the mainstream economic theory of the firm in the near term. Nonetheless, this thesis shall contribute to develop new theoretical and practical knowledge on the applicability of complexity in the firm, disentangle complexity from ambiguity, and show how promising the opportunities offered by such an approach are in order to increase our understanding of the firm.

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FURTHER RESEARCH

Although this author is convinced that our CBVF forms part of a new paradigm for understanding and anticipating the behavior of the firm, he is well aware that such an approach is too far from being accepted as mainstream. In fact, the entire CBVF is at the early stages of investigation, with its building process encompassing such an extensive theoretical and practical background that it deserves systematic further research and elaboration to make it progress.

Due to the scale that a detailed CBVF research programme would have, in this chapter the author summarizes what he considers are the key areas whose deeper study should continue to shed light on our understanding of the firm as a complex system, and significantly enhance the applicability of the CBVF approach in the future.

One of the first areas requiring special attention refers to the **constituents of complexity of the firm**. Even though in this thesis the author proposes what he thinks are the most relevant properties of complexity in the firm, a much deeper investigation would be needed to verify the linkages and interconnectedness that exist among them, as well as to uncover new constituents not even considered in this thesis. In the course of this investigation, the identification of similarities and dissimilarities between the conceptualization of complexity in the firm and in other social and natural complex systems should contribute to expand our knowledge and fine-tune the scope of the CBVF.

As we have seen, in this thesis we have mainly focused on value repositories as the firm chief structural components. Further research should next turn our attention to the particular evolution of value repositories and its inner dynamics. This will necessarily involve building a larger empirical basis for CBVF analysis, which might help us answer questions such as, How do firms decide on the number of value repositories, and how do they make decision upon value repositories? or, How do firm's decisions affect the interactions among value repositories and the marketplace itself? Additionally, a base of comparative analysis between the CBVF and other conventional theories of the firm and quantitative firm modeling methods should allow researchers and practitioners better set out the advantages of a complexity-based approach, and foster cross-pollination of ideas among the different firm approaches.

We have examined the implications of value repositories on behavioral phenomena, however, value repositories —as the idea of modularity (Ethiraj, Levinthal 2004)— have many other important implications for management, strategy, organizational coordination, and financials. Thus, understanding the full implications of value repositories design and knowing the trade-offs is an area deserving greater focus.

Further research should also look at the role played by key external agents interacting within the firm network context —e.g. partners, providers, suppliers, competitors, etc. Certainly more investigation is needed on the manner and degree to which these agents affect the complexity of the firm. More specifically, the study of the role of customers —as the most prominent source for value creation and exchange— and their relationship with the firm, is an area of particular interest for the future development and improvement of the CBVF approach.

Another area requiring further research should target on the way key managerial functions impact value creation. Gathering knowledge on how different functions are involved in the creation and exchange of value is, in fact, central to our understanding of complexity in the firm. Additionally, it deserves further investigation the manner in which the organizational processes of the firm affect value creation and, in particular, how the firm's innovation processes impact the value repositories.

As we have seen in previous chapters, the **methodological framework** proposed in this thesis is a first attempt aimed at developing a comprehensive method for researchers and practitioners to effectively bring the CBVF into practice. Given its importance, the CBVF methodology is a key area that deserves further investigation from a multidisciplinary standpoint, so that we can continue tackling complexity with confidence.

In developing a better methodological framework, much inspiration might come from disciplines such as physics and biology, both with a proven tradition of dealing with challenging complexity-related questions. After all, without a creative and in-depth exploration of the activities, tools and techniques to approach complexity, it is likely that the CBVF would fall short to explain the firm's structural components and its dynamic networked relationships, from where we can later conduct robust modeling, simulating and optimizing processes.

The above would inevitably lead to the need to further investigate and develop CBVF-specific hybrid tools, which in turn should enable researchers and practitioners to conceptualize/ characterize complexity of the firm in an increasingly idiosyncratic manner. This would probably make us reflect on the role of mathematics and quantitative methods in the study of complexity, as well as to further explore into soft computing techniques to improve our empirical knowledge of the firm. The path followed by natural sciences decades ago —i.e. when they had to develop their own analytical tools to cope with complexity— shows us a course of action that might stimulate the next rounds of CBVF investigations.

Particularly relevant in the investigation of the CBVF methodology is to dig deeper into how the modeling and simulation processes may contribute to advance our understanding of the complex behavioral dynamics of the firm. For example, the FCM-based model formulated in this thesis for the airline industry (Chapter 5) has been proved useful for increasing our understanding of the firm's behavior, and it seems plausible that it might provide decision-making capabilities in the near term.

Specifically, FCM models of the firm seem well suited to study feedbacks and test unintended side effects of diverse firm policy interventions. As such, FCMs might continue to be a good reference tool to help researchers and practitioners cross the chasm between firm's reality, qualitative experts' knowledge, and quantitative models. Undergoing advances in the theory and practice of FCM modeling should therefore be brought to CBVF experimentation —i.e. new algorithms, model extensions. This should call for increased collaboration between complexity practitioners and FCM computing research teams.

Furthermore, FCM modeling, together with other advanced modeling techniques —e.g. neural networks, agent-based modeling— should eventually lead to new hybrid methods that are used for firm's scenario generation and simulation. The resulting outcomes might later be used as a standalone output, or as an input for the generation of value creation roadmaps — i.e. to see how different value creation models play out against the future states of the business environment, or to assess the impact of different policies on performance indicators such as Operating margin.

Other applications of CBVF modeling might involve creating the basis for further discussions between C-level executives and decision makers, contrasting simulations against stakeholders opinions, and/or comparing simulation outcomes with already existing scenarios.

Of particular interest would also be to apply the CBVF approach to the domains of a specific firm, and explore the consequences derived from the absolute measures of firm's components on the analysis of complexity.

Although the strong managerial implications and opportunities of the CBVF have been made evident in this thesis, this does not mean that researchers and practitioners should be poised to abandon current conventional theories of the firm. Instead, what this author contends is the idea that, no matter what theory or mindset they choose, they should keep a foot in a complexity-related view of the firm, such as our CBVF.

A complexity engagement would open new perspectives for structural, strategical and performance improvements for the firm as a whole and/or its particular value repositories, and even serve as engine of growth. Ultimately, we must note that our CBVF brings to the fore a life-long view of the firm in sharp contrast to the hectic short-termism perspective so characteristic of modern firms; a view that may be used by managers to retain some control over the firm's own differential advantage— and thus over its own fate.

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APPENDIX A.

REVIEW OF THEORIES OF THE FIRM

A.1 Introduction

This Appendix provides a general overview of the key assumptions made by a selected group of theories of the firm — those whose impact this author considers has been more profound on our current understanding of the firm— and the extent to which they address real firms' behavioral problems by tackling complexity. Moreover, the present analysis covers the key strengths and weaknesses of a heterogeneous body of theories from the last 80 years, drawing particular attention to the way theoreticians of the firm have approached real behavioral problems, addressed complexity, and proposed practical guidance.

Note that this is necessarily a short theoretical review not intended to be exhaustive. The field of the theory of the firm is so vast that a comprehensive assessment would largely exceed the scope of this thesis. Notwithstanding the foregoing, this author is aware that some valuable approaches to the firm have not been addressed in this review, the reason being is because they are either somehow subsumed in the already reviewed theories, or because their influence over subsequent developments have been not as high as others.

The theories of the firm herein reviewed are the following:

- Neoclassical theory of the firm.
- Transaction costs theory.
- Agency theory.
- Resource-based view of the firm.
- Knowledge-based view of the firm.
- Stakeholder theory.
- Organizational theories of the firm.
- Developments in strategy.

A.2 Neoclassical Theory of the Firm

Profit maximization, agent rationality, equilibrium, economies of scale, perfect competition, and linearity of economic interactions are the key assumptions broadly underlying most of the neoclassical theory of the firm (Marshall 1919, Pigou 1932, Robinson 1934, Chamberlin 1949, Marshall, Guillebaud 1961).

In a broad sense, neoclassical scholars think that real business life consisted of the firm growing until it achieved technical and organizational economies of large-scale production, at which time, the managerial abilities of the owners of the firm and their desire for ever greater wealth would wane. The firm would then become increasingly inefficient and, in the end, would die and make way for new firms led by yet another generation of new managers (Marshall, Guillebaud 1961, Moss 1984).

The firm in the neoclassical economic theory *"is little more than an entrepreneur who is attached a cost curve or a production function (…) the single participant explicit treated as a* *rational individual"* (Mahoney 2005). Other relevant participants of the firm's ecosystem —such as the customers, employees, suppliers, partners, etc.— are considered mere "conditions" to which the entrepreneur adjusts in finding an economic solution that is optimal to him/her .

The neoclassical theory of the firm provides an ideal rational individual who chooses among fixed and known alternatives, to each of which the known consequences are attached as if knowledge was fully and perfectly accessible. In fact, the neoclassical theory of the firm does not deal with the behavior of the firm *stricto-sensu*, nor does it deal with the firm as an organization (Dietrich, Krafft 2012). Its chief mission is none other than to *"understand how the price system coordinates the use of resources, not the inner workings of real firms"* (Demsetz 1988). Behind these strongly accepted postulates and its brilliant logic, the neoclassical theory of the firm seems to hide disguised its historical inability to explain some of the central conflicts and dynamics with which the firm has become increasingly concerned.

As a result, the neoclassical theory of the firm works in a rather mechanistic fashion as the assumptions of perfect competition and rational agents come into play, with a low level of contact with empirical data. Moreover, since profit maximization and internal efficiency are assumed, *"there is little room in the neoclassical theory for (…) real business firms"* (Simon 1982).

Similarly, neoclassical theory does not *"describe the processes that humans use for making decisions in complex business situations"* (Mahoney 2005). The "rational" and "efficient" behavior with respect to the individual choice is subsequently reduced as a problem of finding the maximum of some function that is taken (Simon 1982). From a methodological perspective, this means that the regression paradigm becomes the prevalent analytical tool for most hypothesis testing in neoclassical thought.

The central argument of maximizing behavior is no longer supported today, as researchers have demonstrated that individual perception and cognition intervene between the decision-maker and the environment, proving neoclassical economics flaws. Instead, a number of models of satisficing behavior are taking the lead, where maximization is replaced by targets and satisficing goals, and mechanisms of learning and adaptation.

Decision-makers today are no longer those wise *entrepreneurs* able to make the best possible decisions, and we are well aware that our mental models encompass only a fraction of all the relevant characteristics of a particular firm and of all the information available.

Furthermore, researchers have made available a large mass of descriptive data that show how most of the key assumptions of the neoclassical theory of the firm do not hold up in the face of facts. Consequently, the regression paradigm is not the best for testing hypotheses for all data that is non-experimental and laden with non-recursive relationships.

In contrast with the neoclassical approach to the firm, current firm research is moving beyond cross-sectional, multiple regression approaches to methods more attuned to the specific problems and issues likely to influence the behavior of the firm (Hitt, Keats et al. 1998). For example, to deal with situations too complex for the application of known optimization methods one of the most widely used techniques is now simulation. In simulation, the trial and error is supplied by the human investigators rather than by the technique of analysis itself. Other methods that progressively incorporates complexity as part of the analysis include network analysis, panel data analysis, logistic regression, structural equation modeling (Hitt, M A et al 1998), as well as the very latest techniques of soft computing.

In summary, the neoclassical economic theory might be criticized by its conspicuous lack of empirical testing of assumptions, theories and predictions (Simon 1962a). Neoclassicals have not only been careless with the real-life complexity of the firm, but have rather preferred to keep the focus on the efficient allocation of resources based on the marginal analysis and maximization (Williamson 1996). Not surprisingly, the picture of the firm that comes out of new research is that of a searching, information processing, satisficing, allocating "mechanism", focused on the need to increase its empirical demonstrability (Simon 1962b).

A.3 Transaction Costs Theory

The concept of transaction costs helps explain why the firm exists, and what activities the firm may undertake or refuse. Originally conceived by Nobel laureate Prof. Ronald H. Coase in his seminal work "*The Nature of the Firm"* (Coase 1937), the transaction costs theory provides an exemplary explanation on how firms would emerge to organize what would otherwise be market transactions, particularly whenever their costs are less than the costs of carrying out transactions through the market.

The "complexity" problem in the transaction costs theory is mostly epitomized in the market mechanism, considered an institution that exist to facilitate exchange; namely to reduce the costs of carrying out exchange transactions (Coase 1937). Moreover, if we consider transaction costs somehow analogous to frictions in mechanical systems, the very existence of the firm might be devised as a mean to respond to a quantifiable balance between price and costs. As long as using the price mechanism has a cost —e.g. the cost of "organizing" production through the price system— Coase concludes that it shall be profitable to establish a firm. On the contrary, the “diminishing returns to management" makes the bigger companies look less attractive to carry out activities.

Unlike the neoclassical economic theory, the transaction costs theory characterizes the firm rather than as a production function, as a governance structure (Williamson 1985), whose main purpose is economizing on transaction costs. Transactional considerations, nor technology, nor customers, nor any other constraints from the firm’s outer environment, are decisive in determining which mode of organization (market vs firm) will score, and in what circumstances and why (Williamson 1975).

The identification, explanation, and mitigation of contractual hazards are therefore key assumptions of the transaction costs analysis (Williamson 1996), which helps explain why we observe so many kinds of organizations. For example, transaction costs theory suggests that internal production is more likely when the assets are specific and the uncertainties in contracting are large (Masten 1984).

In transaction costs theory there is an institutional environment —laws, polity— and institutions of governance —markets, hierarchies— which serve to incorporate a higher degree of complexity, mostly pertinent to industrial organization. However, this promising intent to approach the theory to the reality of the firm rapidly falls short. Taking the firm’s institutional environment as given, the economic agents purportedly align transactions with governance structures to effect economizing outcomes.

Despite the failed attempt to provide a realistic explanation on the behavior of the firm, the transaction costs theory substantially increases our understanding of the behavior of the firm, particularly when compared with the neoclassical economic theory. It also should be noted that the transactions costs theory has been particularly fruitful in providing valuable insights in the analysis of the multidivisional form (M-form) (Chandler 1962, Williamson 1969), and hybrids form of organization (Hoskisson, Hitt et al. 1999).

A.4 Agency Theory

Whenever one individual depends on the action of another to meet his/her goals, an agency relationship arises. The individual taking the action is called the agent, whereas the affected party is the principal (Pratt, Zeckhauser 1985). Challenges in the agency relationship generally arise whenever the principal cannot perfectly (and costlessly) monitor the agent's action and information. When this happens, the problems of inducement and enforcement then come to the fore (Ross 1973).

The key building blocks of the agency theory are the information and economic incentives (Hölmstrom, Milgrom 1994). This perspective stresses the importance of viewing the firm as “a system”, specifically as a coherent set of complementary contractual arrangements which mitigate incentive conflicts (Foss 1998).

The agency theory postulates that there exist information asymmetries between principals and agents, and that agents typically know more about their tasks than their principals do. As a consequence, no one can expect a firm to function as if all the information were costlessly shared, or as if the economic incentives of principals to agents were costlessly aligned. Regretfully, an agency loss or agency costs invariably emerge (Jensen, Meckling 2000, Pratt, Zeckhauser 1985).

Even though agency costs might suggest an overlap with the transaction costs theory, Williamson (1996) suggests the following three important differences between the agency and the transaction costs theories:

- The units of analysis are different: the individual in the agency theory, and the transaction in the other
- Agency costs focus on ex-ante costs, whereas transaction costs emphasize ex-post costs
- There is a legal centralism assumption of the agency theory, whereas a private ordering assumption is assumed in the transaction costs theory.

From an operational point of view, the firm's main economic challenge in structuring an agency relationship is to minimize the agency costs; or as the agency theory states, to do the best to achieve what is sometimes called a second-best solution (Mahoney 2005).

Economic incentives are the principal's means to influence the agents' behavior and to reap the greatest advantage from the agency relationship, yet reward the agents enough so that they do not quit. Whether the principal is in a position to design the monitoring and incentive mechanism, and obtain all the economic benefits from improvements in performance, are two of the most discussed assumptions that very often are not satisfied (Pratt, Zeckhauser 1985).

As promising as the expectations created by the agency theory were to open up new opportunities for exploring the firm's complexity. the truth is that most of the agency theory debate has revolved around the stale stakeholder-manager dynamics, both in terms of managerial and philosophical implications. Moreover, the principles of the agency theory have been applied to a number of substantive business topics, including innovation, corporate governance, and diversification (Hoskisson, Hitt et al. 1999).

Agency relationships may well be a pervasive fact of economic life (Arrow 1984), however, the agency theory fails to provide plausible answers to some of the major firm's behavioral questions, as well as to deliver practical guidance to practitioners of the firm, aside from costs and incentives management.

Nevertheless, a window of opportunity remains open if the agency theory is to be used to further explain the relationship between the firm and the external agents with which it interacts. The well-studied one-to-one agency relationship might be leveraged to further explain the omni-directional relationship space between the firm and its customers, suppliers, partners, etc. This multi-agent approach —consistent with Arrow's account such that a single principal may have many agents (Arrow 1984), and vice versa—could well serve to take a step further in the complexity of the firm.

Unlike the "canonical" agency theory, where the roles of the principal and the agent seem perfectly delineated and assigned, under the multi-agent approach the firm might adopt, at any given time and in relation to any given agent, the role of either a principal or an agent. From a practical perspective, the roles of the principal and the agent would become two sides of the same coin, as the adoption of either role would depend on the goal pursued by the firm with respect to a particular agent, as well as on the cost-benefit rationale involved. This principal-agent duality of the firm would also entail that:

- the firm might play the role of a principal and an agent simultaneously
- the firm might be eligible either to pay or receive agency incentives

- the principal is no longer in a position to design the monitoring and incentive mechanism alone
- the principal might not obtain all the economic benefits from the improvements in the agent's performance.

The adoption of either a principal or an agent role by the firm in pursuit of greater efficiency (Levinthal 1988), or for the reduction of uncertainty (Hölmstrom 1979), would become an acceptable approach for a more complexity-based view of the firm.

A.5 Resource-based View of the Firm

The resource-based view of the firm is a well-grounded stream of research on the behavior of the firm and business competitiveness. As one of the most influential streams of firm research of our days, its development is to be found scattered across a large number of academic references. Yet, we can trace back its foundational ideas to Edith Penrose's seminal work "*The Theory of the Growth of the Firm"* (1959), where she sets the groundbreaking view of the firm as a bundle of resources.

From Penrose's pioneering work, passing through the contributions made by Wernerfelt and Barney in the eighties and nineties (Wernerfelt 1984, Barney 1991), and to our days, researchers on the research-based view of the firm have mainly focused on two fundamental guidelines: (1) how differences in firms' resources realize superior firm performance, and (2) what and how specific resources give rise to sustainable competitive advantages —e.g. learning, culture, entrepreneurship…

Today, the resource-based view of the firm provides a robust framework for increasing dialogue between scholars from different disciplines. Moreover, several sub-streams have emerged from the original view, examples of which include the strategic leadership and the knowledge-based view of the firm. Such an intense theoretical development has made the resource-based view one of the prevailing economic perspectives in areas such as strategic theory and business management.

The resource-based view emphasizes the role of the internal resources of the firm, particularly the productive services available from management. The general purpose of the business firm is to organize the use of its "own" resources for the production and sale of goods and services at a profit, together with other resources acquired from outside the firm (Penrose 1959, Wernerfelt 1984, Barney 1991). From this perspective, the firm becomes a pool of resources, the utilization of which is organized in an administrative framework. This explains why both the administrative framework and the administrative decision-making processes are key elements in this theory.

In the resource-based view, the outer environment of the firm is an "image” in the entrepreneur's mind of the possibilities and restrictions with which the firm is confronted. In other words, a given “boundary” that sets the limits of the firm, but which can allegedly be shaped at will. Consequently, firms have the capacity to alter the conditions of the outer environment and even to influence consumers’ demand. All that is needed is to make use of an imaginative effort, develop a good sense of timing and appeal to the instinct for predicting what will catch on (Penrose 1959). By learning how to manage the specific set of internal resources and capitalize on the unused productive capacity, the firm may feature the same outer environment differently from other firms, thus seizing growth opportunities that others are not able to create.

The underlying reliance of the theory on the managerial ability to change things go so far so as to explain the limits to the growth of the firm as a function of the conditions inside the firm. In fact, while the resource-based view recognizes that a combination of internal attitudes and external conditions may limit the growth of the firm, the primary limiting factors have to do with the internal capacities, such as the existing managerial personnel and knowledge. The firm's growth and profitability are therefore variables that depend on the managerial capacity and knowledge that the firm is able to gather —what is known as the "Penrose effect" (Tan, Mahoney 2005, Goerzen, Beamish 2007).

The managerial ability and the knowledge held by the firm are extended in other resource-based sub-streams of research by the contribution of intangible assets —i.e. a specific technology, the accumulated information about the consumers, a brand name, the reputation, the corporate culture (Itami, Roehl 1991). According to this complementary perspective, the accumulation of invisible assets becomes critical for future competitiveness, to the extent that the decisions made regarding intangible assets can affect the firm's long-term capabilities and adaptability.

As stated above, Penrose's resource-based view of the firm heavily draws on the figure of the entrepreneur. This refers to the individual or group of people providing entrepreneurial services, no matter what their position or occupational classification are in the firm. Entrepreneurial services are understood as those contributions to the operations of the firm related to the introduction and acceptance of new ideas, the acquisition of new managerial personnel, changes in the organization of the firm, raising of capital, or making of plans for expansion (Welter, Smallbone et al. 2012).

Unfortunately Penrose and the later resource-based view community have not dug deeper as to explain the (critical) process by which the entrepreneur gathers all the knowledge he/she needs to alter the environment around the firm, nor how the entrepreneur gets insight into the firm's market opportunities, nor how to anticipate the consumer acceptance of the products, nor how to determine the factors that influence most the entrepreneur's image of the outer world.

The resource-based view of the firm has continue growing and progressively incorporated more complexity-related elements of analysis to its scope. Questions such as the property rights, the contractual nature of the firm, or the notion of decision rights, have significantly extended the explanatory power of the theory, insofar as they provide the economic incentives that shape resource allocation (Alchian, Demsetz 1972, Hart, Moore 1990, Jensen, Meckling 1992, Jensen, Meckling 2000).

For instance, property rights critically affect decision-making regarding resource use, hence, they are key to understand the economic behavior and performance of the firm. Note that under this perspective, the firm would become a method of property tenure by which owners expect to obtain income.

Notwithstanding the foregoing, as scholars become more aware of the complexity of the firm and our knowledge of the relationship between the firm and its outer environment increases, there is no longer any certainty as to whether the firm will be able to keep a true sustainable competitive advantage alone by holding exclusive property rights over its tangible and/or intangible resources.

A.6 Knowledge-based Theory of the Firm

What has become known as “the knowledge-based” theory of the firm is the result of the questions raised in many different fields of inquiry, in the borderline between economics and business administration, such as strategy research, international business and technology studies (Foss 1998).

One of the first statements of the knowledge-based approach may be found in Penrose’s *“Limits to the Growth and Size of Firms”* (1955). As Penrose explains, firms can be understood as collections of resources and services derived from these resources, all organized under an administrative framework. It is through various learning processes, mostly carried out by the management team, that the firm’s activities are routinized so as to release resources (Penrose 1955).

After Penrose, a step forward is taken by the introduction of the term “capabilities” (Richardson 1972), to talk about the necessarily limited range of productive knowledge firms and individuals possess. According to this perspective, capabilities not only are determinants of the boundaries of the firm, but they also classify productive activities according to the capabilities they share.

Other authors later on have focused their attention in exploring the mechanisms through which firms create knowledge (Grant 1996), conceptualizing the firm as an institution for integrating knowledge, instead of just applying knowledge. The resulting theory, as Grant himself argues, would have implications for the *"basis of organizational capabilities, the principles of organization design (in particular, the analysis of hierarchy and the distribution of decision-making authority), and the determinants of the horizontal and vertical boundaries of the firm"* (Grant 1996).

The knowledge-based view of the firm is different from other theories of the firm in that it emphasizes the role of organizational factors in the production of competitive advantage, primarily focusing on the complex internal organization (Grant 1996, Blomqvist, Kianto 2007). In contrast with the resource-based view of the firm, more interested in identifying the essential productive (knowledge) resources and examining how these resources can be acquired and protected, the knowledge-based approach assumes that knowledge can be managed with tight procedures, policies, and defined action (Von Krogh, 1998).

Advocates of the knowledge-based approach argue that knowledge is the new fundamental basis of competition and for the creation of economic value and competitive advantage. Consequently, knowledge is the most important source of revenue, and it should be looked at as a distinct form of capital. Given the key relevance of knowledge, firms should adopt a strategic approach to knowledge (Blomqvist, Kianto 2007).

The knowledge-based view of the firm represents a significant leap ahead in the intent to provide a more realistic theoretical understanding of the firm when compared with its parent theories. We could even assert that this approach succeeds in calling our attention to a new factor such as knowledge, which significantly affects the behavior of the firm. Nonetheless, the knowledge approach bears the traces of its parent resource-based theory of the firm, from which it does not depart methodologically.

A.7 Stakeholder Theory

In the words of Edward Freeman, one of the precursors of the modern stakeholder theory, a stakeholder is *"any group or individual who can affect, or is affected by, the achievement of a corporation's purpose"* (Freeman 1984). According to this definition, the term "stakeholder" encompasses almost everyone with either a strong or weak connection with the firm. Given the impractical consequences derived from this definition, Freeman himself later strove to narrow such definition to "only" include the *"employees, customers, suppliers, stockholders, banks, environmentalists, government and other groups who can help or hurt the corporation"* (Freeman 1984).

The stakeholder thesis is managerial in essence, and was originally conceived to help corporate managers operate their particular areas of responsibility rather than addressing the problematic of management theorists and other cross-disciplinary scholars. However, the original scope of the theory has not prevented dozens of scholars to dig deeper into the stakeholder theory and make it grow into one of the most prolific areas of management research of our days.

The focus of the stakeholder theory is articulated around two core questions (Freeman, Wicks et al. 2004). First, it addresses the question of what the purpose of the firm is. Second, it inquiries into the responsibility that management have with stakeholders. Both are topics that delve into the critical process of value creation in the firm and the critical role of the people who voluntarily come together and cooperate to improve everyone circumstances and create value. Consequently, for stakeholder theory it is key that managers create relationships with the stakeholders so as to build up communities where everyone strives to give their best to deliver the value the firm promises (Freeman, Wicks et al. 2004).

Stakeholders theorists emphasize that many firms have developed themselves and run their business in terms consistent with the stakeholder theory, and that by focusing on the values and relationships with stakeholders they have achieved outstanding performance —e.g. Google, eBay, J&J…(Collins, Porras 1994). Stakeholder-oriented companies, they claim, are better positioned to create outstanding customer service than "non-stakeholder companies", as they constantly search for ways to cooperate with stakeholders.

For advocates of the stakeholder theory, the future of corporations lays in attending the legitimate interests of those groups and individuals who can affect, or be affected by, their activities (Donaldson, Preston 1995). For this purpose, managers need to use good judgment if they are to create relationships with stakeholders in the right direction (Freeman, Wicks et al. 2004).

Critics of the stakeholder theory have cast doubt on the key assumptions of the theory and pointed out to its weaknesses. Many authors find it difficult to agree that *"companies perform better the more closely they engage everyone affected by their operations (and that, as a result, companies) should be run for the benefit of all those who may be deemed to have a stake in it"* (Argenti 1997). These authors find hard to decide who is a stakeholder and who is not. Moreover, they do not easily accept why the stakeholder theory does not provide a clear idea of what stakeholders should expect to receive, and they argue that it is unrealistic to expect managers to make a trade-off between stakeholder interests, unless the theory interferes with the firm's performance.

Instead, critics claim that what managers really do is to ask themselves *"what effect each decision might have on profits" (Argenti 1997)*, which means that the stakeholders should be treated according to the effect they have on profits. Furthermore, they argue that companies need to behave towards everyone in such a manner that they benefit from its activities and become "collateral beneficiaries".

A large part of the debate between advocates and critics of the stakeholder theory has recently focused on whether companies should focus on the stakeholders or the shareholders instead, as well as on discussing the purpose of the company itself (Sundaram, Inkpen 2004). Literature shows multiple examples in favour of one or the other side in what it seems to be a never-ending debate. But there is also common ground between the two sides. For example, they seem to agree is that companies need to have a clear purpose and cannot survive unless they deliver true value to their chosen stakeholders (Campbell 1997).

At the end, this enriching debate highlights the need for a more complexity-based view of the firm, the development of which will be possible as the stakeholder theory evolves into a more holistic approach to the relationships between the firm and the actors in its ecosystem.

A.8 Organizational Theories of the Firm

The organizational theories of the firm deal with the fact that there are practical limits to human rationality, and that these limits are not static, but depend upon the organizational environment in which individuals' decisions take place (Scott, Davis 2007). Organization and rationality are therefore two intertwined concepts that provide feedback one to another.

According to this approach, given the large number of alternatives and the huge amount of information that every individual must assess in real business life, objective rationality becomes something hard to sustain. Therefore, the goal of the organization is to design an environment of decision such that individuals are rational in their decisions —the organization as a system of cooperative behavior (Simon 1953).

For those researchers operating from the behavioral perspective, the organization is viewed as a more efficient information processor than the individual (Cyert, March 1963), still other authors point to the sociological significance of the firm —because of their ubiquity, their impact on power and status, and as complex set of social processes (Scott, Davis 2007). And the discussion might continue, including those authors arguing that organizations are a means of achieving the benefits of collective action in situations in which the price system fails (Arrow 1974), or those arguing that the firm exists because they can achieve co-ordination more effectively than the market so that investment in managerial hierarchy achieves productivity gains —Chandler's concept of the 'visible hand' (Chandler 1977, Chandler 1990).

Whatever the perspective is, the term "organization" endorses the fact that virtually all decisions require the participation of many individuals for their effectiveness. Therefore, for organizations to work effectively they must be provided with employees and a pattern of human communication and relationships. Employees are key stakeholders for the outcome of organizations, and their work is carried out within the terms of an authority relationship between the employer and the employees. Both the economic relationship created by the employment contract and the compensation framework, play a central role in organizational theories (Simon 1982).

The organizational theories of the firm are closely related to the principles of the evolutionary theory, as specified in Nelson and Winter's seminal work *"An Evolutionary Theory of Economic Change"* (1982), where a set of ideas are provided as to the way organizations evolve and the role the environment plays in economic change.

Nelson and Winter argue that much of the firm's behavior can be understood as a reflection of routines and strategic orientations. In their evolutionary theory, routines play the same role that genes play in biological evolutionary theory. They are a persistent feature of the organism and determine its possible behavior, even better than if the firm carries out a thorough decision-making process into the future (Nelson, Winter 1982).

According to these authors, most of what is regular and predictable in the firm's behavior is subsumed under the term (organizational) "routine". Consequently, the non-regular and unpredictable behavior is furnished by recognizing that there are stochastic elements both in the determination of decisions and of the decision outcomes themselves. This conception of stochasticity in the behavior of the firm holds the ability to alter "inheritance" of the firm's characteristics, and provoke the appearance of organizational variations (or mutations).

Under Nelson and Winter's evolutionary theory, firms are motivated by profitability and engaged in search for ways to constantly improve their profitability. For this purpose, firms have specific organizational capabilities and decision rules, at any given time (Nelson, Winter 1982). Over time, these organizational capabilities and decision rules are modified as a result of both deliberate problem-solving efforts and stochastic events coming from outside the boundaries of the firm. As it can be observed, the economic analogue of natural selection operates as the market determines which firms are profitable and which are unprofitable, and tends to winnow out the unprofitable firms.

Last but not least, it is worth highlighting the conceptualization of the organization as an open system, a perspective from which our complexity-based view of the firm sources many ideas. First introduced by K.E. Boulding in 1956, the open system approach represents an important breakaway from the mechanical models too often presented in the theory of organizations. As Boulding argues:

> *"(…) in dealing with (…) organizations we are dealing with systems in the empirical world far beyond our ability to formulate. We should not be wholly surprised, therefore, if our simpler systems, for all their importance and validity, occasionally let us down" (Boulding 1956).*

After Boulding, the open system approach research agenda has continued to grow, inspiring dozens of authors more deeply to investigate the open system view of the firm. Of particular interest for our complexity-based view of the firm is Sanchez and Heene (2004) perspective of the organization as a goal-seeking open system, which aims to create and distribute value. According to these authors, the organization has important interactions across its boundaries between the resources within the organization and those in its environment, to the extent that the organization takes into account or is influenced by its own influence on the environment (Sanchez, Heene 2004).

New approaches in the field of the organizational theories of the firm —contingency theory, learning organization, etc.— go beyond simple determinism to models that include simultaneity, holism, emergence, real-life knowledge, flexibility, and the need for strategic choices. These new approaches presume evolving conflicts between external contingencies and internal consistency (Maula 2006), which is a significant step further towards a complexity-based view of the firm.

A.9 Developments in Strategy

The most recent developments in the theory of the firm incorporate work on firm strategy and management, which reflect a more “applied” character and the strengthen dialogue between “pure” and “applied” fields.

As such, the interconnectedness between the firm and its outer environment strongly gains importance, with several authors leading the way in the literature.

Worth mentioning is the work of Kapoor and Lee (2013) on US hospitals, who consider firms in the context of their business ecosystems and explore how governance choices with respect to “complementors” and “distributors” shape their competitive behavior. According to these authors, governance choices play an important role in the firm’s ability to coordinate changes in interdependent activities so as to create value (Kapoor, Lee 2013). Their work anticipates the impact on organizational forms of the coordination mechanisms and competitive behavior, the choice of which must be considered in the context of business ecosystems (Iansiti, Levien 2004, Kapoor, Lee 2013).

Also relevant, and complementary to the above, is the examination of shakeouts in the context of business ecosystems and, more precisely, the market turbulence generated by core firm decisions in ecosystems. As some authors show, firms’ decisions can generate financial losses and exit for niche market firms. Pierce’s study on the US automotive industry, highlights the importance of environmental and firm characteristics in shakeouts, and goes as far as to develop hypotheses predicting which niche markets will suffer larger losses and be more susceptible to shakeouts, and how core firm decisions will drive complementor performance and survival (Pierce 2008).

These worthwhile attempts to incorporate a more deeper understanding of the firm's environment into the core of the theory of the firm are complemented by other novel value-centered approaches, such as Porter et al's *"Creating Shared Value"* (2007). As these authors state:

> *"A big part of the problem lies with companies themselves, which remain trapped in an outdated approach to value creation that has emerged over the past few decades. They continue to view value creation narrowly, optimizing short-term financial performance in a bubble while missing the most important customer needs and ignoring the broader influences that determine their longer-term success" (Porter, Kramer 2011)*

Thinking about the possible solutions to help capitalism emerge from the crisis in which it finds itself today, these authors emphasize the role of the firms to *"bringing business and society back together"*. The solution lies in the principle of shared value, which involves creating economic value —not just profit per se— in a way that *also* creates value for society by addressing its needs and challenges:

> *"Shared value, then, is not about personal values. Nor is it about "sharing" the value already created by firms—a redistribution approach. Instead, it is about expanding the total pool of economic and social value" (Porter, Kramer 2011)*

Although sometimes presented as the next big idea by the strategy management circles, Porter et al.'s notion of "shared value" is more conceptual than practical and resembles many of the ideas discussed in the more mature stakeholder theory.

APPENDIX B.

DELPHI'S EXPERT BENCHMARKING OF RESPONSES

In this Appendix we provide an example of an individual report containing a benchmarking of the responses from an expert in Round 3 against the aggregate responses from the Experts' Panel. A report containing the information contained in this Appendix was distributed individually to all Panel members in Round 4 of the Delphi process, and used as a basis to respond the questions set in Round 4 questionnaire (see Appendix D).

In particular, the figures presented in this Appendix include:

- A benchmark of an expert's responses vs Panel members responses asking for the interconnectedness between constraints and value repositories (Fig.30).
- A benchmark of an expert's responses vs Panel members responses asking for the interconnectedness among value repositories (Fig.31).
- A benchmark of an expert's responses vs Panel members responses asking for the interconnectedness between value repositories and Operating Margin (Fig.32).

The data contained in these figures graphically illustrate the differences between expert's responses and those of the Panel members in Round 3, the latter represented as the average values of all experts' responses. This information offered every expert participating in Delphi Round 4 the opportunity to assess his/her previous level of agreement or disagreement with Panel members.

B.1 Interconnectedness between Constraints and Value Repositories

As shown in Fig.30, the most notorious differences —i.e. those at or above 70% difference rate— between expert's responses and those of the Panel members are the following:

- Constraints vs Customer experience, 100% difference rate.
- Constraints vs People and talent, 90%.
- Constraints vs Brand, 80%.
- Constraints vs Capacity management, 70%.
- Constraints vs Safety and security, 70%.
- Constraints vs Information management, 70%.

If we analyze where the smallest differences are given, namely where there has been a higher level of coincidence between the expert and the Panel members —i.e. less than 50% difference rate— the results obtained are the following:

- Constraints vs Network, 40% difference rate.
- Constraints vs Alliances, 40%.
- Constraints vs Customer centric proposition, 30%.

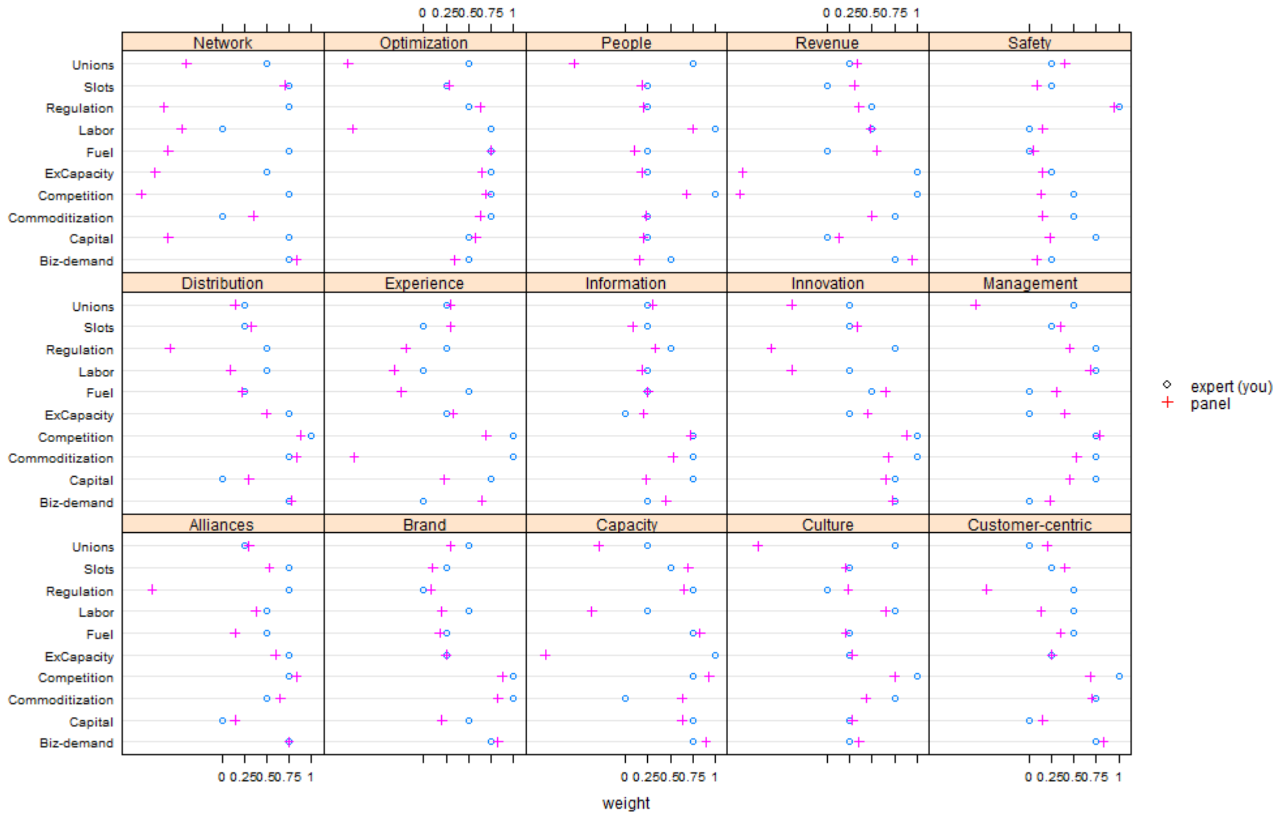

Figure 30. Benchmarking of Responses: Constraints vs Value Repositories
Source: own elaboration

B.2 Interconnectedness among Value Repositories

Fig.31 shows the high level of coincidence between the expert's responses and those of the Panel members, as reflected by the high number of responses whose difference rate is at or below 20%:

- Corporate culture, 13% difference rate.
- Distribution strategy, 13%.
- Management (leadership), 20%.
- Innovation, 20%.

- Information management, 20%.
- Alliances, 27%.
- Customer centric proposition, 27%.

Moreover, when we look at the highest differences in response, the difference rates remain between 50-40%, with the highest difference in 53%, as shown by the cases below:

- Value repositories vs Network, 53% difference rate.
- People and talent, 47%.
- Capacity management, 47%.
- Process and cost optimization, 47%.

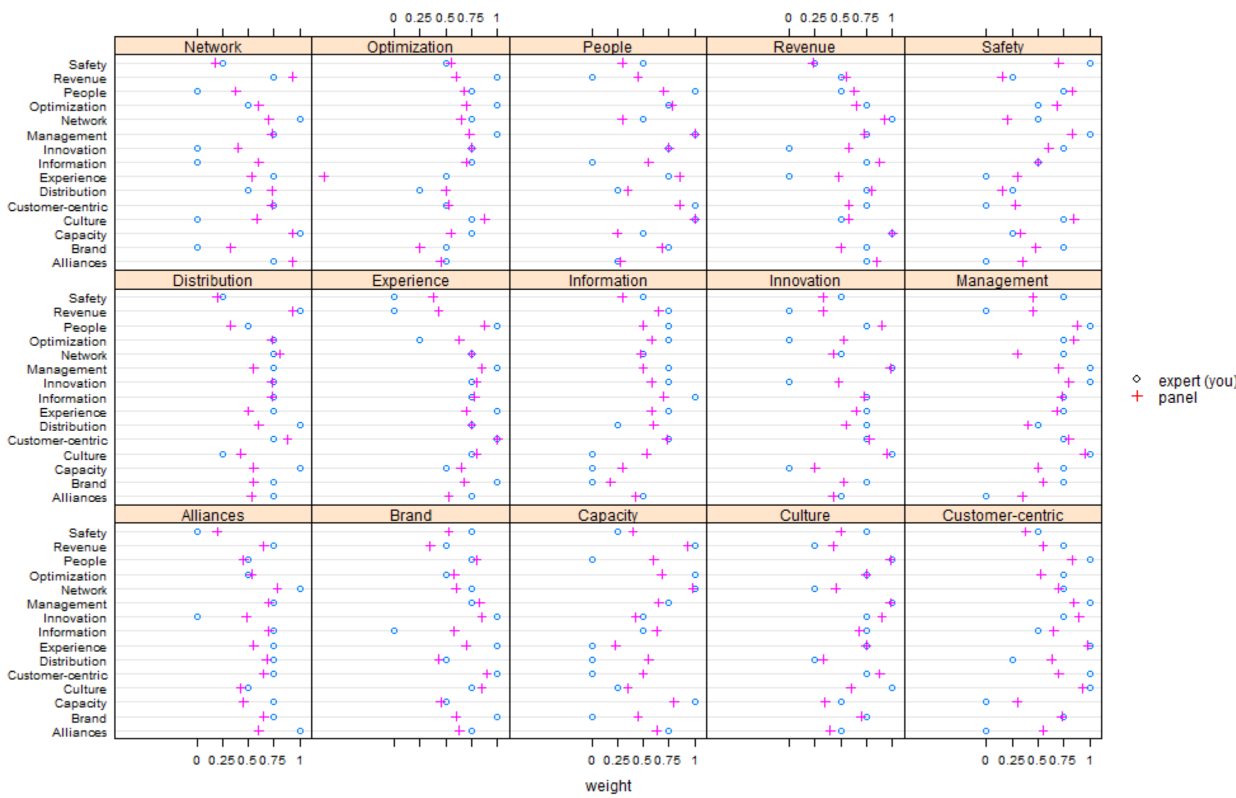

Figure 31. Benchmarking of Responses: Value Repositories

Source: own elaboration

B.3 Interconnectedness between Value Repositories and Operating Margin

The benchmarking of responses on the interconnectedness between Value Repositories and airlines' Operating Margin is presented in Fig.32.

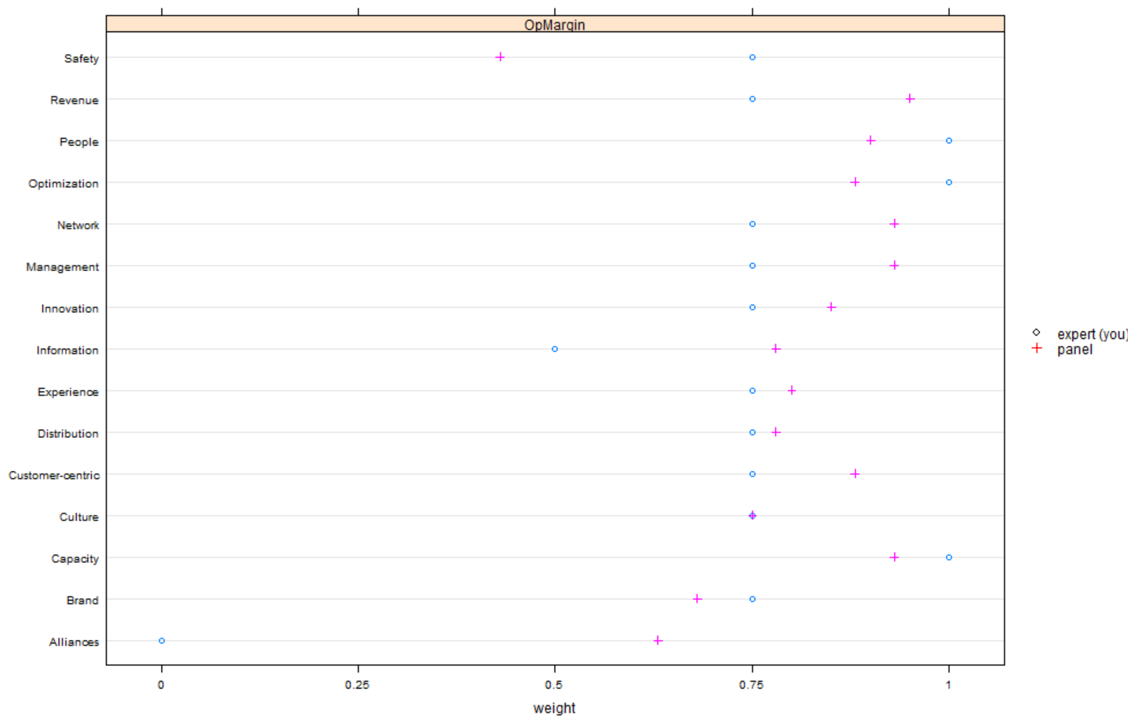

Figure 32. Benchmarking of Responses: Value Repositories vs Operating Margin
Source: own elaboration

As we can see, the difference rate between the expert's responses and those of the Panel members is 67%. This means that 10 out of 15 questions were answered differently between the expert and Panel members. The most noticeable difference refers to the interconnectedness between *Alliances* and *Operating Margin*, which was labelled as "non-existent" by the expert, whereas the Panel members labelled it as "Strong".

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APPENDIX C.

PANEL MEMBERS

The Experts' Panel was the primary participatory group across the thesis field research. The Panel was created on an on-line basis, and gathered a number of experts from different network airlines, positions and geographies across the world. All Panel members were specifically invited for the occasion.

The following table contains the list of the Panel members, including their names, position and name of company:

Name	Position	Company
Mr. Amin Abdulhadi	Director Flight Operations Engineering & Administration	Scandinavian Airlines
Mr. Thomas Bartsch	Former SVP Commercial Intelligence	Qatar Airways
Mrs. Daniela Baytelman	VP Distribution & Ancillary Revenue	LATAM Airlines
Mr. Dimitris Bountolos	VP Customer Experience	Iberia Líneas Aéreas
Mr. Duncan Bureau	VP Global Sales and Distribution	Air Canada
Mr. Anthony Doyle	Director New Product Development	Air Canada
Mr. Ferrán García	Strategic Planning & CEO Office	Iberia Líneas Aéreas
Mr. Raúl Gutiérrez	VP & Chief Information Officer, Club Premier	Aeromexico

Name	Position	Company
Mr. Hans Gydal	Director Sales Excellence	Scandinavian Airlines
Mr. Martin Hoffman	VP Value Stream Owner - Plan to Execution	Scadinavian Airlines
Mr. Carlos Jovel	VP Revenue Management and Pricing	LATAM Airlines
Mr. Rahul Kucheria	Head of Loyalty	Qatar Airways
Mr. Rodrigo Llaguno	VP Customer Experience	Avianca
Mr. Juan Felipe Luque	Director of Cargo Operations	Avianca
Mr. Jiří Marek	Executive Director Sales & Distribution	LOT Polish Airlines
Mr. Juan Alberto Martín	VP Joint Business Agreements	Iberia Líneas Aéreas
Mr. Rafael Andrés Martínez	Head of Distribution & Revenue Mmgt	Aerolíneas Argentinas
Mr. Albert Muntané	Head of Network and Distribution	Air Europa
Mr. Mark Nasr	MD Corporate Strategy and Development	United Airlines
Mr. Mauro Oretti	VP Sales & Marketing	SkyTeam
Mr. Ole Orvér	SVP Network Management	Qatar Airways
Mr. Mariano Salinas	Strategy & Business Development Director	Avianca
Mr. Federico Soto	Former Head of Strategic Management Office	Iberia Líneas Aéreas
Mr. Maarten van der Lei	VP Pricing & Revenue Mmgt Europe KLM	AirFrance/KLM
Mr. Warner van der Veer-Jehee	VP Safety & Quality at KLM E&M Division	AirFrance/KLM
Mr. Helmut Woelfel	VP Commercial	Lufthansa
Mr. Maarten van der Lei	VP Pricing & Revenue Mmgt Europe KLM	AirFrance/KLM
Mr. Warner van der Veer-Jehee	VP Safety & Quality at KLM E&M Division	AirFrance/KLM

Name	Position	Company
Mr. Helmut Woelfel	VP Commercial	Lufthansa

CEO: Chief Executive Officer; SVP: Senior Vice-President; VP: Vice-President

Table 19. List of Panel members
Source: own elaboration

Some of the Panel members chose not to make their personal profiles public. The following table contains less detailed information about these members.

Position	Type of company	Geography
VP Network Operations	Network Airline	Middle East
VP Aircraft Maintenance	Network Airline	Europe
Director Customer Experience	Alliance-Brand	Worldwide
VP Customer Experience and Technology	Alliance-Brand	Worldwide

VP: Vice-President

Table 20. List of Non-disclosed Panel members
Source: own elaboration

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APPENDIX D.

DELPHI QUESTIONNAIRES

D.1 Delphi Round 1 Questionnaire

Universidad de Alcalá

COMPLEX SYSTEMS IN SOCIAL SCIENCES RESEARCH GROUP
Faculty of Economics and Business Administration

MODELLING VALUE CREATION FOR AIRLINE COMPETITIVENESS Research Project

Presentation

WELCOME TO THE DELPHI SURVEY- ROUND 1 (OUT OF 4)!
This research project is initiated by the members of the Complex Systems in Social Sciences Research Group (Faculty of Economics and Business Administration, University of Alcala in Madrid-Spain). The objective of this study is twofold: 1) to answer the question: What actions are required by airlines to increase the value it creates and ensure its competitiveness?, and 2) to simulate the range of changes that would improve value creation in network airlines and enable executives and decision-makers to anticipate operating margins.
The study is purposefully designed to impact on your time as little as possible, and for this reason we will be adopting the Delphi technique.

About Round 1
The questionnaire consists of 2 questions and will take approximately 10-15 minutes or less. Questions are designed to build an "expert consensus" on the external constraints to value creation in network airlines, and on the key value repositories that impact airline's performance. This questionnaire will be conducted with an online Qualtrics-created survey.

What Next?
After completion of Round 1, you will receive a second questionnaire (Round 2) where you will asked to review the items summarized by the research team based on the information provided in the first round. At Round 2 a consensus will be formed on the basic components of value creation in airlines.

Confidentiality
All data obtained from participants will be kept confidential and will only be reported in an aggregated format (by reporting only combined results and never reporting individual ones). All questionnaires will be concealed, and no one other than the members of the research team will have access to them.

In participating in the research, you have the opportunity to:
Learn from and share insights with other airline industry experts about value creation in network airlines and other issues that are relevant to your work. This Delphi study is interactive and iterative allowing you to reflect on issues of significant importance to your business.
- Receive a copy of the pre-publication copies of the major reports being produced, which will help you better understand what is currently influencing value creation in airlines, what is likely to influence them in the future, and provide input for your planning decisions.

Questions about the Research?
If you have questions regarding this study, you may contact Mr Francisco J Navarro at +34 91 678 26 07, franciscojavier.nava@edu.uah.es. To know more about the study, please go to http://www.valueinairlines.com.

Log in

PLEASE LOG IN

First Name

Last Name

Company

Position

Question #1

<u>QUESTION #1</u>: WHAT DO YOU THINK ARE THE MAIN EXTERNAL CONSTRAINTS TO VALUE CREATION IN AIRLINES?

Drag and drop (from left to the right box) the main external constraints that you think affect most to value creation in airlines. You may choose one the specified constraints or add your own constraint by writing it in a blank box. The maximum number of constraints to be considered is 10.

<u>IMPORTANT NOTE</u>: The research team is aware that the term "value" is a subjective concept that can mean different things to different people, even within the same organization. Participants are encouraged to answer question #1 considering "value" on broad terms, either as or a combination of customer use value, value exchanged with the customer, or value offering to the market.

Items

Fuel cost

Labor cost

Airport fees

Handling fees

GDS fees

Government regulation

Competition from other airlines

Leisure travel demand

Business travel demand

ATC fees

Add new one

Add new one

Add new one

Add new one

Add new one

Add new one

Add new one

Add new one

Add new one

Add new one

Key constraints

Question #2

<u>QUESTION #2</u>: WHAT ARE THE KEY VALUE REPOSITORIES IN AIRLINES?

From your best knowledge and experience, please write what you think are the key Value Repositories (VRs) that impact airlines' operating margin in the long term. Participant is requested to consider VRs across all the functions of an airline. If needed, a more detailed explanation of how a concrete value repository works can be given is the text box. You can add up to 15 value repositories.

<u>IMPORTANT NOTE</u>: Value Repositories (VRs) are internal autonomous operating networks that group together *cross-functional activities, resources, processes and/or tools with the sole purpose to create unique and differentiated value to be exchanged with other internal or external VRs. Keep in mind that most of the times VRs do not match the units in the organizational chart, nor the dimensions of Porter's conventional value chain or 5-Forces analysis. For more information about Value Repositories, please click <u>here</u>.*

Value Repository 1

Value Repository 2

Value Repository 3

Value Repository 4

Value Repository 5

Value Repository 6

Value Repository 7

Value Repository 8

Value Repository 9

Value Repository 10

Value Repository 11

Value Repository 12

Value Repository 13

Value Repository 14

Value Repository 15

Share details

We are planning to make the names, companies and position of the members of the expert panel public, this way you and your peers will know more about the profile of participants. If you agree to share your details with your peers please select "Yes" in the options below:

Yes

No

Questions? Visit <u>http://www.valueinairlines.com</u>

D.2 Delphi Round 2 Questionnaire

Presentation

WELCOME TO DELPHI ROUND 2!
The questionnaire consists of 2 questions and will take approximately 10-15 minutes or less. Participant is asked to review the items summarized by the investigators based on the information provided in the first round. Questions are designed to form an "expert consensus" on the external constraints to value creation in network airlines, and on the key value repositories that impact airline's operating margin. This questionnaire will be conducted with an online Qualtrics-created survey.

What Next?
After completion of Round 2, you will receive an interim report summarizing the results obtained in rounds 1 and 2. This is to be followed by a third questionnaire (Round 3) where you will asked to set the connections between the value constraints and value repositories, and among value repositories themselves.

Confidentiality

All data obtained from participants will be kept confidential and will only be reported in an aggregated format (by reporting only combined results and never reporting individual ones). All questionnaires will be concealed, and no one other than the members of the research team will have access to them.

In participating in the research, you have the opportunity to:
- Learn from and share insights with other airline industry experts about value creation in network airlines and other issues that are relevant to your work. This Delphi study is interactive and iterative allowing you to reflect on issues of significant importance to your business.
- Receive a copy of the pre-publication copies of the major reports being produced, which will help you better understand what is currently influencing value creation in airlines, what is likely to influence them in the future, and provide input for your planning decisions.

Questions about the Research?
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About the Research Project
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The study is purposefully designed to impact on your time as little as possible, and for this reason we will be adopting the Delphi technique.

Log in

PLEASE LOG IN

First Name
Last Name
Company
Position

Question #1

<u>QUESTION #1</u>: WHAT DO YOU THINK ARE THE 10 KEY CONSTRAINTS TO VALUE CREATION IN NETWORK AIRLINES?

*The items on the left column are the value constraints stated by the members of the experts panel. You are asked to drag and drop (from the left column to the right box) the **10 constraints** that you think affect most to **value creation** in network airlines.*

Items

Your 10 Key Value Creation Constraints

Government taxation
Economic cycle
Currency exchange rates
Airport fees
Aircraft cost & efficiency
Slot availability
ATC fees
Price transparency
Capital intensity
Labor costs
High demand volatility and price elasticity
Handling fees
Duopolio of aircraft manufacturers
Airport infrastructure
Fuel cost
Environmental awareness
Government regulation
Excess capacity
Leisure travel demand
ATC co-ordination
Competition from other airlines
Commoditizied product offering
GDS fees
Power of unions/labour force
New Distribution Capability (NDC) integration
Business travel demand
Distortion of global competition due to the intervention of regional/local public bodies, or the lack of it
Short-term variables costs
Inflexible, time-lagged supply
IT systems costs and complexity
Government subsidies
Competition from other means of transport
IT interoperability problems

Question #2

QUESTION #2: WHAT DO YOU THINK ARE THE KEY 15 VALUE REPOSITORIES AFFECTING PERFORMANCE IN NETWORK AIRLINES?

*The items on the left column are the value repositories stated by the members of the experts panel. Now you are asked to drag and drop (from the left column to the right box) the **15 value repositories** that you think impact most, either directly or indirectly, to network airlines' **operating margin**.*

*REMINDER: **A Value Repository (VR) is an autonomous, interacting network that group together internal** cross-functional activities, resources, people, processes and/or systems with the sole purpose to create unique and differentiated value that is determinant of the company ultimate performance. For more information about Value Repositories, please click here.*

Items

Information management (1)

Corporate culture (2)

Brand (3)

Safety and security (4)

Alliances (5)

Scheduling (6)

Capacity management (7)

Distribution strategy (8)

People and talent (9)

Sales (10)

Frequent Flyer Programmes (11)

Process and cost optimization (12)

Network (13)

Customer data analytics (14)

Ancillary revenue (15)

Customer experience (16)

Procurement (17)

Revenue management (18)

Operations management (19)

IT management (20)

Relationships with stakeholders (21)

Products and services (22)

Finance (23)

Digital channels (24)

Flight and cabin crew rostering (25)

Management (leadership) (26)

Social ecosystem (27)

Customer-centric proposition (28)

Safety and security (29)

Innovation (30)

Your 15 Key Value Repositories Here

The information provided below complements the content of the Value Repositories made by the member of the experts panel:

(1) Includes information definition and availability; content "product" creation; content distribution; knowledge management
(2) Includes internal culture definition mainly focused on delivering services
(3) Includes brand management; product recognition
(4) No further description is provided
(5) Includes alliance management; monitoring of value contribution
(6) Includes schedule integrity
(7) Includes short term flexible capacity management; fleet definition; aircraft configuration; optimal utilization of aircraft
(8) Includes New Distribution Capability (NDC)
(9) Includes training and communication
(10) Includes commercial plan definition; commercial efforts
(11) No further description is provided
(12) Includes productivity and cost management; cost competitiveness; process simplication
(13) Includes network planning and optimization
(14) Includes integration of key customer data analytics; customer segmentation
(15) Includes baggages fees; In flight catering
(16) Includes management of customer satisfaction; ease of customer transaction; lounge experience; Net Promoter System (NPS)
(17) Includes supply contracts; fuel contracts; access to low cost resources
(18) No further description is provided
(19) Includes hub definition and optimization; on-time performance (OTP); punctuality and regularity
(20) Includes IT systems management
(21) Includes relationship with employees, aviation authorities and governments
(22) Includes design of products and services; product/service quality management; real time dynamic offering
(23) Includes capital management; structured finance
(24) Includes digital business management; Net Promoter System (NPS)
(25) Includes optimal utilization of crews
(26) Includes business plan definition
(27) Includes geographics and demographics
(28) Includes customer integration in all the processes
(29) No further description is provided
(30) No further description is provided

Please write here any comment regarding disagreement with the Value Repositories nomenclature and/or composition as summarized by investigators:

Share Your Details

If you agree to share your details with your peers, please select 'Yes' in the options below:

***IMPORTANT NOTE**: A disclaimer accompanies the list of members of the experts panel, please check it here: http://bit.ly/1F5EhY6*

Yes

No

Questions? Visit http://www.valueinairlines.com

D.3 Delphi Round 3 Questionnaire

MODELLING VALUE CREATION FOR AIRLINE COMPETITIVENESS Research Project

Presentation

WELCOME TO DELPHI ROUND 3!

The questionnaire consists of 3 questions divided in the following sections: (1) Section 1: consists of fifteen matrix-type questions, (2) Section 2: consists of another fifteen matrix-type questions, and (3) Section 3: consists of one matrix type question. Estimated time of completion is 30 45 minutes or less. Participant is asked to set the relationships and impact weights between the 10 Consensus Value Constraints, the 15 Consensus Value Repositories, and airline's Operating Margin. This questionnaire will be conducted with an online Qualtrics created survey.

What Next?

After completion of Round 3, you will receive a copy of your own built-in "Airline's Value Creation Canvas" (AVCC) depicting the relationships and impacts between airline's value constraints, value repositories and operating margin. The AVCC will be followed by our last questionnaire (Round 4) where you and the experts panel peers will be asked to try to reach a final consensus on the same questions.

Confidentiality

All data obtained from participants will be kept confidential and will only be reported in an aggregated format (by reporting only combined results and never reporting individual ones). All questionnaires will be concealed, and no one other than the members of the research team will have access to them.

In participating in the research, you have the opportunity to:

- Learn from and share insights with other airline industry experts about value creation in network airlines and other issues that are relevant to your work. This Delphi study is interactive and iterative allowing you to reflect on issues of significant importance to your business.
- Receive a copy of the pre publication copies of the major reports being produced, which will help you better understand what is currently influencing value creation in airlines, what is likely to influence them in the future, and provide input for your planning decisions.

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The study is purposefully designed to impact on your time as little as possible, and for this reason we will be adopting the Delphi technique.

Log in

PLEASE LOG IN

First Name

Last Name

Company

Position

Question #1: CONSTRAINTS VS VALUE REPOSITORIES

<u>QUESTION #1</u>: HOW DO THE 10 CONSENSUS VALUE CONSTRAINTS IMPACT ON THE 15 CONSENSUS VALUE REPOSITORIES?

The items on the first column are the 10 Consensus Value Constraints reached by the experts in Round 2 of the experts panel. The columns to the right contain the 15 Consensus Value Repositories. **For the sake of clarity this question has been divided in fifteen side-by-side sections each containing a question relating all 10 Consensus Value Constraints with one Consensus Value Repository at a time.**

SECTION 1/15: SELECT THE OPTIONS THAT BEST DESCRIBE THE IMPACT OF THE 10 CONSENSUS VALUE CONSTRAINTS ON THE VALUE REPOSITORY- NETWORK

(1) Only one option is to be selected per row, (2) Leave unknown impacts in blank

	1. NETWORK				
	Very Weak	Weak	Zero	Strong	Very Strong
Government regulation	O	O	O	O	O
Fuel cost	O	O	O	O	O
Competition from other airlines	O	O	O	O	O
Commoditizied product offering	O	O	O	O	O
Power of unions/labour force	O	O	O	O	O
Labor costs	O	O	O	O	O
Slot availability	O	O	O	O	O
Excess capacity	O	O	O	O	O
Capital intensity	O	O	O	O	O
Business travel demand	O	O	O	O	O
	Very Weak	Weak	Zero	Strong	Very Strong

(1) Network: Includes network planning and optimization

<u>REMINDER</u>: A Value Repository (VR) is an autonomous, interacting network that group together internal cross-functional activities, resources, people, processes and/or systems with the sole purpose to create unique and differentiated value that is determinant of the company ultimate performance. For more information about Value Repositories, please click here.

QUESTION#1- SECTION 2/15: SELECT THE OPTIONS THAT BEST DESCRIBE THE IMPACT OF THE 10 CONSENSUS VALUE CONSTRAINTS ON THE VALUE REPOSITORY- REVENUE MANAGEMENT

(1) Only one option is to be selected per row, (2) For unknown impacts, leave option in blank

	2. REVENUE MANAGEMENT				
	Very Weak	Weak	Zero	Strong	Very Strong
Government regulation	O	O	O	O	O
Fuel cost	O	O	O	O	O
Competition from other airlines	O	O	O	O	O
Commoditizied product offering	O	O	O	O	O
Power of unions/labour force	O	O	O	O	O
Labor costs	O	O	O	O	O
Slot availability	O	O	O	O	O
Excess capacity	O	O	O	O	O
Capital intensity	O	O	O	O	O
Business travel demand	O	O	O	O	O
	Very Weak	Weak	Zero	Strong	Very Strong

(2) Revenue Management: no further information is provided

<u>REMINDER</u>: A Value Repository (VR) is an autonomous, interacting network that group together internal cross-functional activities, resources, people, processes and/or systems with the sole purpose to create unique and

(pages 5-14 are not displayed)

processes

REMINDER: A Value Repository (VR) is an autonomous, interacting network that group together internal cross-functional activities, resources, people, processes and/or systems with the sole purpose to create unique and differentiated value that is determinant of the company ultimate performance. For more information about Value Repositories, please click here.

Question #2: VALUE REPOSITORIES VS VALUE REPOSITORIES

QUESTION #2: HOW ARE THE 15 CONSENSUS VALUE REPOSITORIES INTERLINKED AND HOW THEY IMPACT ON EACH OTHER?

The items on the first column are the 15 consensus Value Repositories reached by the experts in Round 2 of the experts panel. The columns to the right also contain the 15 consensus Value Repositories. **For the sake of clarity this question has been divided in three side-by-side sections each containing the questions relating the 15 consensus Value Constraints among them (up until 15 Value Repositories).**

SECTION 1/15: SELECT THE OPTIONS THAT BEST DESCRIBE THE IMPACT AMONG THE 15 CONSENSUS VALUE REPOSITORIES AND NETWORK

(1) Only one option is to be selected per row, (2) Leave unknown impacts in blank, (3) Loops are permitted (the impact of one value repository on itself)

	1. NETWORK				
	Very Weak	Weak	Zero	Strong	Very Strong
1. Network	O	O	O	O	O
2. Revenue management	O	O	O	O	O
3. People and talent	O	O	O	O	O
4. Management (leadership)	O	O	O	O	O
5. Corporate culture	O	O	O	O	O
6. Capacity mananagement	O	O	O	O	O
7. Customer experience	O	O	O	O	O
8. Innovation	O	O	O	O	O
9. Brand	O	O	O	O	O
10. Alliances	O	O	O	O	O
11. Safety and security	O	O	O	O	O
12. Distribution strategy	O	O	O	O	O
13. Process and cost optimization	O	O	O	O	O
14. Information management	O	O	O	O	O
15. Customer-centric proposition	O	O	O	O	O
	Very Weak	Weak	Zero	Strong	Very Strong

The information provided below complements the content of the 15 Consensus Value Repositories made by the members of the experts panel:

(1) Network: Includes network planning and optimization
(2) Revenue Management: no further information is provided
(3) People and talent: Includes training and communication
(4) Management (leadership): Includes business plan definition
(5) Corporate culture: Includes internal culture definition mainly focused on delivering services
(6) Capacity management: Includes short term flexible capacity management; fleet definition; aircraft configuration; optimal utilization of aircraft
(7) Customer experience: Includes management of customer satisfaction; ease of customer transaction; lounge experience; Net Promoter System (NPS)
(8) Innovation: no further information is provided
(9) Brand: Includes brand management; product recognition
(10) Alliances: Includes alliance management; monitoring of value contribution
(11) Safety and security: no further description is provided
(12) Distribution strategy: Includes New Distribution Capability (NDC)
(13) Process and cost optimization: Includes productivity and cost management; cost competitiveness; process simplication
(14) Information management: Includes information definition and availability; content "product" creation; content distribution; knowledge management
(15) Customer-centric proposition: Includes customer integration in all the processes

QUESTION#2- SECTION 2/15: SELECT THE OPTIONS THAT BEST DESCRIBE THE IMPACT AMONG THE 15 CONSENSUS VALUE

(pages 17-35 are not displayed)

14. Information management	O	O	O	O	O
15. Customer centric proposition	O	O	O	O	O
	Very Weak	Weak	Zero	Strong	Very Strong

The information provided below complements the content of the 15 Consensus Value Repositories made by the members of the experts panel:

(1) Network: Includes network planning and optimization
(2) Revenue Management: no further information is provided
(3) People and talent: Includes training and communication
(4) Management (leadership): Includes business plan definition
(5) Corporate culture: Includes internal culture definition mainly focused on delivering services
(6) Capacity management: Includes short term flexible capacity management; fleet definition; aircraft configuration; optimal utilization of aircraft
(7) Customer experience: Includes management of customer satisfaction; ease of customer transaction; lounge experience; Net Promoter System (NPS)
(8) Innovation: no further information is provided
(9) Brand: Includes brand management; product recognition
(10) Alliances: Includes alliance management; monitoring of value contribution
(11) Safety and security: no further description is provided
(12) Distribution strategy: Includes New Distribution Capability (NDC)
(13) Process and cost optimization: Includes productivity and cost management; cost competitiveness; process simplication
(14) Information management: Includes information definition and availability; content "product" creation; content distribution; knowledge management
(15) Customer-centric proposition: Includes customer integration in all the processesC

Question #3: VALUE REPOSITORIES VS OPERATING MARGIN

QUESTION #3: HOW DO THE 15 CONSENSUS VALUE REPOSITORIES IMPACT ON AIRLINES' OPERATING MARGIN?

*The items on the left column are the consensus Value Repositories reached by the members of the experts panel in previous Round 2. You are asked to select one option (very weak, weak, zero, strong, very strong) that best decribes the impact of each consensus Value Repository on the **Operating Margin** of a network airline. For more information about Operating margin please read the note below.*

	OPERATING MARGIN				
	Very Weak	Weak	Zero	Strong	Very Strong
1. Network	O	O	O	O	O
2. Revenue management	O	O	O	O	O
3. People and talent	O	O	O	O	O
4. Management (leadership)	O	O	O	O	O
5. Corporate culture	O	O	O	O	O
6. Capacity management	O	O	O	O	O
7. Customer experience	O	O	O	O	O
8. Innovation	O	O	O	O	O
9. Brand	O	O	O	O	O
10. Alliances	O	O	O	O	O
11. Safety and security	O	O	O	O	O
12. Distribution strategy	O	O	O	O	O
13. Process and cost optimization	O	O	O	O	O
14. Information management	O	O	O	O	O
Customer-centric proposition	O	O	O	O	O
	Very Weak	Weak	Zero	Strong	Very Strong

A NOTE ABOUT OPERATING MARGIN

Operating margin is the key indicator chosen in our study to reflect an airline's overall performance and the opportunity for improvement.

Technically speaking **Operating margin** is the proportion of revenues remaining after paying the costs of operating the business. Operating costs usually include expenditures on labor costs (wages), raw materials, overhead, depreciation and amortization, selling, general, and administrative expenses, advertising, etc. **Operating margin** can be calculated by dividing Operating Profit **by Net Sales**.

Share Your Details

D.4 Delphi Round 4 Questionnaire

MODELLING VALUE CREATION FOR AIRLINE COMPETITIVENESS Research Project

Presentation

WELCOME TO DELPHI ROUND 4!

The questionnaire consists of 3 questions divided in the following sections: (1) Section 1: consists of fifteen matrix-type questions, (2) Section 2: consists of another fifteen matrix-type questions, and (3) Section 3: consists of one matrix type question. Participant is asked to set the final sign and strength of the links between the 10 Consensus Value Constraints, the 15 Value Repositories and the Airline's Operating Margin. Participants will only need to fill Column 1 (Sign of the link) and introduce selected changes with respect to their Round 3 responses in Column 2 (Strength of the link). Estimated time of completion is 10-15 minutes or less. This questionnaire will be conducted with an online Qualtrics-created survey.

What Next?

Round 4 is the last round of this research project. From here on, the research team will prepare an Interim Report with the conclusions gained and the "Airline's Value Creation Canvas" (AVCC) for distribution among participants. Then we will continue according to the methodology to the modelling stage of the Project.

Confidentiality

All data obtained from participants will be kept confidential and will only be reported in an aggregated format (by reporting only combined results and never reporting individual ones). All questionnaires will be concealed, and no one other than the members of the research team will have access to them.

In participating in the research, you have the opportunity to:

- Learn from and share insights with other airline industry experts about value creation in network airlines and other issues that are relevant to your work. This Delphi study is interactive and iterative allowing you to reflect on issues of significant importance to your business.
- Receive a copy of the pre-publication copies of the major reports being produced, which will help you better understand what is currently influencing value creation in airlines, what is likely to influence them in the future, and provide input for your planning decisions.

Questions about the Research?

If you have questions regarding this study, you may contact Mr Francisco J Navarro at +34 91 678 26 07, franciscojavier.nava@edu.uah.es. To know more about the study, please go to http://www.valueinairlines.com.

About the Research Project

This research project is initiated by the members of the Complex Systems in Social Sciences Research Group (Faculty of Economics and Business Administration, University of Alcala in Madrid-Spain). The objective of this study is twofold: 1) to answer the question: What actions are required by airlines to increase the value it creates and ensure its competitiveness?, and 2) to simulate the range of changes that would improve value creation in network airlines and enable executives and decision-makers to anticipate operating margins.

The study is purposefully designed to impact on your time as little as possible, and for this reason we will be adopting the Delphi technique.

Log in

PLEASE LOG IN

First Name	
Last Name	
Company	
Position	

Question #1: CONSTRAINTS VS VALUE REPOSITORIES

ACTION #1: SET THE FINAL SIGN AND STRENGTH OF THE LINKS BETWEEN THE 10 CONSENSUS VALUE CONSTRAINTS AND THE 15 CONSENSUS VALUE REPOSITORIES

HOW TO FILL COLUMN 1 (SIGN OF A LINK): Select an option that describes whether the link between a Value Constraint and a Value Repository is either Positive or Negative. A Positive link is a relationship between two factors (i.e a value constraint and a value repository) such that as one factor increases, the other increases. A Negative link is a relationship such that as one factor increases, the other decreases. Neutral refers to a link that is non-existent.

HOW TO FILL COLUMN 2 (STRENGTH OF A LINK): Select an option that describes the strength (weak, strong, etc) of a link between a Value Constraint and a Value Repository.

NOTE FOR PARTICIPANTS: Participants will only need to fill Column 1 (Sign of the link) and introduce selected changes with respect to their Round 3 responses in Column 2 (Strength of the link).

SECTION 1/15: 10 CONSENSUS VALUE CONSTRAINTS vs NETWORK VALUE REPOSITORY

	NETWORK- SIGN OF THE LINK			NETWORK- STRENGTH OF THE LINK
	Positive	Neutral	Negative	
Government regulation	O	O	O	▾
Fuel cost	O	O	O	▾
Competition from other airlines	O	O	O	▾
Commoditizied product offering	O	O	O	▾
Power of unions/labour force	O	O	O	▾
Labor costs	O	O	O	▾
Slot availability	O	O	O	▾
Excess capacity	O	O	O	▾
Capital intensity	O	O	O	▾
Business travel demand	O	O	O	▾
	Positive	Neutral	Negative	

(1) Network: Includes network planning and optimization

REMINDER: A Positive link is a relationship between two factors (i.e a value constraint and a value repository) such that as the value of one factor increases, the other increases. A Negative link is a relationship such that as the value of one factor increases, the other decreases. Neutral refers to a link that is non-existent.

ACTION#1- SECTION 2/15: CONSENSUS VALUE CONSTRAINTS vs REVENUE MANAGEMENT VALUE REPOSITORY

	REVENUE MANAGEMENT- SIGN OF THE LINK			REVENUE MANAGEMENT- STRENGTH OF THE LINK
	Positive	Neutral	Negative	
Government regulation	O	O	O	▾
Fuel cost	O	O	O	▾
Competition from other airlines	O	O	O	▾
Commoditizied product offering	O	O	O	▾
Power of unions/labour force	O	O	O	▾
Labor costs	O	O	O	▾

(pages 5-15 are not displayed)

as the value of one factor increases, the other decreases. Neutral refers to a link that is non-existent.

Question #2: VALUE REPOSITORIES VS VALUE REPOSITORIES

ACTION #2: SET THE FINAL SIGN AND STRENGTH OF THE LINKS BETWEEN THE 15 CONSENSUS VALUE REPOSITORIES

HOW TO FILL COLUMN 1 (SIGN OF A LINK): Select an option that describes whether the link between a two Value Repositories is either Positive or Negative. A Positive link is a relationship between two factors (i.e two value repositories) such that as one factor increases, the other increases. A Negative link is a relationship such that as one factor increases, the other decreases. Neutral refers to a link that is non-existent.

HOW TO FILL COLUMN 2 (STRENGTH OF A LINK): Select an option that describes the strength (weak, strong, etc) of a link between a two Consensus Value Repositories.

NOTE FOR PARTICIPANTS: Participants will only need to fill Column 1 (Sign of the link) and introduce selected changes with respect to their Round 3 responses in Column 2 (Strength of the link).

SECTION 1/15: THE 15 CONSENSUS VALUE REPOSITORIES vs NETWORK VALUE REPOSITORY

	NETWORK- SIGN OF THE LINK			NETWORK- STRENGTH OF THE LINK
	Positive	Neutral	Negative	
1. Network	○	○	○	▾
2. Revenue management	○	○	○	▾
3. People and talent	○	○	○	▾
4. Management (leadership)	○	○	○	▾
5. Corporate culture	○	○	○	▾
6. Capacity mananagement	○	○	○	▾
7. Customer experience	○	○	○	▾
8. Innovation	○	○	○	▾
9. Brand	○	○	○	▾
10. Alliances	○	○	○	▾
11. Safety and security	○	○	○	▾
12. Distribution strategy	○	○	○	▾
13. Process and cost optimization	○	○	○	▾
14. Information management	○	○	○	▾
15. Customer-centric proposition	○	○	○	▾
	Positive	Neutral	Negative	

The information provided below complements the content of the 15 Consensus Value Repositories made by the members of the experts panel.

(1) Network: Includes network planning and optimization
(2) Revenue Management: no further information is provided
(3) People and talent: Includes training and communication
(4) Management (leadership): Includes business plan definition
(5) Corporate culture: Includes internal culture definition mainly focused on delivering services
(6) Capacity management: Includes short term flexible capacity management; fleet definition; aircraft configuration; optimal utilization of aircraft
(7) Customer experience: Includes management of customer satisfaction; ease of customer transaction; lounge experience; Net Promoter System (NPS)
(8) Innovation: no further information is provided
(9) Brand: Includes brand management; product recognition
(10) Alliances: Includes alliance management; monitoring of value contribution
(11) Safety and security: no further description is provided
(12) Distribution strategy: Includes New Distribution Capability (NDC)
(13) Process and cost optimization: Includes productivity and cost management; cost competitiveness; process simplication
(14) Information management: Includes information definition and availability; content "product" creation; content distribution; knowledge management
(15) Customer-centric proposition: Includes customer integration in all the processes

(pages 18-40 are not displayed)

repository and operating margin) such that as one factor increases, the other increases. A Negative link is a relationship such that as one factor increases, the other decreases. Neutral refers to a link that is non-existent.

HOW TO FILL COLUMN 2 (STRENGTH OF A LINK): Select an option that describes the strength of a link between a Consensus Value Repository and Airline's Operating Margin.

NOTE FOR PARTICIPANTS: Participants will only need to fill Column 1 (Sign of the link) and introduce selected changes with respect to their Round 3 responses in Column 2 (Strength of the link).

	OPERATING MARGIN- SIGN OF THE LINK			OPERATING MARGIN- STRENGTH OF THE LINK
	Positive	Neutral	Negative	
1. Network	○	○	○	▾
2. Revenue management	○	○	○	▾
3. People and talent	○	○	○	▾
4. Management (leadership)	○	○	○	▾
5. Corporate culture	○	○	○	▾
6. Capacity management	○	○	○	▾
7. Customer experience	○	○	○	▾
8. Innovation	○	○	○	▾
9. Brand	○	○	○	▾
10. Alliances	○	○	○	▾
11. Safety and security	○	○	○	▾
12. Distribution strategy	○	○	○	▾
13. Process and cost optimization	○	○	○	▾
14. Information management	○	○	○	▾
Customer-centric proposition	○	○	○	▾
	Positive	Neutral	Negative	

A NOTE ABOUT OPERATING MARGIN

Operating margin is the key indicator chosen in our study to reflect an airline's overall performance and the opportunity for improvement.

Technically speaking **Operating margin** is the proportion of revenues remaining after paying the costs of operating the business. Operating costs usually include expenditures on labor costs (wages), raw materials, overhead, depreciation and amortization, selling, general, and administrative expenses, advertising, etc. **Operating margin** can be calculated by dividing Operating Profit by **Net Sales**.

REMINDER: A Positive link is a relationship between two factors (i.e a value constraint and a value repository) such that as the value of one factor increases, the other increases. A Negative link is a relationship such that as the value of one factor increases, the other decreases. Neutral refers to a link that is non-existent.

Share Your Details

If you agree to share your personal data (name, title and company) with your peers in the experts panel, please select 'Yes' in the options below:

IMPORTANT NOTE: A disclaimer accompanies the list of members of the experts panel, please check it here: http://bit.ly/1F5EhY6

Yes
No

Questions? Visit http://www.valueinairlines.com

APPENDIX E.

FIELD RESEARCH DATA

E.1 Participants Profile (participants.xlsx)

Expert	Area	Geography	Position
1	Engineering	Europe	Director
2	Commercial	Middle East	SVP
3	Sales & Distribution	South America	VP
4	Commercial	Europe	VP
5	Sales & Distribution	North America	VP
6	Network & Revenue	South America	Director
7	Commercial	North America	Director
8	Corporate	Europe	VP
9	Corporate	Europe	Manager
10	Sales & Distribution	Europe	Director
11	Commercial	Europe	VP
12	Network & Revenue	South America	VP
13	Commercial	Middle East	Manager
14	Commercial	South America	VP
15	Network & Revenue	Middle East	VP
16	Commercial	North America	Director

Expert	Area	Geography	Position
17	Sales & Distribution	Europe	Director
18	Commercial	Europe	VP
19	Network & Revenue	South America	VP
20	Network & Revenue	Europe	Director
21	Corporate	North America	Director
22	Sales & Distribution	Europe	VP
23	Network & Revenue	Middle East	SVP
24	Corporate	Europe	Manager
25	Network & Revenue	Europe	VP
26	Engineering	Europe	VP
27	Engineering	Europe	VP
28	Commercial	Europe	VP

E.2 Participation Data (participants.xlsx)

Expert	Type	Geography	Round
1	Complete	Europe	R1
2	Complete	Middle East	R1
2	Complete	Middle East	R2
2	Complete	Middle East	R3
2	Complete	Middle East	R4
3	Complete	South America	R1
3	Complete	South America	R2
3	Complete	South America	R3
4	Complete	Europe	R1
5	Complete	North America	R2

Expert	Type	Geography	Round
6	Complete	South America	R3
7	Complete	North America	R1
7	Complete	North America	R2
7	Complete	North America	R3
7	Complete	North America	R4
8	Incomplete	Europe	R1
8	Complete	Europe	R2
8	Complete	Europe	R3
8	Incomplete	Europe	R4
9	Complete	Europe	R1
9	Complete	Europe	R2
9	Complete	Europe	R3
9	Incomplete	Europe	R4
10	Complete	Europe	R2
11	Incomplete	Europe	R1
12	Complete	South America	R1
13	Incomplete	Middle East	R1
14	Complete	South America	R1
14	Complete	South America	R2
14	Complete	South America	R3
15	Complete	Middle East	R1
16	Complete	North America	R2
17	Complete	Europe	R1
18	Complete	Europe	R1
18	Complete	Europe	R2
18	Complete	Europe	R3
18	Complete	Europe	R4

Expert	Type	Geography	Round
19	Complete	South America	R1
19	Complete	South America	R2
19	Complete	South America	R3
19	Complete	South America	R4
20	Complete	Europe	R1
20	Complete	Europe	R2
20	Complete	Europe	R3
20	Complete	Europe	R4
21	Complete	North America	R2
22	Complete	Europe	R1
22	Complete	Europe	R2
22	Complete	Europe	R3
22	Complete	Europe	R4
23	Complete	Middle East	R2
24	Complete	Europe	R1
24	Complete	Europe	R2
24	Complete	Europe	R3
24	Complete	Europe	R4
25	Incomplete	Europe	R1
26	Incomplete	Europe	R1
27	Incomplete	Europe	R1
27	Complete	Europe	R2
27	Complete	Europe	R3
27	Incomplete	Europe	R4
28	Incomplete	Europe	R1
28	Complete	Europe	R2
100	Not valid	Unknown	R1

Expert	Type	Geography	Round
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R1
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R2
100	Not valid	Unknown	R3
100	Not valid	Unknown	R3
100	Not valid	Unknown	R3
100	Not valid	Unknown	R3
100	Not valid	Unknown	R3
100	Not valid	Unknown	R3
100	Not valid	Unknown	R4

E.3 Delphi Round 1 Constraints (round_1_R.xlsx)

Constraint	Frequency
Labor costs	18
Competition from other airlines	16
Government regulation	15
Fuel cost	14
Airport fees	8
GDS fees	6
Leisure travel demand	5
Business travel demand	4
ATC fees	3
IT systems costs and complexity	2
Handling fees	2
IT interoperability problems	1
Aircraft cost & efficiency	1
Slot availability	1
Economic cycle	1
Competition from other means of transport	1
Power of unions/labour force	1
Government subsidies	1
Capital intensity	1
High demand volatility and price elasticity	1
Inflexible, time-lagged supply	1
Short-term variable costs	1
Price transparency	1
Commoditizied product offering	1

Constraint	Frequency
Duopolio of aircraft manufacturers	1
ATC co-ordination	1
Airport infrastructure	1
New Distribution Capability (NDC) Integration	1
Environmental awareness	1
Excess capacity	1
Currency exchange rates	1
Distortion of global competition due to the intervention of regional/local bodies, or the lack of it	1
Government taxation	1
Health threats	1
Cost of sales (including transaction fees and fraud)	1
Access to talent and ability to retain talent	1
Freedom of movement over borders, visa policies and processing delays	1
Airport security screening and processing procedures	1
Product distribution capabilities/costs which includes but expands beyond the GDS costs	1

E.4 Delphi Round 1 Value Repositories (round_1_R.xlsx)

Value Repository	Frequency
Capacity management	6
Information management	5
Network	5
Customer experience	4
Scheduling	3

Value Repository	Frequency
Sales	3
Procurement	3
Operations management	3
Relationships with stakeholders	3
Corporate culture	3
Products and services	3
People and talent	3
Process and cost optimization	3
Digital channels	2
Alliances	2
Revenue management	2
Distribution strategy	2
Customer centric proposition	2
Frequent flyer programmes	2
Flight and cabin crew rostering	2
Finance	2
Customer data analytics	2
Brand	2
Social ecosystem	2
Ancillary revenue	2
Management/ Leadership	2
IT Management	1
Safety and security	1
Innovation	1

E.5 Delphi Round 2 Constraints (round_2_R.xlsx)

Constraint	Frequency	Adj. Frequency
Government regulation	15	15,00002
Fuel cost	11	11,000018
Competition from other airlines	11	11,00001
Commoditizied product offering	11	11,000009
Power of unions/labour force	10	10,000031
Labor costs	10	10,000028
Slot availability	8	8,000034
Excess capacity	7	7,000017
Capital intensity	7	7,000008
Business travel demand	7	7,000007
Airport infrastructure	7	7,000004
Aircraft cost and efficiency	7	7,000002
High demand volatility and price elasticity	6	6,000024
GDS fees	6	6,000019
Economic cycle	6	6,000015
Airport fees	6	6,000003
Government taxation	5	5,000022
Government subsidies	5	5,000021
Distortion of global competition due to the intervention of regional/local public bodies, or the lack of it	5	5,000013
Duopoly of aircraft manufacturers	4	4,000014
Price transparency	3	3,000032
Leisure travel demand	3	3,000029

Constraint	Frequency	Adj. Frequency
IT systems costs and complexity	3	3,000027
IT interoperability problems	3	3,000026
Currency exchange rates	3	3,000012
Competition from other means of transport	3	3,000011
Inflexible, time-lagged supply	2	2,000025
Handling fees	2	2,000023
ATC co-ordination	2	2,000005
Short-term variables costs	1	1,000033
ATC fees	1	1,000006
New Distribution Capability (NDC) integration	0	0,00003
Environmental awareness	0	0,000016

E.6 Delphi Round 2 Value Repositories (round_2_R.xlsx)

Value Repository	Frequency	Adj. Frequency
Network	17	17,000019
Revenue management	16	16,000026
People and talent	16	16,000021
Management/ Leadership	15	15,000018
Corporate culture	14	14,000006
Capacity management	14	14,000005
Customer experience	13	13,000008
Innovation	12	12,000016
Brand	12	12,000004
Alliances	12	12,000002

Value Repository	Frequency	Adj. Frequency
Safety and security	11	11,000027
Distribution strategy	11	11,000011
Process and cost optimization	10	10,000022
Information management	10	10,000015
Customer centric proposition	10	10,000009
Frequent Flyer Programmes	9	9,000014
Ancillary revenue	9	9,000003
Scheduling	8	8,000029
Operations management	8	8,00002
Sales	7	7,000028
Products and services	7	7,000024
IT management	6	6,000017
Finance	5	5,000012
Customer data analytics	5	5,000007
Digital channels	4	4,00001
Relationships with stakeholders	3	3,000025
Procurement	3	3,000023
Flight and cabin crew rostering	2	2,000013
Social ecosystem	0	0,00003

E.7 Delphi Rounds 3 and 4 Data

Delphi Rounds 3 and 4 data files are not presented here due to the large size of the files. Please refer to the following files in the accompanying CD for more detail:

- round_3_cons_R.csv

- round_3_vr_R.csv
- round_3_om_R.csv
- round_4_conssi_R.csv
- round_4_consst_R.csv
- round_4_vrsi_R.csv
- round_4_vrst_R.csv
- round_4_omsi_R.csv
- round_4_omst_R.csv

E.8 Edges Values and Attributes (edgespanel.csv)

From	To	Weight
Regulation	Network	-0.65
Fuel	Network	-0.6
Competition	Network	-0.9
Commoditization	Network	0.35
Unions	Network	-0.4
Labor	Network	-0.45
Slots	Network	0.7
ExCapacity	Network	-0.75
Capital	Network	-0.6
Biz-demand	Network	0.83
Regulation	Revenue	0.35
Fuel	Revenue	0.55
Competition	Revenue	-0.98
Commoditization	Revenue	0.5

From	To	Weight
Unions	Revenue	0.33
Labor	Revenue	0.48
Slots	Revenue	0.3
ExCapacity	Revenue	-0.95
Capital	Revenue	0.13
Biz-demand	Revenue	0.95
Regulation	People	0.2
Fuel	People	0.1
Competition	People	0.68
Commoditization	People	0.23
Unions	People	-0.58
Labor	People	0.75
Slots	People	0.18
ExCapacity	People	0.18
Capital	People	0.2
Biz-demand	People	0.15
Regulation	Management	0.45
Fuel	Management	0.3
Competition	Management	0.78
Commoditization	Management	0.53
Unions	Management	-0.6
Labor	Management	0.68
Slots	Management	0.35
ExCapacity	Management	0.4
Capital	Management	0.45
Biz-demand	Management	0.23
Regulation	Culture	0.23

From	To	Weight
Fuel	Culture	0.2
Competition	Culture	0.75
Commoditization	Culture	0.43
Unions	Culture	-0.78
Labor	Culture	0.65
Slots	Culture	0.2
ExCapacity	Culture	0.28
Capital	Culture	0.28
Biz-demand	Culture	0.35
Regulation	Capacity	0.65
Fuel	Capacity	0.83
Competition	Capacity	0.93
Commoditization	Capacity	0.63
Unions	Capacity	-0.3
Labor	Capacity	-0.38
Slots	Capacity	0.7
ExCapacity	Capacity	-0.9
Capital	Capacity	0.63
Biz-demand	Capacity	0.9
Regulation	Experience	-0.2
Fuel	Experience	-0.25
Competition	Experience	0.7
Commoditization	Experience	-0.78
Unions	Experience	0.3
Labor	Experience	-0.33
Slots	Experience	0.3
ExCapacity	Experience	0.33

From	To	Weight
Capital	Experience	0.23
Biz-demand	Experience	0.65
Regulation	Innovation	-0.63
Fuel	Innovation	0.65
Competition	Innovation	0.88
Commoditization	Innovation	0.68
Unions	Innovation	-0.4
Labor	Innovation	-0.4
Slots	Innovation	0.33
ExCapacity	Innovation	0.45
Capital	Innovation	0.65
Biz-demand	Innovation	0.73
Regulation	Brand	0.08
Fuel	Brand	0.18
Competition	Brand	0.88
Commoditization	Brand	0.83
Unions	Brand	0.3
Labor	Brand	0.2
Slots	Brand	0.1
ExCapacity	Brand	0.25
Capital	Brand	0.2
Biz-demand	Brand	0.83
Regulation	Alliances	-0.78
Fuel	Alliances	0.15
Competition	Alliances	0.83
Commoditization	Alliances	0.65
Unions	Alliances	0.3

From	To	Weight
Labor	Alliances	0.38
Slots	Alliances	0.53
ExCapacity	Alliances	0.6
Capital	Alliances	0.15
Biz-demand	Alliances	0.75
Regulation	Safety	0.95
Fuel	Safety	0.05
Competition	Safety	0.13
Commoditization	Safety	0.15
Unions	Safety	0.4
Labor	Safety	0.15
Slots	Safety	0.08
ExCapacity	Safety	0.15
Capital	Safety	0.23
Biz-demand	Safety	0.08
Regulation	Distribution	-0.58
Fuel	Distribution	0.23
Competition	Distribution	0.88
Commoditization	Distribution	0.83
Unions	Distribution	0.15
Labor	Distribution	0.1
Slots	Distribution	0.33
ExCapacity	Distribution	0.5
Capital	Distribution	0.3
Biz-demand	Distribution	0.78
Regulation	Optimization	0.63
Fuel	Optimization	0.75

From	To	Weight
Competition	Optimization	0.7
Commoditization	Optimization	0.63
Unions	Optimization	-0.85
Labor	Optimization	-0.8
Slots	Optimization	0.28
ExCapacity	Optimization	0.65
Capital	Optimization	0.58
Biz-demand	Optimization	0.35
Regulation	Information	0.33
Fuel	Information	0.25
Competition	Information	0.73
Commoditization	Information	0.53
Unions	Information	0.3
Labor	Information	0.18
Slots	Information	0.08
ExCapacity	Information	0.2
Capital	Information	0.23
Biz-demand	Information	0.45
Regulation	Customer-centric	-0.48
Fuel	Customer-centric	0.35
Competition	Customer-centric	0.68
Commoditization	Customer-centric	0.7
Unions	Customer-centric	0.2
Labor	Customer-centric	0.13
Slots	Customer-centric	0.4
ExCapacity	Customer-centric	0.25
Capital	Customer-centric	0.15

From	To	Weight
Biz-demand	Customer-centric	0.83
Network	Network	0.7
Revenue	Network	0.93
People	Network	0.38
Management	Network	0.73
Culture	Network	0.58
Capacity	Network	0.93
Experience	Network	0.53
Innovation	Network	0.4
Brand	Network	0.33
Alliances	Network	0.93
Safety	Network	0.18
Distribution	Network	0.73
Optimization	Network	0.6
Information	Network	0.6
Customer-centric	Network	0.73
Network	Revenue	0.93
Revenue	Revenue	0.55
People	Revenue	0.63
Management	Revenue	0.73
Culture	Revenue	0.58
Capacity	Revenue	1
Experience	Revenue	0.48
Innovation	Revenue	0.58
Brand	Revenue	0.5
Alliances	Revenue	0.85
Safety	Revenue	0.23

From	To	Weight
Distribution	Revenue	0.8
Optimization	Revenue	0.65
Information	Revenue	0.88
Customer-centric	Revenue	0.58
Network	People	0.3
Revenue	People	0.45
People	People	0.7
Management	People	1
Culture	People	1
Capacity	People	0.25
Experience	People	0.85
Innovation	People	0.75
Brand	People	0.68
Alliances	People	0.28
Safety	People	0.3
Distribution	People	0.35
Optimization	People	0.78
Information	People	0.55
Customer-centric	People	0.85
Network	Management	0.3
Revenue	Management	0.45
People	Management	0.88
Management	Management	0.7
Culture	Management	0.95
Capacity	Management	0.5
Experience	Management	0.68
Innovation	Management	0.8

From	To	Weight
Brand	Management	0.55
Alliances	Management	0.35
Safety	Management	0.45
Distribution	Management	0.4
Optimization	Management	0.85
Information	Management	0.73
Customer-centric	Management	0.8
Network	Culture	0.45
Revenue	Culture	0.43
People	Culture	0.98
Management	Culture	0.98
Culture	Culture	0.6
Capacity	Culture	0.35
Experience	Culture	0.75
Innovation	Culture	0.9
Brand	Culture	0.7
Alliances	Culture	0.4
Safety	Culture	0.5
Distribution	Culture	0.33
Optimization	Culture	0.75
Information	Culture	0.68
Customer-centric	Culture	0.88
Network	Capacity	0.98
Revenue	Capacity	0.93
People	Capacity	0.6
Management	Capacity	0.65
Culture	Capacity	0.35

From	To	Weight
Capacity	Capacity	0.8
Experience	Capacity	0.23
Innovation	Capacity	0.43
Brand	Capacity	0.45
Alliances	Capacity	0.63
Safety	Capacity	0.4
Distribution	Capacity	0.55
Optimization	Capacity	0.68
Information	Capacity	0.63
Customer-centric	Capacity	0.5
Network	Experience	0.75
Revenue	Experience	0.43
People	Experience	0.88
Management	Experience	0.85
Culture	Experience	0.8
Capacity	Experience	0.65
Experience	Experience	0.7
Innovation	Experience	0.8
Brand	Experience	0.68
Alliances	Experience	0.53
Safety	Experience	0.38
Distribution	Experience	0.75
Optimization	Experience	0.63
Information	Experience	0.78
Customer-centric	Experience	1
Network	Innovation	0.43
Revenue	Innovation	0.33

From	To	Weight
People	Innovation	0.9
Management	Innovation	0.98
Culture	Innovation	0.95
Capacity	Innovation	0.25
Experience	Innovation	0.65
Innovation	Innovation	0.48
Brand	Innovation	0.53
Alliances	Innovation	0.43
Safety	Innovation	0.33
Distribution	Innovation	0.55
Optimization	Innovation	0.53
Information	Innovation	0.73
Customer-centric	Innovation	0.78
Network	Brand	0.6
Revenue	Brand	0.35
People	Brand	0.8
Management	Brand	0.83
Culture	Brand	0.85
Capacity	Brand	0.45
Experience	Brand	0.7
Innovation	Brand	0.85
Brand	Brand	0.6
Alliances	Brand	0.63
Safety	Brand	0.53
Distribution	Brand	0.43
Optimization	Brand	0.58
Information	Brand	0.58

From	To	Weight
Customer-centric	Brand	0.9
Network	Alliances	0.78
Revenue	Alliances	0.65
People	Alliances	0.45
Management	Alliances	0.7
Culture	Alliances	0.43
Capacity	Alliances	0.45
Experience	Alliances	0.55
Innovation	Alliances	0.48
Brand	Alliances	0.65
Alliances	Alliances	0.6
Safety	Alliances	0.2
Distribution	Alliances	0.68
Optimization	Alliances	0.53
Information	Alliances	0.7
Customer-centric	Alliances	0.65
Network	Safety	0.2
Revenue	Safety	0.15
People	Safety	0.83
Management	Safety	0.83
Culture	Safety	0.85
Capacity	Safety	0.33
Experience	Safety	0.3
Innovation	Safety	0.6
Brand	Safety	0.48
Alliances	Safety	0.35
Safety	Safety	0.7

From	To	Weight
Distribution	Safety	0.15
Optimization	Safety	0.68
Information	Safety	0.5
Customer-centric	Safety	0.28
Network	Distribution	0.8
Revenue	Distribution	0.93
People	Distribution	0.33
Management	Distribution	0.55
Culture	Distribution	0.43
Capacity	Distribution	0.55
Experience	Distribution	0.5
Innovation	Distribution	0.73
Brand	Distribution	0.55
Alliances	Distribution	0.53
Safety	Distribution	0.2
Distribution	Distribution	0.6
Optimization	Distribution	0.73
Information	Distribution	0.73
Customer-centric	Distribution	0.88
Network	Optimization	0.65
Revenue	Optimization	0.6
People	Optimization	0.68
Management	Optimization	0.73
Culture	Optimization	0.88
Capacity	Optimization	0.55
Experience	Optimization	-0.68
Innovation	Optimization	0.75

From	To	Weight
Brand	Optimization	0.25
Alliances	Optimization	0.45
Safety	Optimization	0.55
Distribution	Optimization	0.5
Optimization	Optimization	0.7
Information	Optimization	0.7
Customer-centric	Optimization	0.53
Network	Information	0.48
Revenue	Information	0.65
People	Information	0.5
Management	Information	0.5
Culture	Information	0.53
Capacity	Information	0.3
Experience	Information	0.58
Innovation	Information	0.58
Brand	Information	0.18
Alliances	Information	0.43
Safety	Information	0.3
Distribution	Information	0.6
Optimization	Information	0.58
Information	Information	0.7
Customer-centric	Information	0.73
Network	Customer-centric	0.7
Revenue	Customer-centric	0.55
People	Customer-centric	0.83
Management	Customer-centric	0.85
Culture	Customer-centric	0.93

From	To	Weight
Capacity	Customer-centric	0.3
Experience	Customer-centric	0.98
Innovation	Customer-centric	0.9
Brand	Customer-centric	0.73
Alliances	Customer-centric	0.55
Safety	Customer-centric	0.38
Distribution	Customer-centric	0.63
Optimization	Customer-centric	0.53
Information	Customer-centric	0.65
Customer-centric	Customer-centric	0.7
Network	OpMargin	0.93
Revenue	OpMargin	0.95
People	OpMargin	0.9
Management	OpMargin	0.93
Culture	OpMargin	0.75
Capacity	OpMargin	0.93
Experience	OpMargin	0.8
Innovation	OpMargin	0.85
Brand	OpMargin	0.68
Alliances	OpMargin	0.63
Safety	OpMargin	0.43
Distribution	OpMargin	0.78
Optimization	OpMargin	0.88
Information	OpMargin	0.78
Customer-centric	OpMargin	0.88

E.9 Vertices Attributes (vertices.csv)

name	label	type	id
Regulation	RE	constraint	1
Fuel	FU	constraint	2
Competition	CP	constraint	3
Commoditization	CO	constraint	4
Unions	UN	constraint	5
Labor	LA	constraint	6
Slots	SL	constraint	7
ExCapacity	EC	constraint	8
Capital	CL	constraint	9
Biz-demand	BZ	constraint	10
Network	NW	valuerepo	11
Revenue	RV	valuerepo	12
People	PE	valuerepo	13
Management	MM	valuerepo	14
Culture	CU	valuerepo	15
Capacity	CM	valuerepo	16
Experience	EX	valuerepo	17
Innovation	IV	valuerepo	18
Brand	BD	valuerepo	19
Alliances	AL	valuerepo	20
Safety	SF	valuerepo	21
Distribution	DI	valuerepo	22
Optimization	OP	valuerepo	23
Information	IN	valuerepo	24

name	label	type	id
Customer-centric	CC	valuerepo	25
OpMargin	OM	om	26

APPENDIX F.

R CODE FOR REPRODUCIBLE RESEARCH

F.1 Code for Delphi Method Analysis

F.1.1 Required R libraries

```
library(dplyr)
library(plyr)
library(xlsx)
library(gtools)
library(ggplot2)
library(vcd)
library(vcdExtra)
library(grid)
library(gridExtra)
```

F.1.2 Analysis of Panel members

```
# load and read participants raw data
data_profile_raw <- read.xlsx("participants.xlsx", sheetIndex= 1, heade
r = TRUE)
data_participation_raw <- read.xlsx("participants.xlsx", sheetIndex= 2,
header = TRUE)
```

```
# summary of participants profiles
profile <- count(data_profile_raw, "Area")
profile_tot <- data.frame(Area= "Total", freq= sum(profile$freq) )
rbind(profile, profile_tot)
```

```
# summary of participants per geography and Delphi round
geo <- table(data_participation_raw$Geography[1:63], data_participation
```

```
_raw$Round[1:63])
class(geo)

## [1] "table"

# total number of valid responses received in Delphi R1:R4
geo_tot <- sum(sum(geo))
geo_tot

## [1] 63

# total number of invalid responses received in Delphi R1:R4
geo_tot_in <- count(data_participation_raw[64:91,2])
geo_tot_in

# plot of participants per geograghy and Delphi round
barplot(geo, main="Geography of Participants",
        xlab="Delphi rounds", col=c("darkblue", "darkgreen", "red", "or
ange"),
          legend = c("Europe", "Middle East", "North America", "South A
merica"))
```

```
# create participants by positition data frame
position_raw <- count(data_profile_raw$Position)
names(position_raw) <- c("Position", "Frequency")
position_order <- position_raw[order(position_raw$Frequency, decreasing
= TRUE),]

# add a "Total" row
position_tot <- data.frame(Position= "Total", Frequency= sum(position_o
rder$Frequency))
position_order <- rbind(position_order, position_tot)

# print participants by position data frame
position_order
```

```
# summary of type of responses per Delphi round R1:R4
responses_type <- table(data_participation_raw$Type, data_participation
_raw$Round)

# plot of participants per geograghy and Delphi round
barplot(responses_type, main="Type of Responses",
        xlab="Delphi rounds", col=c("darkblue", "darkgreen", "red", "or
ange"),
          legend = rownames(responses_type))
```

F.1.3 Delphi round 1 analysis

```
# load and read raw data file
r1_constraints_raw <- read.xlsx("round_1_R.xlsx", sheetIndex= 1, header
= TRUE)
r1_valuerepos_raw <- read.xlsx("round_1_R.xlsx", sheetIndex = 2, header
= TRUE)
```

```
# Summary of Categories by Variable

r1_categories <- data.frame("Constraints"= nrow(r1_constraints_raw), "V
alue Repositories"= nrow(r1_valuerepos_raw))
```

```
# Constraints, summary of top 10 categories

# add column "Percentage" showing the percentage of relative frequencie
s
r1_constraints_percent <- round((r1_constraints_raw$Frequency1/sum(r1_c
onstraints_raw$Frequency1))*100, digits=0)

r1_constraints_raw$Percentage <- r1_constraints_percent

## subset data frame "constraints_r1_raw" to the show only the first 10
categories
r1_constraints_summary <- r1_constraints_raw[1:10,]

## add column "Other" to show a summary of categories 11:39
other <- data.frame(Constraint1= "Other constraints", Frequency1= sum(r
1_constraints_raw$Frequency1[11:39]), Percentage= round(sum(r1_constrai
nts_raw$Frequency1[11:39])/sum(r1_constraints_raw$Frequency1)*100, digi
ts=0))

r1_constraints_other <- rbind(r1_constraints_summary, other)

## add column "Total"
total <- data.frame(Constraint1= "TOTAL", Frequency1= sum(r1_constraint
s_other$Frequency1[1:11]), Percentage= sum(r1_constraints_other$Percent
age[1:11]))

r1_constraints_final <- rbind(r1_constraints_other, total)

## print sumnmary table of frequencies
r1_constraints_final

# Value Repositories, summary of top 15 categories
```

```
## add column "Percentage" showing the percentage of relative requencie
s
r1_valuerepos_percent <- round((r1_valuerepos_raw$Frequency1/sum(r1_val
uerepos_raw$Frequency1))*100, digits= 2)
r1_valuerepos_raw$Percentage <- r1_valuerepos_percent

## subset data frame "valuerepos_r1_raw" to the show only the first 15
categories
r1_valuerepos_summary <- r1_valuerepos_raw[1:15,]

## add column "Other" to show a summary of categories 16:29
other <- data.frame(ValueRepository1= "Other Value repositories", Frequ
ency1= sum(r1_valuerepos_raw$Frequency1[16:29]), Percentage= round(sum(
r1_valuerepos_raw$Frequency1[16:29])/sum(r1_valuerepos_raw$Frequency1)*
100, digits=2))

r1_valuerepos_other <- rbind(r1_valuerepos_summary, other)

## add column "Total"
total <- data.frame(ValueRepository1= "TOTAL", Frequency1= sum(r1_value
repos_other$Frequency1[1:16]), Percentage= sum(r1_valuerepos_other$Perc
entage[1:16]))

r1_valuerepos_final <- rbind(r1_valuerepos_other, total)

## print sumnmary table of frequencies
r1_valuerepos_final
```

F.1.4 Delphi round 2 analysis

```
# load and read raw data file
r2_constraints_raw <- read.xlsx("round_2_R.xlsx", sheetIndex= 1, header
= TRUE)
r2_valuerepos_raw <- read.xlsx("round_2_R.xlsx", sheetIndex = 2, header
= TRUE)
```

```
# Constraints, summary of top 10 categories
# add column "Percentage" showing the percentage of relative frequencie
s
r2_constraints_percent <- round((r2_constraints_raw$Adj.Frequency/sum(r
2_constraints_raw$Adj.Frequency))*100, digits=0)
r2_constraints_raw$Percentage <- r2_constraints_percent

## subset data frame "constraints_r2_raw" to the show only the first 10
categories
r2_constraints_summary10 <- r2_constraints_raw[1:10,c(1,2,4)]
```

```
## add column "Other" to show a summary of categories 11:33
other <- data.frame(Constraint2= "Other constraints", Frequency2= sum(r
2_constraints_raw$Frequency2[11:33]), Percentage= round(sum(r2_constrai
nts_raw$Adj.Frequency[11:33])/sum(r2_constraints_raw$Adj.Frequency)*100
, digits=0))
r2_constraints_other <- rbind(r2_constraints_summary10, other)

## add column "Total"
total <- data.frame(Constraint2= "TOTAL", Frequency2= sum(r2_constraint
s_other$Frequency2[1:11]), Percentage= sum(r2_constraints_other$Percent
age[1:11]))

r2_constraints_final <- rbind(r2_constraints_other, total)

## print sumnmary table of frequencies
r2_constraints_final
```

```
# Value Repositories, summary of top 10 categories
## add column "Percentage" showing the percentage of relative frequenci
es
r2_valuerepos_percent <- round((r2_valuerepos_raw$Adj.Frequency/sum(r2_
valuerepos_raw$Adj.Frequency))*100, digits=0)
r2_valuerepos_raw$Percentage <- r2_valuerepos_percent

## subset data frame "constraints_r2_raw" to the show only the first 10
categories
r2_valuerepos_summary10 <- r2_valuerepos_raw[1:10,c(1,2,4)]
r2_valuerepos_summary10

# add column "Other" to show a summary of categories 11:33
other <- data.frame(ValueRepository2= "Other Value Repositories", Frequ
ency2= sum(r2_valuerepos_raw$Frequency2[11:29]), Percentage= round(sum(
r2_valuerepos_raw$Adj.Frequency[11:29])/sum(r2_valuerepos_raw$Adj.Frequ
ency)*100, digits=0))
r2_valuerepos_other <- rbind(r2_valuerepos_summary10, other)

## add column "Total"
total <- data.frame(ValueRepository2= "TOTAL", Frequency2= sum(r2_value
repos_other$Frequency2[1:11]), Percentage= sum(r2_valuerepos_other$Perc
entage[1:11]))

r2_valuerepos_final <- rbind(r2_valuerepos_other, total)

## print sumnmary table of frequencies
r2_valuerepos_final

# Comparison of "Constraints" vs Value Repositories in Delphi R1:R2
constraints_merge <- merge(r1_constraints_raw, r2_constraints_raw, by.x
```

```
="Constraint1", by.y= "Constraint2", all= TRUE)
constraints_merge_reduc1 <- constraints_merge[order(constraints_merge$A
dj.Frequency, decreasing = TRUE),]
constraints_merge_reduc2 <- constraints_merge_reduc1[,c(1,2,4)]
constraints_merge_reduc2[1:10,]

# comparison of "Value_repositories" in Delphi R1:R2
valuerepos_merge <- merge(r1_valuerepos_raw, r2_valuerepos_raw, by.x="V
alueRepository1", by.y= "ValueRepository2", all= TRUE)
valuerepos_merge_reduc1 <- valuerepos_merge[,c(1,2,4)]
valuerepos_merge_reduc2 <- valuerepos_merge_reduc1[order(valuerepos_mer
ge_reduc1$Frequency2, decreasing = TRUE),]
names(valuerepos_merge_reduc2) <- c("ValueRepository", "Frequency R1",
"Frequency R2")
valuerepos_merge_reduc2[1:15,]
```

F.1.5 Delphi round 3 analysis

```
# load Constraints vs Value Repositories raw data
r3_cons_raw <- read.csv("round_3_cons_R.csv", header= TRUE)

# make Strength an ordered variable
r3_cons_raw$Strength <- ordered(r3_cons_raw$Strength, levels=c("Z","VW"
, "W","S","VS"))
```

```
# load Value Repositories vs Value Repositories raw data
r3_vr_raw <- read.csv("round_3_vr_R.csv", header= TRUE)
# make Strength an ordered variable
r3_vr_raw$Strength <- ordered(r3_vr_raw$Strength, levels=c("Z","VW", "W
","S","VS"))
```

```
# load Value Repositories vs Operating Margin raw data
r3_om_raw <- read.csv("round_3_om_R.csv", header= TRUE)
# make Strength an ordered variable
r3_om_raw$Strength <- ordered(r3_om_raw$Strength, levels=c("Z","VW", "W
","S","VS"))
```

```
# plot Constraints vs Value Repositories Heatmap
r3_cons_heat<- r3_cons_raw %>%
  group_by(Constraint, ValueRepository) %>%
  slice(which.max(Freq))

heat.cons3 <- ggplot(r3_cons_heat, cex = 0.5, aes(x = ValueRepository,
```

```
y= Constraint, fill = Strength)) + ggtitle("Round 3: Constraints vs Val
ue Repositories") + geom_tile() + scale_fill_manual(values = c("#F2F2F2
","#F22738","#EB91B4","#01ABE9","#1B346C")) + ylim(rev(levels(r3_cons_h
eat$Constraint)))

heat.cons3 + theme(axis.text.x = element_text(angle = 45, hjust = 1, si
ze=18), axis.text.y = element_text(size=18), legend.text=element_text(s
ize=14), plot.title = element_text(vjust=1, face="bold"))
```

```
# plot Value Repositories vs Value Repositories Heatmap
r3_vr_heat<- r3_vr_raw %>%
  group_by(ValueRepository1, ValueRepository2) %>%
  slice(which.max(Freq))

heat.vr3 <- ggplot(r3_vr_heat, aes(x = ValueRepository1, y= ValueReposi
tory2, fill = Strength)) + ggtitle("Round 3: Value Repositories vs Valu
e Repositories") + geom_tile() + scale_fill_manual(values = c("#F2F2F2"
,"#F22738","#EB91B4","#01ABE9","#1B346C")) + ylim(rev(levels(r3_vr_heat
$ValueRepository2)))

heat.vr3 + theme(axis.text.x = element_text(angle = 45, hjust = 1, size
=18), axis.text.y = element_text(size=18), legend.text=element_text(siz
e=14), plot.title = element_text(vjust=1, face="bold"))
```

```
# plot Value Repositories vs Operating Margin

# convert data frame to table
r3_om.tab <- xtabs(Freq~ValueRepository+Strength, data=r3_om_raw)

# cell percentages
r3_om.tab.prop <- prop.table(r3_om.tab,1)

# plot a mosaic
mosaic(r3_om.tab.prop, gp = gpar(fill=c("red","orange","light green","g
reen","blue"), fontsize=12), main="Value Repositories vs Operating Marg
in (%)", labeling_args = list(rot_labels = c(bottom = 90,left = 0), off
set_varnames = c(left = 5), offset_labels = c(left = 2.5),margins = c(l
eft = 4, bottom = 3)))
```

F.1.6 Delphi round 4 analysis

```
# load Constraints raw data- STRENGTH
r4_consst_raw <- read.csv("round_4_consst_R.csv", header= TRUE)
```

```
# make Strength an ordered variable
r4_consst_raw$Strength <- ordered(r4_consst_raw$Strength, levels=c("Z",
"VW", "W","S","VS"))

# load Constraints raw data- SIGN
r4_conssi_raw <- read.csv("round_4_conssi_R.csv", header= TRUE)

# make Sign an ordered variable
r4_conssi_raw$Sign <- ordered(r4_conssi_raw$Sign, levels=c("Neg","Neu",
"Pos"))
```

```
# load Value Repositories raw data- STRENGTH
r4_vrst_raw <- read.csv("round_4_vrst_R.csv", header= TRUE)

# make Strength an ordered variable
r4_vrst_raw$Strength <- ordered(r4_vrst_raw$Strength, levels=c("Z","VW"
, "W","S","VS"))

# load Value Repositories raw data- SIGN
r4_vrsi_raw <- read.csv("round_4_vrsi_R.csv", header= TRUE)

# make Sign an ordered variable
r4_vrsi_raw$Sign <- ordered(r4_vrsi_raw$Sign, levels=c("Neg","Neu", "Po
s"))

# load Operating Margin raw data- STRENGTH
r4_omst_raw <- read.csv("round_4_omst_R.csv", header= TRUE)

# make Strength an ordered variable
r4_omst_raw$Strength <- ordered(r4_omst_raw$Strength, levels=c("Z","VW"
, "W","S","VS"))

# load Operating Margin raw data- SIGN
r4_omsi_raw <- read.csv("round_4_omsi_R.csv", header= TRUE)

# make Sign an ordered variable
r4_omsi_raw$Sign <- ordered(r4_omsi_raw$Sign, levels=c("Neg","Neu", "Po
s"))
```

```
# plot Constraints vs Value Repositories Heatmap- STRENGTH
r4_consst_heat<- r4_consst_raw %>%
  group_by(Constraint, ValueRepository) %>%
  slice(which.max(Freq))

heat.consst4 <- ggplot(r4_consst_heat, aes(x = ValueRepository, y= Cons
traint, fill = Strength)) + ggtitle("Round 4: Constraints vs Value Repo
```

```
sitories- STRENGTH") + geom_tile() + scale_fill_manual(values = c("#F2F
2F2","#F22738","#EB91B4","#01ABE9","#1B346C")) + ylim(rev(levels(r4_con
sst_heat$Constraint)))

heat.consst4 + theme(axis.text.x = element_text(angle = 45, hjust = 1,
size=18), axis.text.y = element_text(size=18), legend.text=element_text
(size=14), plot.title = element_text(vjust=1, face="bold"))
```

```
# plot Value Repositories vs Value Repositories Heatmap- STRENGTH
r4_vrst_heat<- r4_vrst_raw %>%
  group_by(ValueRepository1, ValueRepository2) %>%
  slice(which.max(Freq))

heat.vr4 <- ggplot(r4_vrst_heat, aes(x = ValueRepository1, y= ValueRepo
sitory2, fill = Strength)) + ggtitle("Round 4: Value Repositories vs Va
lue Repositories- STRENGTH") + geom_tile() + scale_fill_manual(values =
c("#F2F2F2","#F22738","#EB91B4","#01ABE9","#1B346C")) + ylim(rev(levels
(r4_vrst_heat$ValueRepository2)))

heat.vr4 + theme(axis.text.x = element_text(angle = 45, hjust = 1, size
=18), axis.text.y = element_text(size=18), legend.text=element_text(siz
e=14), plot.title = element_text(vjust=1, face="bold"))

# plot Value Repositories vs Operating Margin- STRENGTH

r4_omst.tab <- xtabs(Freq~ValueRepository+Strength, data=r4_omst_raw)

# cell percentages
r4_omst.tab.prop <- prop.table(r4_omst.tab,1)

# plot a mosaic
mosaic(r4_omst.tab.prop, gp = gpar(fill=c("red","orange","light green",
"green","blue"), fontsize=12), main="Value Repositories vs Operating Ma
rgin- STRENGTH (%)", labeling_args = list(rot_labels = c(bottom = 90,le
ft = 0), offset_varnames = c(left = 5), offset_labels = c(left = 2.5),m
argins = c(left = 4, bottom = 3)))
```

F.2 Code for Network Analysis

F.2.1 Required R libraries

```
library(igraph)
library(sna)
library(network)
library(ape)
```

F.2.2 Eigen Centrality

```
# load data
edgespanel <- read.csv("edgespanel.csv", header= TRUE, stringsAsFactors
= FALSE)
vertices <- read.csv("vertices.csv", header= TRUE, stringsAsFactors = F
ALSE)

# make edges weights as numeric
edgespanel$weight <- as.numeric(as.character(sub("," , ".", edgespanel$
weight)))

# make a data frame with the edges and vertices attributes
paneldata.g <- graph.data.frame(edgespanel[151:375,], directed= "TRUE",
vertices= vertices[11:25,])

# eigen_centrality
eigen_centrality(paneldata.g, directed= TRUE, scale= TRUE, weights = NU
LL)
```

F.2.3 Hierarchical clustering

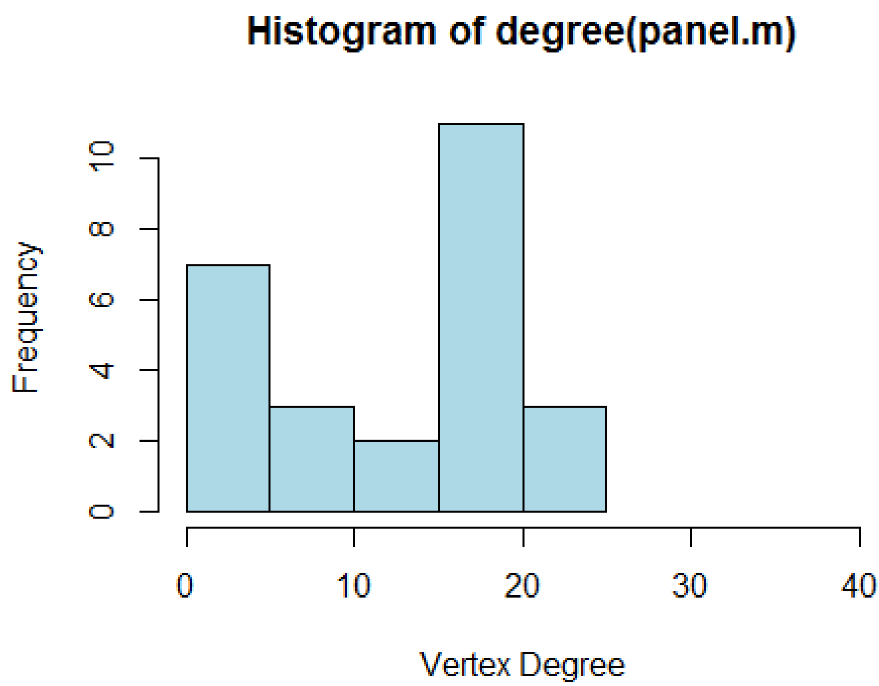
```
# load data
edgesraw <- read.csv("edgespanel.csv", header= TRUE, stringsAsFactors =
FALSE)
verticesraw <- read.csv("vertices.csv", header= TRUE, stringsAsFactors
= FALSE)

edgespanel <- edgesraw[151:375,]
vertices <- verticesraw[11:25,]

# make edges weights as numeric
edgespanel$weight <- as.numeric(as.character(sub("," , ".", edgespanel$
weight)))

# make a data frame with the edges and vertices attributes
paneldata.g <- graph.data.frame(edgespanel, directed= "TRUE", vertices=
vertices)

# delete edges with weight<0.5
panel.g <- delete_edges(paneldata.g, which(E(paneldata.g)$weight <=0.75
))

# Fast agglomerative hierarchical clustering algorithm
panel.und <- as.undirected(panel.g)
panel.agc <- fastgreedy.community(panel.und)
length(panel.agc)
```

```
## [1] 2

sizes(panel.agc)

## Community sizes
## 1 2
## 6 9

membership(panel.agc)

##         Network         Revenue          People      Management
##               1               1               2               2
##         Culture        Capacity      Experience      Innovation
##               2               1               2               2
##           Brand       Alliances          Safety    Distribution
##               2               1               2               1
##    Optimization     Information Customer-centric
##               2               1               2

plot(panel.agc, panel.g, edge.arrow.size=0.2)

# Corresponding dendrogram for this partitioning
dendPlot(panel.agc, mode= "phylo")
```

F.2.4 Topological network complexity methods

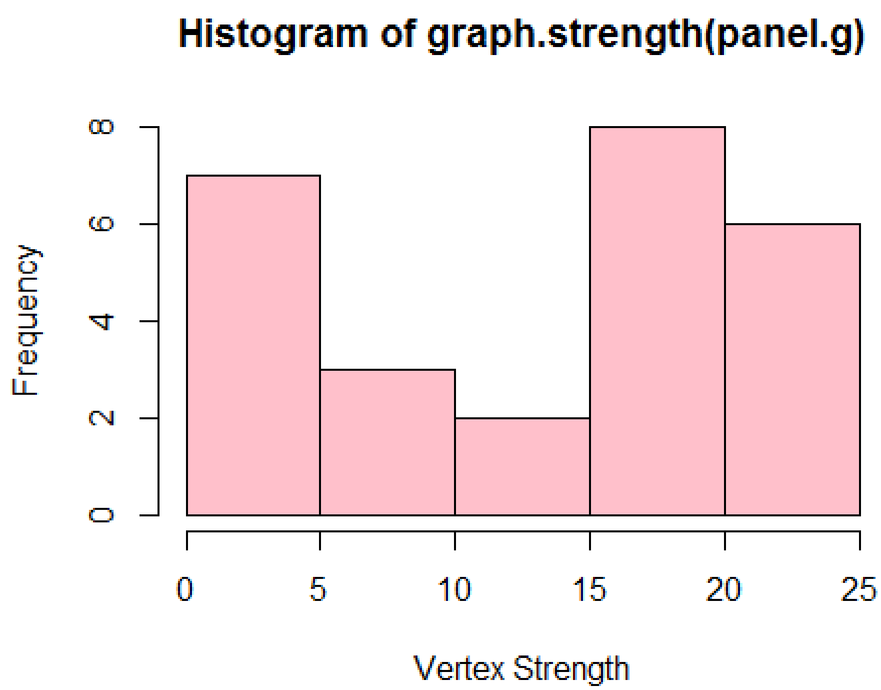
```
#########################################
# Basic Network Metrics
#########################################
is.simple(panel.g)

## [1] FALSE

igraph::is.connected(panel.g)

## [1] TRUE

igraph::is.connected(panel.g, "weak") # see clusters

## [1] TRUE

igraph::is.connected(panel.g, "strong") # see clusters

## [1] FALSE

diameter(panel.g, directed = TRUE)

## [1] 1.93

########################################
# Vertex Degree
########################################
```

```
# Group of vertices by degree
hist(degree(panel.m), col="lightblue", xlim=c(0,40), xlab="Vertex Degre
e")
```



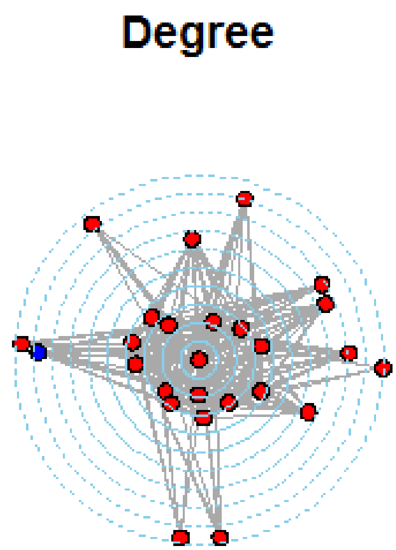

```
sort(degree(panel.m, "all"), decreasing= TRUE)

##  [1] 23.37 21.73 21.17 19.91 19.48 19.44 18.95 18.83 17.88 17.62 17.
43
## [12] 16.73 16.64 15.31 11.67 11.30  7.29  7.25  6.82  4.87  4.35  3.
38
## [23]  2.88  2.81  2.46  1.93

sort(degree(panel.m, "total"), decreasing= TRUE)

##  [1] 23.37 21.73 21.17 19.91 19.48 19.44 18.95 18.83 17.88 17.62 17.
43
## [12] 16.73 16.64 15.31 11.67 11.30  7.29  7.25  6.82  4.87  4.35  3.
38
## [23]  2.88  2.81  2.46  1.93

sort(degree(panel.m, "out"), decreasing= TRUE)

##  [1] 23.37 21.73 21.17 19.91 19.48 19.44 18.95 18.83 17.88 17.62 17.
43
## [12] 16.73 16.64 15.31 11.67 11.30  7.29  7.25  6.82  4.87  4.35  3.
```

```
38
## [23]  2.88  2.81  2.46  1.93

sort(degree(panel.m, "in"), decreasing = TRUE)

##  [1] 23.37 21.73 21.17 19.91 19.48 19.44 18.95 18.83 17.88 17.62 17.
43
## [12] 16.73 16.64 15.31 11.67 11.30  7.29  7.25  6.82  4.87  4.35  3.
38
## [23]  2.88  2.81  2.46  1.93

mean(igraph::degree(panel.g))

## [1] 18.69231

# Vertex strength: sum of weights of edges incident to a given vertex
hist(graph.strength(panel.g), col="pink", xlab="Vertex Strength")
```

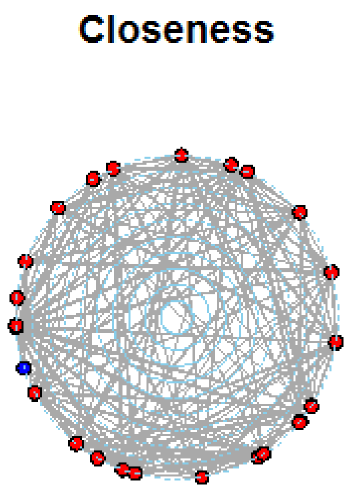



```
##########################################
# Vertex Centrality
##########################################

# Number of clusters found
panel.scc <- clusters(panel.g, mode=c("strong"))
table(panel.scc$size)
```

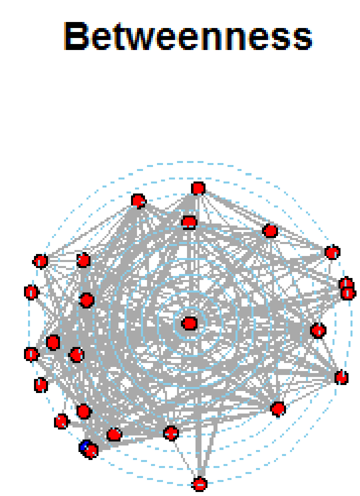
```
## < table of extent 0 >

# Number of neighbors per a concrete vertex
neighbors(panel.g,5)

## + 4/26 vertices, named:
## [1] People       Management   Culture      Optimization

# Vertex centrality by degree
central.panel.m <- network::as.network.matrix(panel.m)
gplot.target(central.panel.m, degree(central.panel.m), main="Degree", c
irc.lab= FALSE, circ.col="skyblue", usearrows = FALSE, vertex.col=c("bl
ue", rep("red", 32), "yellow"), edge.col="darkgray")
```



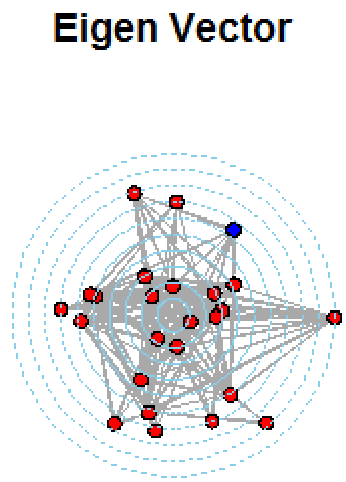

```
# Vertex centrality by closeness
central.panel.m <- network::as.network.matrix(panel.m)
gplot.target(central.panel.m, closeness(central.panel.m), main="Closene
ss", circ.lab= FALSE, circ.col="skyblue", usearrows = FALSE, vertex.col
=c("blue", rep("red", 32), "yellow"), edge.col="darkgray")
```



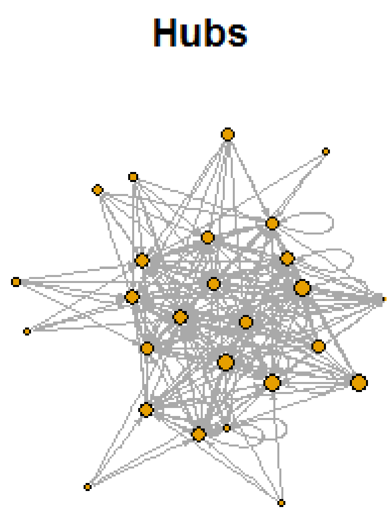

```
# Vertex centrality by betweenness
central.panel.m <- network::as.network.matrix(panel.m)
gplot.target(central.panel.m, betweenness(central.panel.m), main="Betwe
enness", circ.lab= FALSE, circ.col="skyblue", usearrows = FALSE, vertex
.col=c("blue", rep("red", 32), "yellow"), edge.col="darkgray")
```



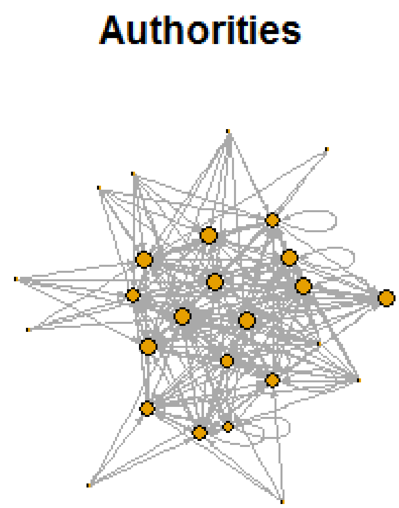

```
# Vertex centrality by eigenvector
central.panel.m <- network::as.network.matrix(panel.m)
gplot.target(central.panel.m, evcent(central.panel.m), main="Eigen Vect
or", circ.lab= FALSE, circ.col="skyblue", usearrows = FALSE, vertex.col
=c("blue", rep("red", 32), "yellow"), edge.col="darkgray")
```




```r
# Hubs and Authorities
l <- layout.kamada.kawai(panel.g)
plot(panel.g, layout=l, edge.arrow.size=0.2, main="Hubs", vertex.label=
"", vertex.size=10 * sqrt(hub.score(panel.g)$vector))
```




```r
plot(panel.g, layout=l, edge.arrow.size=0.2, main="Authorities", vertex
.label="", vertex.size=10 *sqrt(authority.score(panel.g)$vector))
```



```
#########################################
# Edges characteristics
#########################################

# Edge betweennnes centrality
edgebtw <- edge.betweenness(panel.g)
E(panel.g)[order(edgebtw, decreasing= T)[1:10]]

## + 10/243 edges (vertex names):
##  [1] Slots       ->Alliances    Capacity    ->Optimization
##  [3] Capital     ->Optimization Capacity    ->Management
##  [5] Alliances   ->Experience   Optimization->Brand
##  [7] Unions      ->People       Labor       ->Optimization
##  [9] Optimization->Culture      Safety      ->Brand

#########################################
# Network cohesion
#########################################

# Census of cliques
table(sapply(cliques(panel.g), length)) # how structured the graph is


##    1    2    3    4    5    6    7    8    9   10
##   26  168  568 1234 1813 1803 1190  497  118   12

cliques(panel.g)[sapply(cliques(panel.g), length) == 10]

## [[1]]
## + 10/26 vertices, named:
##  [1] Competition      Network          Revenue          Management
##  [5] Capacity         Alliances        Distribution     Optimization
```

```
##  [9] Information      Customer-centric
##
## [[2]]
## + 10/26 vertices, named:
##  [1] Competition      Network          Revenue          Management
##  [5] Brand            Alliances        Distribution     Optimization
##  [9] Information      Customer-centric
##
## [[3]]
## + 10/26 vertices, named:
##  [1] Competition      Network          Management       Capacity
##  [5] Experience       Alliances        Distribution     Optimization
##  [9] Information      Customer-centric
##
## [[4]]
## + 10/26 vertices, named:
##  [1] Competition      Network          Management       Experience
##  [5] Brand            Alliances        Distribution     Optimization
##  [9] Information      Customer-centric
##
## [[5]]
## + 10/26 vertices, named:
##  [1] Competition      Revenue          People           Management
##  [5] Culture          Innovation       Brand            Optimization
##  [9] Information      Customer-centric
##
## [[6]]
## + 10/26 vertices, named:
##  [1] Competition      People           Management       Culture
##  [5] Experience       Innovation       Brand            Optimization
##  [9] Information      Customer-centric
##
## [[7]]
## + 10/26 vertices, named:
##  [1] Network          Revenue          Management       Capacity
##  [5] Alliances        Distribution     Optimization     Information
##  [9] Customer-centric OpMargin
##
## [[8]]
## + 10/26 vertices, named:
##  [1] Network          Revenue          Management       Brand
##  [5] Alliances        Distribution     Optimization     Information
##  [9] Customer-centric OpMargin
##
## [[9]]
## + 10/26 vertices, named:
##  [1] Network          Management       Capacity         Experience
##  [5] Alliances        Distribution     Optimization     Information
```

```
##  [9] Customer-centric OpMargin
## 
## [[10]]
## + 10/26 vertices, named:
##  [1] Network          Management       Experience       Brand
##  [5] Alliances        Distribution     Optimization     Information
##  [9] Customer-centric OpMargin
## 
## [[11]]
## + 10/26 vertices, named:
##  [1] Revenue          People           Management       Culture
##  [5] Innovation       Brand            Optimization     Information
##  [9] Customer-centric OpMargin
## 
## [[12]]
## + 10/26 vertices, named:
##  [1] People           Management       Culture          Experience
##  [5] Innovation       Brand            Optimization     Information
##  [9] Customer-centric OpMargin
```

```
clique.number(panel.g) # the size of the largest clique
```

```
## Warning in .Call("R_igraph_clique_number", graph, PACKAGE = "igraph"
): At
## cliques.c:908 :directionality of edges is ignored for directed graph
s
```

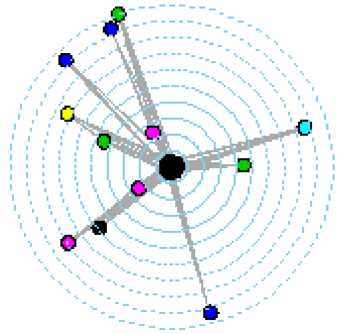
```
## [1] 10
```

```
# Maximal cliques
table(sapply(maximal.cliques(panel.g), length)) # a clique that is not
a subset of a larger clique
```

```
## Warning in .Call("R_igraph_maximal_cliques", graph, subset,
## as.numeric(min), : At maximal_cliques_template.h:203 :Edge direction
s are
## ignored for maximal clique calculation
```

```
## 
##  3  4  5  6  7  8  9 10
##  1  5  3  3  5  5 14 12
```

```
# k-core decomposition of the network
panelcores <- graph.coreness(panel.g)  #coreness one(black), two(red),
three(green), four(blue)
gplot.target(panel.m, panelcores, circ.lab = FALSE, circ.col="skyblue",
usearrows = FALSE, vertex.col=panelcores, edge.col="darkgray")
```



```
# Census of dyads and triads
panel.g<- simplify(panel.g)
dyad_census(panel.g) # match this analysis with that of hubs and author
ities

## $mut
## [1] 61
##
## $asym
## [1] 107
##
## $null
## [1] 157

# Motifs
graph.motifs(panel.g, size=3) #small connected subgraphs of interest

##  [1]  NA  NA 238  NA 124 238  46  73 182  53  47   0  17  89  92 115

# Transitivity
transitivity(panel.g) #measure of global clustering, relative frequency
with which connected triples close to form triangles

## [1] 0.6955102

# Reciprocity
reciprocity(panel.g, mode="default") # match this result with that of d
yad census

## [1] 0.5327511

reciprocity(panel.g, mode="ratio")

## [1] 0.3630952

########################################
# Connectivity
########################################
```

```
# Census of all connected components within the graph
comps <- decompose.graph(panel.g) # see giant components
table(sapply(comps, vcount))

##
## 26
##  1

table(sapply(decompose.graph(panel.g), vcount)) # alternative code

##
## 26
##  1

# Further analysis of giant component, check for small world properties
panel.gc <- decompose.graph(panel.g)[[1]]
average.path.length(panel.gc) # the shortest path distance between pair
s of vertices is quite small

## [1] 1.420779

diameter(panel.gc) # the clustering is relatively high, check for i.e.
transitivity

## [1] 1.93

# Vertex and edge (high/low) connectivity
vertex.connectivity(panel.gc) # it requires the removal of .. vertex/ed
ge to break this subgraph into additional components

## [1] 0

edge.connectivity(panel.gc)

## [1] 0

# Indentify Vertex-cut or edge-cut, thus if the network is vulnerable
panel.cut.vertices <- articulation.points(panel.gc)
length(panel.cut.vertices)

      ## [1] 0

########################################
# Assortativity
########################################
# check whether edges only connect vertices of the same category (1), o
r no different from a random # assignment of edges
assortativity.nominal(panel.g, (V(panel.g)$type == "constraint")+1, dir
ected = TRUE)

## [1] 0
```

```
assortativity.nominal(panel.g, (V(panel.g)$type == "valuerepo")+1, dire
cted = TRUE)

## [1] -0.1125172

assortativity.nominal(panel.g, (V(panel.g)$type == "om")+1, directed =
TRUE)

## [1] 0

# degree-degree correlation of adjacent vertices
assortativity.degree(panel.g)  # match this analysis with that of verte
x centrality

## [1] -0.2089687
```

F.3 Code for Fuzzy Cognitive Map

F.3.1 Required R libraries

```
# load libraries
library(igraph)
library(FCMapper)
```

F.3.2 Fuzzy Cognitive Map

```
# load and read data
edgespanel <- read.csv("edgespanel.csv", header= TRUE, stringsAsFactors
= FALSE)
vertices <- read.csv("vertices.csv", header= TRUE, stringsAsFactors = F
ALSE)
#edgespanel$weightws <- as.numeric(as.character(sub("," , ".", edgespan
el$weightws)))

# igraph data frame with the edges and vertices attributes
panel.g <- graph.data.frame(edgespanel, directed= "TRUE", vertices=vert
ices)
edgespanel.g <- delete_edges(panel.g, which(E(panel.g)$weightws <0.75))

# adjacency matrix
edgespanel.adj <- as_adjacency_matrix(edgespanel.g, attr = "weightws")
edgespanel.m <- as.matrix(edgespanel.adj)
diag(edgespanel.m) <- 1  #condition for Stylios Type II FCM

# save adjacency matrix to paste in document
# write.csv(edgespanel.m, file = "./FCM_adjmatrix.csv")

dimnames(edgespanel.m) <- NULL
```

```
# pass adj matrix to check.matrix
check.matrix(edgespanel.m)

## [1] "Matrix is square."
## [1] "All values of the matrix are within -1 and 1."
## [1] "The diagonal is not equal to 0 (ie, there is a self-loop). Cons
ider whether this is appropriate."

# set parameters for simulation scenario
concept.names <- vertices$name

###################################################
# Scenarios Settings
###################################################
iter = 30
lambda <- 0.2
w <- edgespanel.m
act_vector <- matrix(0, nrow = iter, ncol = length(w[1,]))
act_vector[1,] <- rep(0.5, 26)

# Scenario 1
#set.concepts <- c("Regulation", "Fuel", "Competition", "Labor", "Biz-d
emand")
#set.values <- c(-0.9, -0.9, -0.9, -0.9, -0.9)

#Scenario 2
#set.concepts = c("Optimization", "Innovation", "Experience", "Informat
ion", "Customer-centric")
#set.values = c(0.9, 0.9, 0.9, 0.9, 0.9)

#Scenario 3
#set.concepts = c("Network", "Revenue", "Capacity", "Distribution")
#set.values = c(0.9, 0.9, 0.9, 0.9)

#act_vector[1,which(concept.names %in% set.concepts == TRUE)] = set.val
ues

###################################################
# FCM Inference Engine with Hebbian Learning Rule
###################################################
alfa1 <- 0.1
#alfa2 <- 1

for (k in 2:iter) {
  act_vector[k, ] = 1/(1 + exp(-lambda * (act_vector[k - 1,] %*% w)))

  #w <- w + alfa1*(act_vector[i,]*act_vector[i-1,])-alfa2*(act_vector[i
,] + act_vector[i-1,])
```

```
#w <- w -alfa2*(act_vector[i,] + act_vector[i-1,])

  for (i in 1:length(w[1,])) {
    for (j in 1:length(w[1,])) {
      if (i == j) {
        dw <- 0
      } else {
        dci <- act_vector[i+1] - act_vector[i]
        dcj <- act_vector[j+1] - act_vector[j]
        if (dci * dcj > 0) {
          dw <- dci * dcj
        } else {
          dw <- 0
        }
      }
      w[i,j] <- w[i,j] + alfa1* dw
    }
  }
 #act_vector[k, which(concept.names %in% set.concepts == TRUE)] = set.v
alues
 #print(act_vector[k,])

}


# FCM outcome stability check

if (all.equal(act_vector[iter,], act_vector[iter-1,]) != TRUE) {
 print("WARNING: Convergence not reached. Try increasing the number of
iterations.")
}


# FCM outcome data frame
results = data.frame(concept.names, act_vector[iter, ])
colnames(results) = c("Concept", "Equilibrium_value")

# plot results
plot(act_vector[, 1] ~ seq(1, iter, 1), type = "n", ylim = c(-0.15, 1),
xlab = "Time Step", ylab = "Value of AVCN component")

for (n in 1:length(w[1, ])) {
  points(act_vector[, n] ~ seq(1, iter, 1), type = "l", col = n)
}

legend("bottom", legend = concept.names, cex = 0.7, col = seq(1, n, 1),
lty= 1, lwd=1.5, ncol=7, bty= "n", text.width=c(2.2,2.2,2.2,2.2))
```

F.4 Code for Panel Members Benchmarking Dotplots

```
# USER’S NOTE:
# Users need to change the letter "X" in the corresponding file names
# and variables in order to create the individual members’ dotplots

# upload required R libraries
library(lattice)

# load and read data
edgesX_raw <- read.csv("edgesX.csv", header= TRUE, stringsAsFactors = F
ALSE)
edgesX_raw$weight <- as.numeric(as.character(sub("," , ".", edgesX_raw$
weight)))

# creates dotplot Constraints vs Value Repositories
edgesX.cons <- edgesX_raw[c(1:150, 391:540),]
dotplot(constraint ~ weight | valuerepo, data= edgesX.cons, group = who
,
        pch = c(1, 3), key = list(space = "right", transparent = TRUE,
points = list(pch = c(1, 3), col = 1:2), text = list(c("expert (you)",
"panel"))), scales=list(x=list(at=c(0, .25, .5, .75, 1), labels=c(0, .2
5, .5, .75, 1))),
          panel = function(...) {
          panel.superpose
          panel.dotplot(...)
        })
dev.copy(png,filename="dotplot_X_1.png", width = 1000, height = 650);
dev.off ()

# creates dotplot of Value Repositories
edgesX.vr <- edgesX_raw[c(151:375, 541:765),]
dotplot(constraint ~ weight | valuerepo, data= edgesX.vr, group = who,
        pch = c(1, 3), key = list(space = "right", transparent = TRUE,
points = list(pch = c(1, 3), col = 1:2), text = list(c("expert (you)",
"panel"))), scales=list(x=list(at=c(0, .25, .5, .75, 1), labels=c(0, .2
5, .5, .75, 1))),
        panel = function(...) {
          panel.superpose
          panel.dotplot(...)
        })

dev.copy(png,filename="dotplot_X_2.png", width = 1000, height = 650);
dev.off ()

# creates dotplot of Value Repositories vs Operating Margin
edgesX.om <- edgesX_raw[c(376:390, 766:780),]
dotplot(constraint ~ weight | valuerepo, data= edgesX.om, group = who,
        pch = c(1, 3), key = list(space = "right", transparent = TRUE,
points = list(pch = c(1, 3), col = 1:2), text = list(c("expert (you)",
```

```
"panel"))), scales=list(x=list(at=c(0, .25, .5, .75, 1), labels=c(0, .2
5, .5, .75, 1))),
        panel = function(...) {
          panel.superpose
          panel.dotplot(...)
        })

dev.copy(png,filename="dotplot_X_3.png", width = 1000, height = 650);
dev.off ()
```

APPENDIX G.

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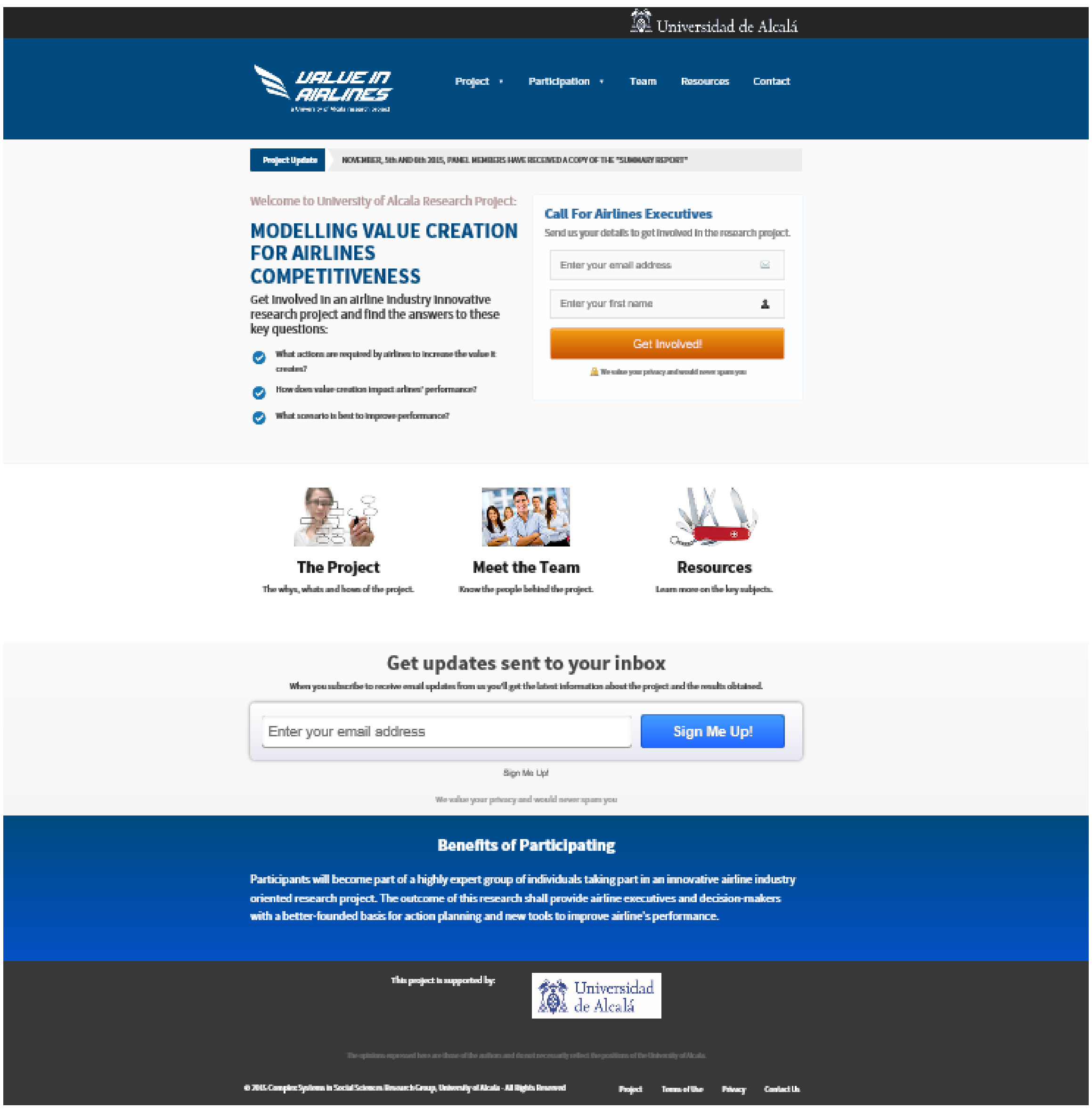

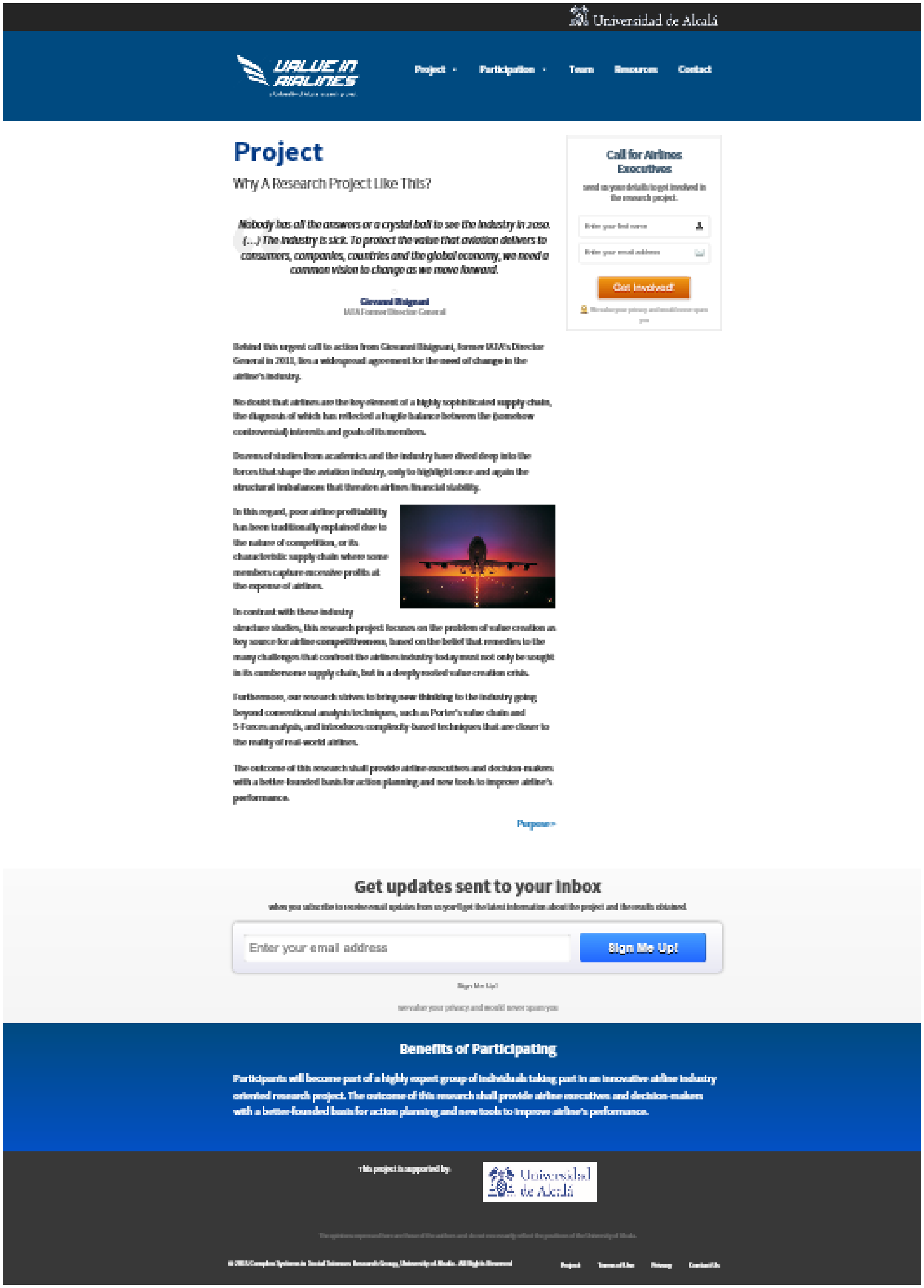

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Project

Why A Research Project Like This?

> *Nobody has all the answers or a crystal ball to see the industry in 2050. (...) The industry is sick. To protect the value that aviation delivers to consumers, companies, countries and the global economy, we need a common vision to change as we move forward.*
>
> **Giovanni Bisignani**
> IATA Former Director General

Call for Airlines Executives

send us your details to get involved in the research project.

Get Involved!

Behind this urgent call to action from Giovanni Bisignani, former IATA's Director General in 2011, lies a widespread agreement for the need of change in the airline's industry.

No doubt that airlines are the key element of a highly sophisticated supply chain, the diagnosis of which has reflected a fragile balance between the (somehow controversial) interests and goals of its members.

Dozens of studies from academics and the industry have dived deep into the forces that shape the aviation industry, only to highlight once and again the structural imbalances that threaten airlines financial stability.

In this regard, poor airline profitability has been traditionally explained due to the nature of competition, or its characteristic supply chain where some members capture excessive profits at the expense of airlines.

In contrast with these industry structure studies, this research project focuses on the problem of value creation as key source for airline competitiveness, based on the belief that remedies to the many challenges that confront the airlines industry today must not only be sought in its cumbersome supply chain, but in a deeply rooted value creation crisis.

Furthermore, our research strives to bring new thinking to the industry going beyond conventional analysis techniques, such as Porter's value chain and 5-Forces analysis, and introduces complexity-based techniques that are closer to the reality of real-world airlines.

The outcome of this research shall provide airline executives and decision-makers with a better-founded basis for action planning and new tools to improve airline's performance.

Purpose »

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Participants Profile
A typical profile of participants include C-level executives and business unit decision-makers from world's top network airlines, as well as key industry leaders. Participants are by invitation only
Benefits of Participation
Participants will become part of a highly expert group of individuals taking part in an innovative airline industry oriented research project. Participants will be provided with pre-publication copies of the major reports being produced by the research team and will have full access to the final simulation tool. Credit for their contributions will also be given when the results of the research are published.
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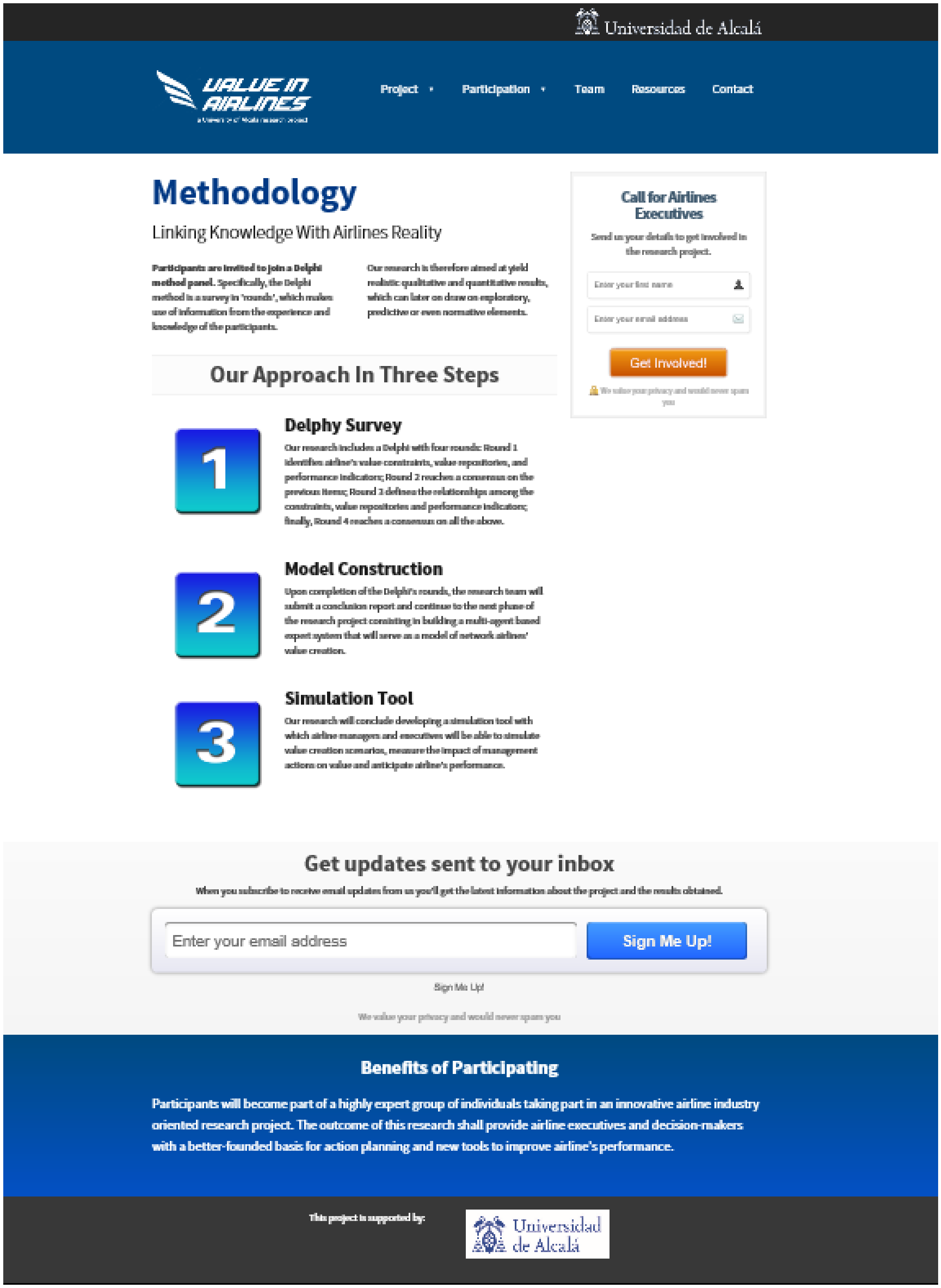
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Methodology
Linking Knowledge With Airlines Reality
Participants are invited to join a Delphi method panel. Specifically, the Delphi method is a survey in 'rounds', which makes use of information from the experience and knowledge of the participants.
Our research is therefore aimed at yield realistic qualitative and quantitative results, which can later on draw on exploratory, predictive or even normative elements.
Call for Airlines Executives
Send us your details to get involved in the research project.
Enter your first name
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Our Approach In Three Steps
1
Delphy Survey
Our research includes a Delphi with four rounds: Round 1 identifies airline's value constraints, value repositories, and performance indicators; Round 2 reaches a consensus on the previous items; Round 3 defines the relationships among the constraints, value repositories and performance indicators; finally, Round 4 reaches a consensus on all the above.
2
Model Construction
Upon completion of the Delphi's rounds, the research team will submit a conclusion report and continue to the next phase of the research project consisting in building a multi-agent based expert system that will serve as a model of network airlines' value creation.
3
Simulation Tool
Our research will conclude developing a simulation tool with which airline managers and executives will be able to simulate value creation scenarios, measure the impact of management actions on value and anticipate airline's performance.
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Mr.Thomas Bartsch	Former SVP Commercial Intelligence	Qatar Airways
Mrs.Daniela Baytelman	VP Distribution & Ancillary Revenue	LATAM Airlines
Mr.Dimitris Bountolos	VP Customer Experience	Iberia Líneas Aéreas
Mr.Duncan Bureau	VP Global Sales and Distribution	Air Canada
Mr.Anthony Doyle	Director New Product Development	Air Canada
Mr.Fermín García	Strategic Planning & CEO Office	Iberia Líneas Aéreas
Mr.Raúl Gutiérrez	VP & Chief Information Officer, Club Premier	Aeromexico
Mr.Hans Gydal	Director Sales Excellence	Scandinavian Airlines
Mr.Martin Hoffman	VP Value Stream Owner - Plan to Execution	Scadinavian Airlines
Mr.Carlos Jovel	VP Revenue Management and Pricing	LATAM Airlines
Mr.Rahul Kucheria	Head of Loyalty	Qatar Airways
Mr.Rodrigo Llaguno	VP Customer Experience	Avianca
Mr.Juan Felipe Luque	Director of Cargo Operations	Avianca
Mr.Jiří Marek	Executive Director Sales & Distribution	LOT Polish Airlines
Mr.Juan Alberto Martín	VP Joint Business Agreements	Iberia Líneas Aéreas
Mr.Rafael Andrés Martínez	Head of Distribution & Revenue Mngt	Aerolíneas Argentinas
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Mr.Federico Soto	Former Head of Strategic Management Office	Iberia Líneas Aéreas
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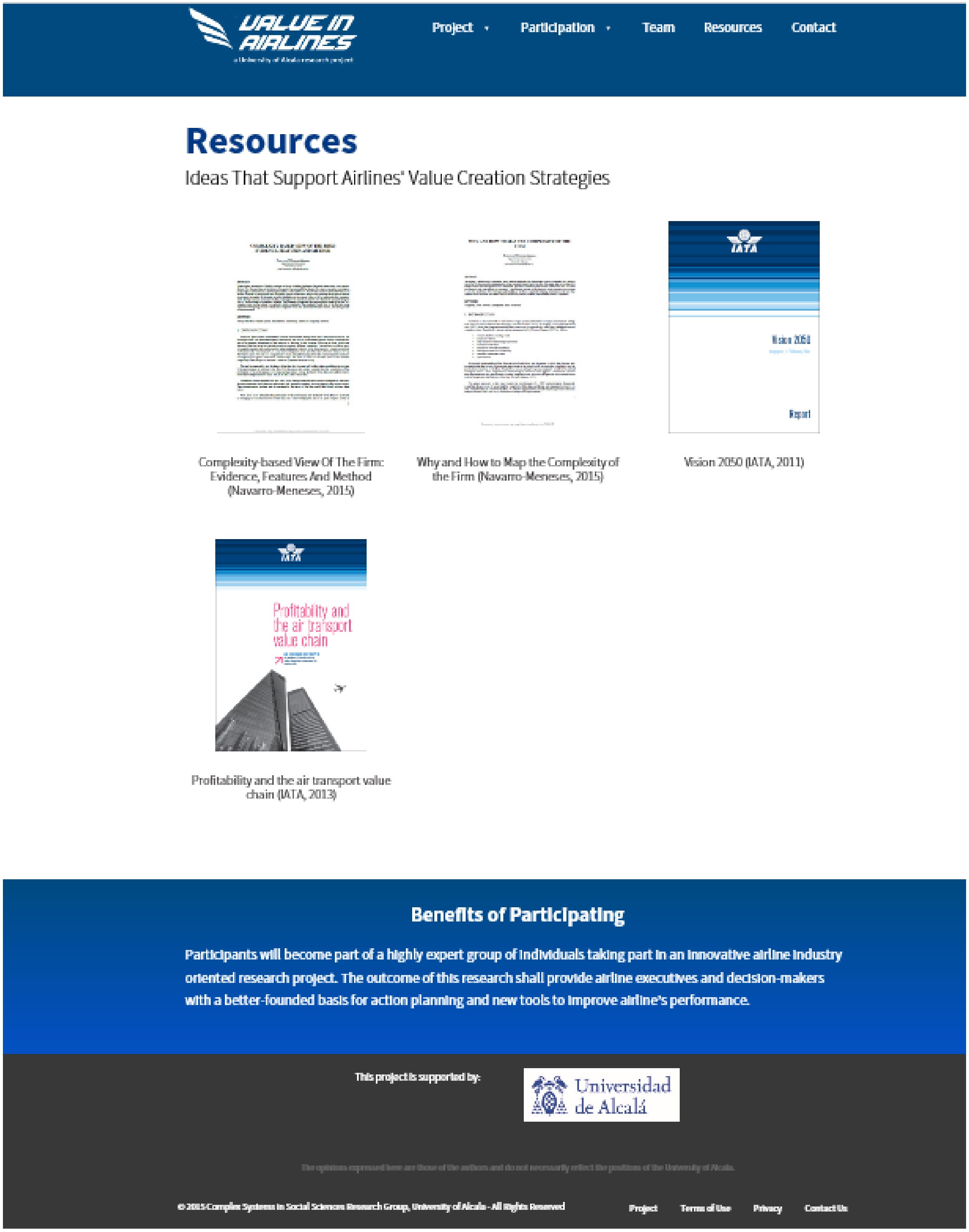
Mr.Warner van der Veer-Jehee	VP Safety & Quality at KLM E&M Division	AirFrance/KLM
Mr.Helmut Woelfel	VP Commercial	Lufthansa

Members Not Disclosing Their Profiles

Title:	Company:	Headquarters/Geography:
VP Network Operations	Network Airline	Middle East
VP Aircraft Maintenance	Network Airline	Europe
Director Customer Experience	Alliance Brand	Worldwide
VP Customer Experience and Technology	Alliance Brand	Worldwide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Ideas That Support Airlines' Value Creation Strategies
Complexity-based View Of The Firm: Evidence, Features And Method (Navarro-Meneses, 2015)
Why and How to Map the Complexity of the Firm (Navarro-Meneses, 2015)
IATA
Vision 2050
Report
Vision 2050 (IATA, 2011)
IATA
Profitability and the air transport value chain
Profitability and the air transport value chain (IATA, 2013)
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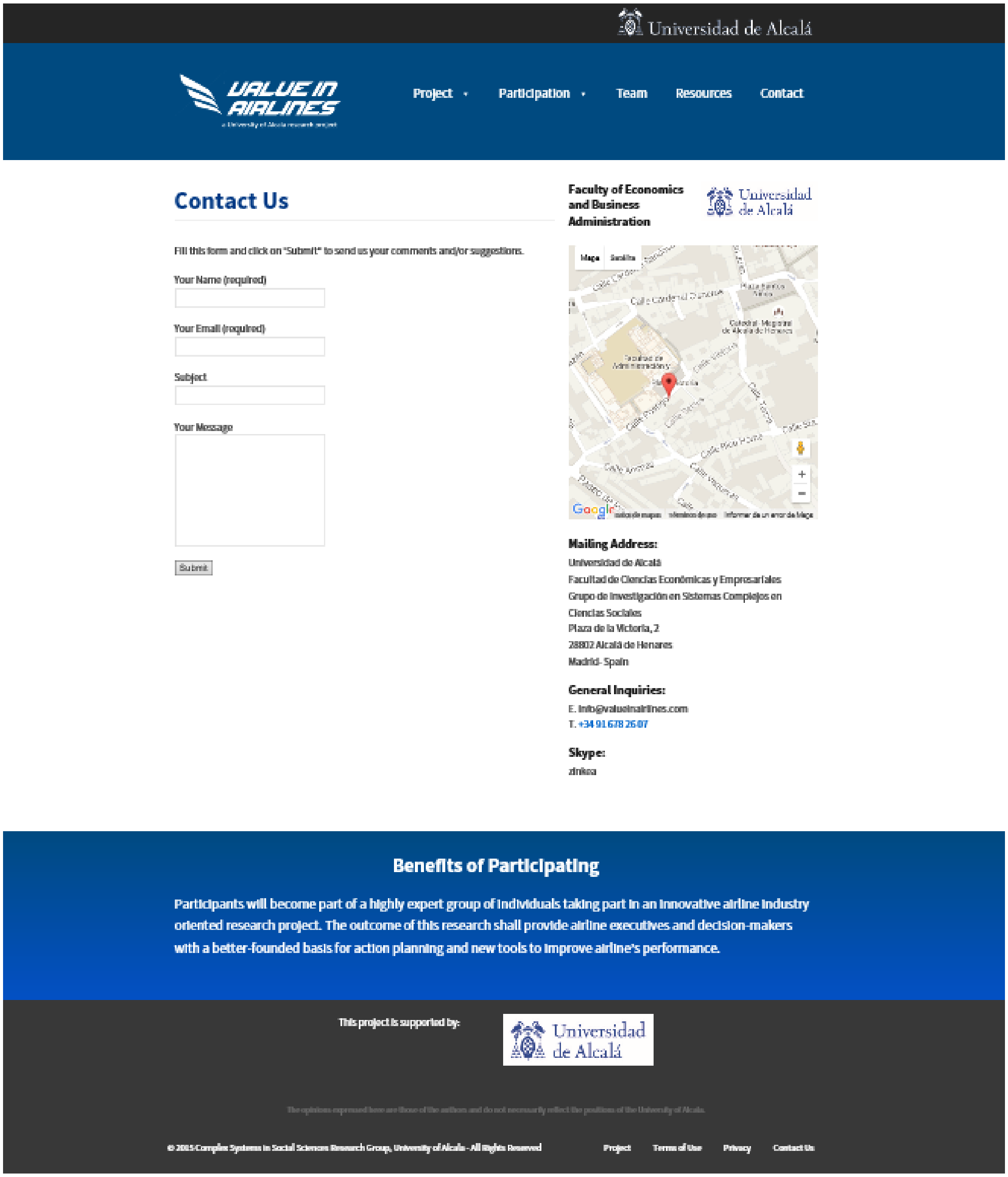

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APPENDIX H.

SOFTWARE TOOLS

H.1 R Programming Software

R is an open source software for statistical computation and graphics. The R distribution includes the ability to save and run commands stored in script files, and an integrated editor in the R Graphical User Interface (R-GUI). It compiles and runs on a wide variety of platforms including Unix/Linux, PC, and Macintosh. Thousands of contributed packages are available, and users are provided tools to make packages (Albert, Rizzo 2012).

At the core of R is an interpreted computer language. This language provides the logical control of branching and looping, and modular programming using functions. The base R distribution contains functions and data to implement and illustrate most common statistical procedures, including linear and nonlinear modeling, classical statistical tests, time-series analysis, classification, clustering analysis, density estimation, and much more.

One of R's strengths is the ease with which well-designed publication-quality plots can be produced, including mathematical symbols and formulae where needed. Great care has been taken over the defaults for the minor design choices in graphics, but the user retains full control.

An extensive suite of probability distribution functions and generators are provided, as well as a graphical environment for exploratory data analysis and creating presentation graphics. R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form.

H.2 Network Workbench

Network Workbench (NWB) software, available at http://nwb.cns.iu.edu, is a large-scale network analysis, modeling and visualization toolkit for biomedical, social science and physics research. This software is used in the thesis to draw the AVCN graph and perform network analysis.

The NWB supports network science research across scientific boundaries. Users of the NWB can upload their own networks and perform network analysis with the most effective algorithms available. In addition, they are able to generate, run, and validate network models to advance their understanding of the structure and dynamics of particular networks. NWB also provides advanced visualization tools to interactively explore and understand specific networks, as well as their interaction with other types of networks.

The NWB provides members of the scientific research community at large with a direct transfer of knowledge and results from the fields of specialist network research to a wider scientific community. Researchers have access to validated algorithms that in the past have been obtained through time-consuming personal developments of ad hoc computer programs (Indiana, Northeastern et al. 2006).

H.3 Qualtrics Survey System

Qualtrics (http://www.qualtrics.com) is an online survey management software that enables users to do many kinds of online data collection and analysis including market research, customer satisfaction and loyalty, product and concept testing, employee evaluations and website feedback. According to recent news reports, Qualtrics has about 6,000 clients running 2.1 million surveys on an average day (Brustein 2014) This software is used in the thesis to create and deliver the questionnaires of the field research Delphi process.

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BIBLIOGRAPHY

ADAMI, C., 2002. What is complexity. *Bioessays,* 24(12), pp. 1085-94.

ADLER, M. and ZIGLIO, E., 1996. *Gazing into the oracle: The Delphi method and its application to social policy and public health.* Jessica Kingsley Publishers.

AHUJA, R.K., MAGNANTI, T.L. and ORLIN, J.B., 1993. *Network flows: theory, algorithms, and applications.* Prentice Hall.

AHUJA, R.K., MAGNANTI, T.L., ORLIN, J.B. and REDDY, M.R., 1995. Applications of network optimization. *Handbooks in Operations Research and Management Science,* 7, pp. 1-83.

AI-JUNKIE, , Kohonen's Self Organizing Feature Maps. Available: http://www.ai-junkie.com/ann/som/som1.html.

ALBERGHINA, L. and WESTERHOFF, H.V., 2007. *Systems biology: definitions and perspectives.* Springer Science & Business Media.

ALBERT, J. and RIZZO, M., 2012. *R by Example.* Springer Science & Business Media.

ALCHIAN, A.A. and DEMSETZ, H., 1972. Production, information costs, and economic organization. *The American Economic Review,* , pp. 777-795.

ALLEE, V., 2002. *A value network approach for modeling and measuring intangibles.* Madrid: Transparent Enterprise.

ALLEN, P., MAGUIRE, S. and MCKELVEY, B., 2011. *The Sage Handbook of Complexity and Management.* Sage Publications.

AMMAN, H.M., TESFATSION, L., JUDD, K.L., KENDRICK, D.A. and RUST, J., 2006. *Handbook of Computational Economics.* Elsevier.

AMOS, T. and PEARSE, N., 2008. Pragmatic research design: An illustration of the use of the Delphi technique. *Electronic Journal of Business Research Methods,* 6(2), pp. 95-102.

ANDERSON, J.C., HAKANSSON, H. and JOHANSON, J., 1994. Dyadic business relationships within a business network context. *Journal of Marketing,* 58(4), pp. 1.

ANDERSON, N., HERRIOT, P. and HODGKINSON, G.P., 2001. The practitioner-researcher divide in Industrial, Work and Organizational (IWO) psychology: Where are we now, and where do we go from here? *Journal of Occupational and Organizational Psychology,* 74(4), pp. 391-411.

ANDO, T., 2010. *Bayesian model selection and statistical modeling.* CRC Press.

ARGENTI, J., 1997. Stakeholders: the case against. *Long range planning,* 30(3), pp. 442-445.

ARROW, K.J., 1974. *The Limits of Organization.* New York, N.Y.: W. W. Norton and Company.

ARROW, K.J., 1984. *The Economics of Agency.* Institute for Mathematical Studies in the Social Sciences, Stanford University.

ARTHUR, W.B., 1999. Complexity and the economy. *Science,* (248), pp. 107-109.

ATIYA, A.F., 2001. Bankruptcy prediction for credit risk using neural networks: A survey and new results. *Neural Networks, IEEE Transactions on,* 12(4), pp. 929-935.

AXTELL, R., 2000. *Why agents? On the varied motivations for agent computing in the social sciences.* Retrieved from: http://www.brook.edu/es/dynamics/papers/agents/agents.pdf.

BAILEY, K.D., 1990. *Social entropy theory.* SUNY Press.

BALASUBRAMANIAN, R. and AGARWAL, D., 2013. Delphi Technique-A Review. *International Journal of Public Health Dentistry,* 3(2), pp. 16-25.

BARABÁSI, A.L., 2002. *Linked: The new science of networks.* Perseus Pub.

BARABÁSI, A.L. and BONABEAU, E., 2003. Scale-free networks. *Scientific American,* 288(5), pp. 60-69.

BARBER, E., 2008. How to measure the "value" in value chains. *International Journal of Physical Distribution & Logistics Management,* 38(9), pp. 685-698.

BARNEY, J., 1991. Firm resources and sustained competitive advantage. *Journal of management,* 17(1), pp. 99-120.

BATTISTA, G.D., EADES, P., TAMASSIA, R. and TOLLIS, I.G., 1999. *Graph drawing: Algorithms for the visualisation of graphs.* Prentice Hall.

BHOWMICK, K. and SHAH, M., 2015. Kohonen's Self-Organizing Feature Maps and Linear Vector Quantization: A Comparison. *International Journal of Computer Applications,* 122(6), pp. 33-35.

BIEM, A. and CASWELL, N., 2008. A Value Network Model for Strategic Analysis. *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008).* IEEE, pp. 361.

BINDER, M. and EDWARDS, J.S., 2010. Using grounded theory method for theory building in operations management research: A study on inter-firm relationship governance. *International Journal of Operations & Production Management,* 30(3), pp. 232-259.

BLOIS, K., 2006. The boundaries of the firm—a question of interpretation? *Industry and Innovation,* 13(2), pp. 135-150.

BLOMQVIST, K. and KIANTO, A., 2007. Knowledge-based view of the firm-theoretical notions and implications for management. *Department of Business Administration and Technology Business Research Center, Lappeenranta University of Technology,* .

BOHÓRQUEZ, L.E. and ESPINOSA, A., 2015. Theoretical approaches to managing complexity in organizations: A comparative analysis. *Estudios Gerenciales,* 31(134), pp. 20-29.

BONABEAU, E., 2002. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences,* 99(suppl 3), pp. 7280-7287.

BONCHEV, D. and BUCK, G.A., 2005. Quantitative measures of network complexity. In: D. BONCHEV and D. ROUVRAY, eds, *Complexity in Chemistry, Biology, and Ecology.* . Springer US, pp. 191-235.

BOOGERD, F.C., BRUGGEMAN, F.J., HOFMEYR, J.S. and WESTERHOFF, H.V., 2007. Towards philosophical foundations of Systems Biology: introduction. *Systems Biology, Philosophical foundations,* , pp. 3-19.

BOSCHETTI, F., 2008. Mapping the complexity of ecological models. *ecological complexity,* 5(1), pp. 37-47.

BOULDING, K.E., 1956. General systems theory-the skeleton of science. *Management science,* 2(3), pp. 197-208.

BOWMAN, C. and AMBROSINI, V., 2000. Value creation versus value capture: towards a coherent definition of value in strategy. *British Journal of Management,* 11(1), pp. 1-15.

BRANDENBURGER, A.M. and STUART, H.W., 1996. Value-based business strategy. *Journal of Economics and Management Strategy,* 5, pp. 5-24.

BRANDES, U., RAAB, J. and WAGNER, D., 2001. Exploratory network visualization: Simultaneous display of actor status and connections. *Journal of Social Structure,* 2(4), pp. 1-28.

BRUSTEIN, J., 2014-last update, How an Online Survey Company Joined the $1 Billion Club. Available: http://www.bloomberg.com/bw/articles/2014-09-24/how-qualtrics-turned-online-surveys-into-a-1-billion-business.

BUNGE, M.A., 1967. *Scientific Research: The search for truth.* Springer-Verlag.

CACUCI, D.G., IONESCU-BUJOR, M. and NAVON, I.M., 2005. *Sensitivity and uncertainty analysis, volume II: applications to large-scale systems.* CRC Press.

CALVEZ, B. and HUTZLER, G., 2006. Automatic tuning of agent-based models using genetic algorithms. In: J. SICHMAN and L. ANTUNES, eds, *Multi-Agent-Based Simulation VI.* . Springer Berlin Heidelberg, pp. 41-57.

CAMPBELL, A., 1997. Stakeholders: the case in favour. *Long range planning,* 30(3), pp. 446-449.

CANTWELL, J.A., 2013. Blurred boundaries between firms, and new boundaries within (large multinational) firms: the impact of decentralized networks for innovation. *Seoul Journal of Economics,* 26, pp. 1-32.

CAPRA, F., 1985. *The Tao of Physics.* Boulder, Colorado: Shambhala.

CARRILLO-HERMOSILLA, J. and UNRUH, G.C., 2006. Technology stability and change: an integrated evolutionary approach. *Journal of Economic Issues,* 40(3), pp. 707-742.

CARRILLO-HERMOSILLA, J., 2015. Technological Diffusion and Standardization Patterns: An Industrial Taxonomy. *Journal of Economic Issues,* 49(1), pp. 253-263.

CASTELLETTI, A. and SONCINI-SESSA, R., 2007. Bayesian Networks and participatory modelling in water resource management. *Environmental Modelling & Software,* 22(8), pp. 1075-1088.

CASTILLO, O., MELIN, P., KACPRZYK, J. and PEDRYCZ, W., 2006. *Hybrid Intelligent Systems: Analysis and Design (Studies in Fuzziness and Soft Computing).* Springer-Verlag New York, Inc.

CAUDILL, M. and BUTLER, C., 1992. *Naturally intelligent systems.* MIT Press.

CHAMBERLIN, E.H., 1949. The theory of monopolistic competition: A re-orientation of the theory of value.

CHANDLER, A.D., 1962. Strategy and structure: Chapters in the history of the American enterprise. *Massachusetts Institute of Technology Cambridge,* .

CHANDLER, A.D, 1977. The Visible Hand. *Cambridge MA,* .

CHANDLER, A.D., 1990. Scale and scope: The dynamics of industrial competition. *Cambridge, MA, Harvard Business School,* .

CHANG, M. and HARRINGTON, J.E., 2006. Agent-based models of organizations. *Handbook of computational economics,* 2, pp. 1273-1337.

CHEN, S.H. and POLLINO, C.A., 2012. Good practice in Bayesian network modelling. *Environmental Modelling & Software,* 37, pp. 134-145.

CLAUSET, A., MOORE, C. and NEWMAN, M.E.J., 2008. Hierarchical structure and the prediction of missing links in networks. *Nature,* 453(7191), pp. 98-101.

COASE, R.H., 1937. The Nature of the Firm. *Economica,* 4(16), pp. 386-405.

COCKBURN, D. and KOBTI, Z., 2009. Agent specialization in complex social swarms. *Innovations in Swarm Intelligence.* . Springer, pp. 77-89.

COLLINS, J.C. and PORRAS, J.I., 1994. *Built to Last: Successful Habits of Visionary Companies.* Harper Business.

COOK, K.S. and EMERSON, R.M., 1987. *Social exchange theory.* SAGE Publications.

COUGHLAN, P. and COUGHLAN, D., 2002. Action research for operations management. *International journal of operations & production management,* 22(2), pp. 220-240.

CRUTCHFIELD, J., 2008. Five questions on complexity: Responses. In: C. GERSHENSON, ed, *Complexity: 5 Questions.* Copenhagen, Denmark: Automatic Press /VIP, .

CYERT, R.M. and MARCH, J.G., 1963. A behavioral theory of the firm. *Englewood Cliffs, NJ,* 2.

CYERT, R.M. and HEDRICK, C.L., 1972. Theory of the Firm: Past, Present, and Future; An Interpretation. *Journal of Economic Literature,* 10(2), pp. 398-412.

DANEKE, G.A., 1997. From metaphor to method: Nonlinear science and practical management. *The International Journal of Organizational Analysis,* 5(3), pp. 249-266.

DAVIS, B. and SUMARA, D., 2014. *Complexity and Education: Inquiries Into Learning, Teaching, and Research.* Taylor & Francis.

DAY, E., 2002. The Role of Value in Consumer Satisfaction. *Journal of Consumer Satisfaction, Dissatisfaction and Complaining Behavior,* 15, pp. 22-32.

DE TONI, A.F., NARDINI, A., NONINO, F. and ZANUTTO, G., 2001. Complexity measures in manufacturing systems.

DEAN, J.W., OTTENSMEYER, E. and RAMIREZ, R., 1997. An aesthetic perspective on organizations. In: L. COOPER and S.E. JACKSON, eds, *Creating Tomorrow's Organizations: A Handbook for Future Research in Organizational Behavior.* Chichester: Wiley, pp. 419-438.

DEHMER, M., 2011. Information theory of networks. *Symmetry,* 3, pp. 767-779.

DEMSETZ, H., 1988. *Ownership, control, and the firm.* Oxford: Blackwell.

DESAI, V.S., CROOK, J.N. and OVERSTREET, G.A., 1996. A comparison of neural networks and linear scoring models in the credit union environment. *European Journal of Operational Research,* 95(1), pp. 24-37.

DESARBO, W.S., JEDIDI, K. and SINHA, I., 2001. Customer value analysis in a heterogeneous market. *Strategic Management Journal,* 22(9), pp. 845-857.

DESHMUKH, A.V., TALAVAGE, J.J. and BARASH, M.M., 1998. Complexity in manufacturing systems, part 1: Analysis of static complexity. *IIE Transactions,* 30(7), pp. 645-655.

DIETRICH, M. and KRAFFT, J., 2012. *Handbook on the Economics and Theory of the Firm.* Edward Elgar Publishing.

DONALDSON, T. and PRESTON, L.E., 1995. The Stakeholder Theory of the Corporation: Concepts, Evidence, and Implications. *The Academy of Management Review,* 20(1), pp. 65-91.

EDITORIAL, 2009. No man is an island. *Nature Physics,* 5(1),.

EIDELSON, R.J., 1997. Complex adaptive systems in the behavioral and social sciences. *Review of General Psychology,* 1(1), pp. 42-71.

ETHIRAJ, S.K. and LEVINTHAL, D., 2004. Modularity and innovation in complex systems. *Management Science,* 50(2), pp. 159-173.

FAGIOLO, G., 2007. Clustering in complex directed networks. *Physical Review E,* 76(2),.

FEO, T.A. and RESENDE, M.G., 1995. Greedy randomized adaptive search procedures. *Journal of Global Optimization,* 6(2), pp. 109-133.

FLOUDAS, C.A. and PARDALOS, P.M., 2013. *State of the art in global optimization: computational methods and applications.* Springer Science & Business Media.

FORRESTER, J.W., 1987. Lessons from system dynamics modeling. *System Dynamics Review,* 3(2), pp. 136-149.

FORRESTER, J.W., 1994. System dynamics, systems thinking, and soft OR. *System Dynamics Review,* 10(2-3), pp. 245-256.

FOSS, N.J., 1998. *The theory of the firm: an introduction to themes and contributions.* Institut for Industrikonomi og Virksomhedsstrategi.

FOSS, N.J. and KLEIN, P.G., 2005. The theory of the firm and its critics: a stocktaking and assessment. *Available at SSRN 695484,* .

FREEMAN, L.C., 2000. Visualizing social networks. *Journal of Social Structure,* 1(1),.

FREEMAN, R.E., 1984. *Strategic management: A stakeholder approach.* 1st Ed edn. Pitman.

FREEMAN, R.E., WICKS, A.C. and PARMAR, B., 2004. Stakeholder Theory and The Corporate Objective Revisited. *Organization Science,* 15(3), pp. 364-369.

FRIESZ, T.L. and BERNSTEIN, D., 2015. *Foundations of Network Optimization and Games.* Springer.

GARRISON, R.H., NOREEN, E.W. and BREWER, P.C., 2006. *Managerial accounting.* McGraw-Hill/Irwin.

GAVETTI, G., GREVE, H.R., LEVINTHAL, D.A. and OCASIO, W., 2012. The behavioral theory of the firm: Assessment and prospects. *The academy of management annals,* 6(1), pp. 1-40.

GELL-MANN, M., 1995. What is complexity? *Complexity,* 1(1),.

GHARAJEDAGHI, J., 2011. *Systems thinking: Managing chaos and complexity: A platform for designing business architecture.* Elsevier.

GHOSHAL, S. and MORAN, P., 1997. *Value Creation By Firms.* INSEAD.

GIBBONS, M., LIMOGES, C., NOWOTNY, H., SCHWARTZMAN, S., SCOTT, P. and TROW, M., 1994. *The new production of knowledge: The dynamics of sand Research in contemporary societies.* SAGE Publications.

GILBERT, N. and TROITZSCH, K., 2005. *Simulation for the social scientist.* McGraw-Hill Education (UK).

GLASER, B.G. and STRAUSS, A.L., 2009. *The discovery of grounded theory: Strategies for qualitative research.* Transaction Publishers.

GLOVER, F., 1989. Tabu Search—Part I. *ORSA Journal on Computing,* 1(3), pp. 190-206.

GNATZY, T., WARTH, J., VON DER GRACHT, H. and DARKOW, I., 2011. Validating an innovative real-time Delphi approach-A methodological comparison between real-time and conventional Delphi studies. *Technological Forecasting and Social Change,* 78(9), pp. 1681-1694.

GODFREY, P.C. and HILL, C.W.L., 1995. The problem of unobservables in strategic management research. *Strategic Management Journal,* 16(7), pp. 519-533.

GOERZEN, A. and BEAMISH, P.W., 2007. The Penrose effect:“Excess” expatriates in multinational enterprises. *Management International Review,* 47(2), pp. 221-239.

GOFFE, W.L., FERRIER, G.D. and ROGERS, J., 1994. Global optimization of statistical functions with simulated annealing. *Journal of Econometrics,* 60(1), pp. 65-99.

GOLDENFELD, N. and KADANOFF, L.P., 1999. Simple lessons from Complexity. *Science,* (284), pp. 87-89.

GORZEŃ-MITKA, I. and OKRĘGLICKA, M., 2015. Managing Complexity: A Discussion of Current Strategies and Approaches. *Procedia Economics and Finance,* 27, pp. 438-444.

GRANT, R.M., 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal,* 17(S2), pp. 109-122.

GRIMM, V., BERGER, U., BASTIANSEN, F., ELIASSEN, S., GINOT, V., GISKE, J., GOSS-CUSTARD, J., GRAND, T., HEINZ, S.K., HUSE, G., HUTH, A., JEPSEN, J.U., JØRGENSEN, C., MOOIJ, W.M., MÜLLER, B., PE’ER, G., PIOU, C., RAILSBACK, S.F., ROBBINS, A.M., ROBBINS, M.M., ROSSMANITH, E., RÜGER, N., STRAND, E., SOUISSI, S., STILLMAN, R.A., VABØ, R., VISSER, U. and DEANGELIS, D.L., 2006. A standard protocol for describing individual-based and agent-based models. *Ecological Modelling,* 198(1–2), pp. 115-126.

GRZEGORCZYK, M. and HUSMEIER, D., 2009. Bayesian networks and their applications in systems biology. *and Posters,* 17, pp. 48.

GULATI, R., 1998. Alliances and networks. *Strategic Management Journal,* 19(4), pp. 293-317.

HAGAN, M., DEMUTH, H., BEALE, M. and DE JESUS, O., 2014. *Neural Network Design (2nd Edition).* Martin Hagan.

HAILE, N. and ALTMANN, J., 2013. Estimating the value obtained from using a software service platform. *Economics of Grids, Clouds, Systems, and Services.* . Springer, pp. 244-255.

HAKANSSON, H. and SNEHOTA, I., 2006. No business is an island: The network concept of business strategy. *Scandinavian Journal of Management,* 22(3), pp. 256-270.

HAKSEVER, C., CHAGANTI, R. and COOK, R.G., 2004. A model of value creation: Strategic view. *Journal of Business Ethics,* 49(3), pp. 295-307.

HARRISON, J.S. and WICKS, A.C., 2013. Stakeholder theory, value, and firm performance. *Business ethics quarterly,* 23(01), pp. 97-124.

HART, O. and MOORE, J., 1990. Property Rights and the Nature of the Firm. *Journal of political economy,* , pp. 1119-1158.

HEILBRONER, R.L., 1983. The Problem of Value in the Constitution of Economic Thought. *Social Research,* 50(2), pp. 253-277.

HEISENBERG, W.K., 1958. *Physics and Philosophy. The Revolution in Modern Science.* Based on The Gifford Lectures delivered at the University of St. Andrews during the Winter Term 1955-1956.

HELANDER, N., 2004. *Value-creating networks: an analysis of the software component business.* University of Oulu.

HELBING, D., 2012. *Social Self-organization: Agent-based simulations and experiments to study emergent social behavior.* Springer.

HELPER, S., 2000. Economists and field research:" You can observe a lot just by watching". *American Economic Review,* 90(2), pp. 228-232.

HERGERT, M. and MORRIS, D., 1989. Accounting data for value chain analysis. *Strategic Management Journal,* 10(2), pp. 175-188.

HERRALA, M., PAKKALA, P. and HAAPASALO, H., 2011. *Value-creating networks. A conceptual model and analysis.* Department of Industrial Engineering and Management, University of Oulu.

HILLMAN, A.J. and KEIM, G.D., 2001. Shareholder value, stakeholder management, and social issues: what's the bottom line? *Strategic Management Journal,* 22(2), pp. 125-139.

HINKELMANN, F., MURRUGARRA, D., JARRAH, A.S. and LAUBENBACHER, R., 2010. A mathematical framework for agent based models of complex biological networks. *Bulletin of Mathematical Biology,* .

HITT, M.A., KEATS, B.W. and DEMARIE, S.M., 1998. Navigating in the new competitive landscape: Building strategic flexibility and competitive advantage in the 21st century. *Academy of Management,* 12(4), pp. 22-42.

HITT, M.A., GIMENO, J. and HOSKISSON, R.E., 1998. Current and Future Research Methods in Strategic Management. *Organizational Research Methods,* 1(1), pp. 6-44.

HOLLAND, J.H., 1975. *Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence.* University of Michigan Press.

HOLLAND, J.H., 2000. *Emergence: From chaos to order.* Oxford University Press.

HÖLMSTROM, B., 1979. Moral hazard and observability. *The Bell journal of economics,* , pp. 74-91.

HÖLMSTROM, B. and MILGROM, P., 1994. The firm as an incentive system. *The American Economic Review,* , pp. 972-991.

HOLMSTRÖM, B. and ROBERTS, J., 1998. The boundaries of the firm revisited. *The Journal of Economic Perspectives,* , pp. 73-94.

HOLWEG, M. and PIL, F.K., 2006. Evolving from value chain to value grid. *MIT Sloan Management Review,* 47(4), pp. 72-80.

HOSKISSON, R.E., HITT, M.A., WAN, W.P. and YIU, D., 1999. Theory and research in strategic management: Swings of a pendulum. *Journal of management,* 25(3), pp. 417-456.

HOU-SHUN, L., 1956. The Concept of Economic Homeostasis. *Financial Analysts Journal,* 12(4), pp. 51-53.

HOWARD, N., ROLLAND, C. and QUSAIBATY, A., 2004. Process Complexity: Towards a Theory of Intentoriented Process Design. *2nd International Conference of Information and Systems.* Egypt: ICIS, .

IANSITI, M. and LEVIEN, R., 2004. *The keystone advantage: what the new dynamics of business ecosystems mean for strategy, innovation, and sustainability.* Harvard Business Press.

INDIANA, U., 2005-last update, Pathfinder Network Scaling. Available: Information Visualization Cyberinfrastructure http://iv.slis.indiana.edu/.

INDIANA, U., NORTHEASTERN, U. and MICHIGAN, U., 2006-last update, Network Workbench Tool. Available: http://nwb.slis.indiana.edu.

INTERNATIONAL AIR TRANSPORT ASSOCIATION, 2011. Vision 2050. *Available in: www.iata.org,* .

ITAMI, H. and ROEHL, T.W., 1991. *Mobilizing invisible assets.* Harvard University Press.

IZQUIERDO, L.R., ORDAX, J.M.G., SANTOS, J.I. and MARTÍNEZ, R.D.O., 2008. Modelado de sistemas complejos mediante simulación basada en agentes y mediante dinámica de sistemas. *Empiria. Revista de metodología de ciencias sociales,* (16), pp. 85-112.

JACCARD, J. and JACOBY, J., 2010. *Theory construction and model-building skills: A practical guide for social scientists.* Guilford Press.

JACKSON, M.O., 2008. *Social and economic networks.* Princeton University Press Princeton.

JANG, J.S.R., SUN, C.T. and MIZUTANI, E., 1997. *Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence.* Prentice Hall.

JARVENPAA, S.L. and IVES, B., 1994. The global network organization of the future: Information management opportunities and challenges. *Journal of Management Information Systems,* 10(4), pp. 25-57.

JÄRVINEN, P., 2005. *Action research as an approach in design science.* University of Tampere, Retrieved from http://www.sis.uta.fi/cs/reports/dsarja/D-2005-2.pdf.

JAYNES, E.T., 1991. *How Should We Use Entropy In Economics?* .

JENSEN, M.C. and MECKLING, W.H., 1992. Specific and general knowledge and organizational structure. *Available at SSRN 6658,* .

JENSEN, M.C. and MECKLING, W.H., 2000. The theory of the firm: managerial behavior, agency costs and ownership structure. *Theory of the Firm, Bd,* 1, pp. 248-306.

JENSEN, M.C., 2002. Value Maximization, Stakeholder Theory, and the Corporate Objective Function. *Business Ethics Quarterly,* 12(2), pp. 235-256.

JETTER, A.J. and KOK, K., 2014. Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. *Futures,* 61, pp. 45-57.

JOHNSON, R.A., KAST, F.E. and ROSENZWEIG, J.E., 1973. *The theory and management of systems.* McGraw-Hill.

JOHNSTON, R. and LAWRENCE, P.R., 1988. Beyond vertical integration -- the rise of the value-adding partnership. *Harvard Business Review,* .

JØRGENSEN, S.E. and BENDORICCHIO, G., 2001. *Fundamentals of ecological modelling.* Elsevier.

JØRGENSEN, S.E., 2006. An integrated ecosystem theory. *Annals of the European Academy of Science,* , pp. 19-33.

JOYCE, K.E., HAYASAKA, S. and LAURIENTI, P.J., 2012. A genetic algorithm for controlling an agent-based model of the functional human brain. *Biomed Sci Instrum,* 48, pp. 210-217.

KANEKO, K., 2006. *Life: an introduction to complex systems biology.* Springer.

KAPLAN, R.S. and NORTON, D.P., 1996. *The balanced scorecard: Translating strategy into action.* Harvard Business School Press.

KAPLAN, R.S. and NORTON, D.P., 2004. *Strategy maps: Converting intangible assets into tangible outcomes.* Harvard Business Press.

KAPOOR, R. and LEE, J.M., 2013. Coordinating and competing in ecosystems: How organizational forms shape new technology investments. *Strategic Management Journal,* 34(3), pp. 274-296.

KARSTEN, S.G., 1990. Quantum theory and social economics: The holistic approach of modern physics serves better than Newton's mechanics in approaching reality. *American Journal of Economics and Sociology,* , pp. 385-399.

KAST, F.E. and ROSENZWEIG, J.E., 1972. General Systems Theory: Applications for Organization and Management. *The Academy of Management Journal,* 15(4, General Systems Theory), pp. 447-465.

KAUFFMAN, S.A., 1990. The Sciences of Complexity and" Origins of Order". *Proceedings of the Biennial Meeting of the Philosophy of Science Association.* . JSTOR, pp. 299-322.

KHULLER, S. and RAGHAVACHARI, B., 2013. Network Optimization. In: P.M. PARDALOS, D. DU and R.L. GRAHAM, eds, Springer New York, pp. 1989-2026.

KITANO, H., 2002. Systems biology: toward system-level understanding of biological systems. In: H. KITANO, ed, *Foundations of systems biology.* Cambridge, MA: MIT Press, pp. 1-36.

KOHONEN, T., 1998. The self-organizing map. *Neurocomputing,* 21(1), pp. 1-6.

KOHONEN, T., 2013. Essentials of the self-organizing map. *Neural Networks,* 37(Twenty-fifth Anniversary Commemorative Issue), pp. 52-65.

KOLACZYK, E.D., 2009. *Statistical Analysis of Network Data. Methods and Models.* Springer.

KOLACZYK, E.D. and CSÁRDI, G., 2014. *Statistical analysis of network data with R.* Springer.

KOLLER, T., GOEDHART, M. and WESSELS, D., 2010. *Valuation: measuring and managing the value of companies.* john Wiley and sons.

KOSKO, B., 1987. Adaptive inference in fuzzy knowledge networks. *Proc. 1st Int. Conf. Neural Networks.* pp. 261-268.

KOTHANDARAMAN, P. and WILSON, D.T., 2001. The future of competition: value-creating networks. *Industrial marketing management,* 30(4), pp. 379-389.

KRIESEL, D., 2007. *A brief introduction to neural networks.* Retrieved from: http://www.dkriesel.com.

KRYCHA, K.A. and WAGNER, U., 1999. Applications of artificial neural networks in management science: a survey. *Journal of Retailing and Consumer Services,* 6(4), pp. 185-203.

KUDRYAVTSEV, L.D., 2001-last update, Homogeneous function. Available: http://www.encyclopediaofmath.org/index.php?title=Homogeneous_function&oldid=11366.

LADYMAN, J., LAMBERT, J. and WIESNER, K., 2013. What is a complex system? *European Journal for Philosophy of Science,* 3(1), pp. 33-67.

LAMBERTINI, L., 2013. John von Neumann between Physics and Economics: A Methodological Note. *Review of Economic Analysis,* 5, pp. 177–189.

LEE, K.C., LEE, H., LEE, N. and LIM, J., 2013. An agent-based fuzzy cognitive map approach to the strategic marketing planning for industrial firms. *Industrial Marketing Management,* 42(4), pp. 552-563.

LEONDES, C.T., 1998. *Optimization Techniques.* Elsevier Science.

LEPAK, D.P., SMITH, K.G. and TAYLOR, M.S., 2007. Introduction to special topic forum: Value creation and value capture. A multilevel perspective. *The Academy of Management Review,* 32(1), pp. 180-194.

LEVINTHAL, D., 1988. A survey of agency models of organizations. *Journal of Economic Behavior & Organization,* 9(2), pp. 153-185.

LEVINTHAL, D., 2007. Technology: the role of network structures. *Strategic Entrepreneurship Journal,* 1(3-4), pp. 189-190.

LI, E.Y., 1994. Artificial neural networks and their business applications. *Information & Management,* 27(5), pp. 303-3013.

LIEBERMAN, M.B. and BALASUBRAMANIAN, N., 2007. Measuring value creation and its distribution among stakeholders of the firm. *Available at SSRN 2382099,* .

LIMA, F.W., HADZIBEGANOVIC, T. and STAUFFER, D., 2009. Evolution of ethnocentrism on undirected and directed Barabási–Albert networks. *Physica A: Statistical Mechanics and its Applications,* 388(24), pp. 4999-5004.

LINSTONE, H.A. and TUROFF, M., 2002. The Delphi Method. *Techniques and applications,* 53.

LIPPMANN, R.P., 1987. An introduction to computing with neural nets. *ASSP Magazine, IEEE,* 4(2), pp. 4-22.

LUENBERGER, D.G., 1979. *Introduction to Dynamic Systems: Theory, Models, and Applications.* Wiley.

M'CHIRGUI, Z., 2012. Small-world or Scale-Free Phenomena in Internet: What Implications for the Next-generation Networks? *Review of European Studies,* 4(1), pp. p85.

MACAL, C.M. and NORTH, M.J., 2009. Agent-based modeling and simulation. *Proceedings of the 2009 Winter Simulation Conference (WSC).* IEEE, pp. 86-98.

MAHONEY, J.T., 2005. *Economic foundations of strategy.* SAGE Publications.

MANGIAMELI, P., CHEN, S.K. and WEST, D., 1996. A comparison of SOM neural network and hierarchical clustering methods. *European Journal of Operational Research,* 93(2), pp. 402-417.

MARSHALL, A., 1919. *Industry and Trade, a Study of Industrial Technique and Business Organization.* Macmillan.

MARSHALL, A. and GUILLEBAUD, C.W., 1961. *Principles of Economics. 9th (variorum) ed.* Macmillan.

MARTIN, R., 2012. Opening Up The Boundaries of the Firm. *Harvard Business Review,* .

MASTEN, S.E., 1984. The organization of production: Evidence from the aerospace industry. *Journal of Law and Economics,* , pp. 403-417.

MAULA, M., 2006. *Organizations as learning systems:'living composition'as an enabling infrastructure.* Emerald Group Publishing.

MCGARVEY, B., HANNON, B. and HANNON, B.M., 2004. *Dynamic modeling for business management: An introduction.* Springer Science & Business Media.

MCKAY, R.S., 2008. Nonlinearity in complexity science. *Nonlinearity,* (21), pp. T273–T281.

MCMILLAN, E., 2008. *Complexity, management and the dynamics of change: Challenges for practice.* Routledge.

MELLA, P., 2009. *The Holonic Revolution. Holons, Holarchies and Holonic Networks. The Ghost in the Production Machine.* Pavia University Press.

MENDOZA, G.A. and PRABHU, R., 2006. Participatory modeling and analysis for sustainable forest management: Overview of soft system dynamics models and applications. *Forest Policy and Economics,* 9(2), pp. 179-196.

MEYER, A.D., GABA, V. and COLWELL, K.A., 2005. Organizing far from equilibrium: Nonlinear change in organizational fields. *Organization Science,* 16(5), pp. 456-473.

MEYER, R.R., 1985. Network Optimization. In: K. SCHITTKOWSKI, ed, Springer Berlin Heidelberg, pp. 125-139.

MITCHELL, M., 1998. *An introduction to genetic algorithms.* Bradford Books.

MOODY, J., MCFARLAND, D. and BENDER-DEMOLL, S., 2005. Dynamic network visualization. *American Journal of Sociology,* 110(4), pp. 1206-1241.

MORGENBESSER, S., 1966. Is It a Science? *Social Research,* 33(2), pp. 255.

MOSS, S., 1984. The History of the Theory of the Firm from Marshall to Robinson and Chamberlin: the Source of Positivism in Economics. *Economica,* , pp. 307-318.

MOTTER, A.E. and TOROCZKAI, Z., 2007. Introduction: Optimization in networks. *Chaos,* 17(026101),.

MOWSHOWITZ, A. and DEHMER, M., 2010. A symmetry index for graphs. *Journal of Mathematical Biophysics,* 30, pp. 533-546.

NAGARAJAN, R., SCUTARI, M. and LÈBRE, S., 2014. *Bayesian Networks in R: with Applications in Systems Biology.* Springer New York.

NAMBISAN, S., AGARWAL, R. and TANNIRU, M., 1999. Organizational mechanisms for enhancing user innovation in information technology. *MIS quarterly,* , pp. 365-395.

NELSON, R. and WINTER, S.G., 1982. *An Evolutionary Theory of Economic Change.* Cambridge, Mass.: Harvard University Press.

NELSON, R.R. and SAMPAT, B.N., 2001. Making sense of institutions as a factor shaping economic performance. *Revista de Economía Institucional,* 3(5), pp. 17-51.

NIELSEN, T.D. and JENSEN, F.V., 2009. *Bayesian networks and decision graphs.* Springer Science & Business Media.

NOLAN, P., 2007. *Capitalism and freedom: the contradictory character of globalisation.* Anthem Press.

NORMANN, R. and RAMIREZ, R., 1993. From value chain to value constellation: Designing interactive strategy. *Harvard Business Review,* 71(4),.

NORTH, D.C., 1990. *Institutions, Institutional Change and Economic Performance.* Cambridge University Press.

OBERHEIM, E. and HOYNINGEN-HUENE, P., 2013. The Incommensurability of Scientific Theories. *The Stanford Encyclopedia of Philosophy,* (Spring 2013),.

OECD, 2008. Report on Applications of Complexity Science for Public Policy: New Tools for Finding Unanticipated Consequences and Unrealized Opportunities. *OECD Global Science Forum.* . OECD, .

OREMLAND, M. and LAUBENBACHER, R., 2014. Optimization of Agent-Based Models: Scaling Methods and Heuristic Algorithms. *Journal of Artificial Societies and Social Simulation,* 17(2), pp. 6.

PABLO-MARTÍ, F., MUÑOZ-YEBRA, C. and SANTOS, J.L., 2014. An agent-based model of firm location with different regional policies, *Social Simulation Conference* 2014.

PABLO-MARTÍ, F., SANTOS, J.L. and KASZOWSKA, J., 2015. An agent-based model of population dynamics for the European regions. *Emergence: Complexity and Organization,* 17(2), pp. C1.

PALIWAL, M. and KUMAR, U.A., 2009. Neural networks and statistical techniques: A review of applications. *Expert Systems with Applications,* 36(1), pp. 2-17.

PANNELL, D.J., 1997. Sensitivity analysis of normative economic models: theoretical framework and practical strategies. *Agricultural economics,* 16(2), pp. 139-152.

PANWAI, S. and DIA, H., 2005. A reactive agent-based neural network car following model. *Proceedings. 2005 IEEE Intelligent Transportation Systems, 2005.* . IEEE, pp. 375-380.

PAPAGEORGIOU, E., 2012. Learning algorithms for fuzzy cognitive maps—a review study. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on,* 42(2), pp. 150-163.

PAPAGEORGIOU, E. and SALMERON, J.L., 2013. A review of fuzzy cognitive maps research during the last decade. *Fuzzy Systems, IEEE Transactions on,* 21(1), pp. 66-79.

PAPANDREOU, A.G., 2000. Some basic problems in the theory of the firm. *The Theory of the Firm: Critical Perspectives on Business and Management,* 1, pp. 14.

PARADICE, D., 2009. *Emerging Systems Approaches in Information Technologies: Concepts, Theories, and Applications: Concepts, Theories, and Applications.* IGI Global.

PAROLINI, C., 1996. The Value Nets: A methodology for the analysis of value-creating systems. *Strategic Management Conference.* . SMS, .

PARTRIDGE, M.J. and PERREN, L.J., 1994. Cost analysis of the value chain: Another role for strategic management accounting. *Management Accounting,* 72(7), pp. 22.

PEARL, J., 2014. *Probabilistic reasoning in intelligent systems: networks of plausible inference.* Morgan Kaufmann.

PENROSE, E., 1955. Limits to the Growth and Size of Firms. *The American Economic Review,* , pp. 531-543.

PENROSE, E.T., 1959. *The Theory of the Growth of the Firm.* New York: John Wiley & Sons.

PEPPARD, J. and RYLANDER, A., 2006. From value chain to value network:: Insights for mobile operators. *European Management Journal,* 24(2), pp. 128-141.

PIERCE, L., 2008. Big losses in ecosystem niches: How core firm decisions drive complementary product shakeouts. *Available at SSRN 1157054,* .

PIGOU, A.C., 1932. The economics of welfare, 1920. *McMillan&Co., London,* .

PORTER, M., 1985. *Competitive advantage: Creating and sustaining superior performance.* New York: Free Press.

PORTER, M.E. and KRAMER, M.R., 2011. Creating shared value. *Harvard business review,* 89(1/2), pp. 62-77.

PRATT, J.W. and ZECKHAUSER, R., 1985. *Principals and agents: the structure of business.* Harvard Business School Press.

PREVOLNIK, M., ŠKORJANC, D., ČANDEK-POTOKAR, M. and NOVIČ, M., 2011. Application of artificial neural networks in meat production and technology. *Computer and Information Science,* 11, pp. 223-240.

PRIEM, R.L., 2007. A consumer perspective on value creation. *Academy of Management Review,* 32(1), pp. 219-235.

QUADDUS, M.A. and KHAN, M.S., 1999. Business applications of artificial neural networks: an updated review and analysis. *Neural Information Processing, 1999. Proceedings. 6th International Conference on.* Perth, WA: ICONIP'99, pp. 824 vol.2.

RAMÍREZ, R., 1999. Value Co-Production: Intellectual Origins and Implications for Practice and Research. *Strategic Management Journal,* 20(1), pp. 49-65.

RAO RAGHURAJ, K. and LAKSHMINARAYANAN, S., 2006. Alternate complexity measures and stability analysis of process and biological networks. *Proceedings of the 11th APCChE Congress.* Kuala Lumpur: APCChE, .

RASHEVSKY, N., 1955. Life, information theory, and topology. *The Bulletin of mathematical biophysics,* 17(3), pp. 229-235.

RAUCH, W., 1979. The decision delphi. *Technological Forecasting and Social Change,* 15(3), pp. 159-169.

RENCHER, A.C. and CHRISTENSEN, W.F., 2012. *Methods of Multivariate Analysis.* Wiley.

RICHARDSON, G.B., 1972. The organisation of industry. *The economic journal,* , pp. 883-896.

RICHARDSON, K. and CILLIERS., P., 2001. Special Editors' Introduction: What Is Complexity Science? A View from Different Directions. *Emergence,* 3(1), pp. 5-23.

RIND, D., 1999. Complexity and the climate. *Science,* (284), pp. 105-107.

ROBINSON, A., 1934. The problem of management and the size of firms. *The Economic Journal,* , pp. 242-257.

RODIN, V., QUERREC, G., BALLET, P., BATAILLE, F., DESMEULLES, G., ABGRALL, J. and TISSEAU, J., 2009. Multi-Agents System to Model Cell Signalling by Using Fuzzy Cognitive Maps. Application to Computer Simulation of Multiple Myeloma. *Ninth IEEE International Conference on Bioinformatics and BioEngineering.* . IEEE, pp. 236-241.

ROOKE, J., MOLLOY, E., SINCLAIR, M., KOSKELA, L., SIRIWARDENA, M., KAGIOGLOU, M. and SIEMIENIUCH, C., 2008. Models and metaphors: complexity theory and through-life management in the built environment. *Architectural Engineering and Design Management,* 4(1), pp. 47-57.

ROSS, S.A., 1973. The economic theory of agency: The principal's problem. *The American Economic Review,* , pp. 134-139.

ROUSE, W.B., 2007. Complex engineered, organizational and natural systems. *Systems Engineering,* 10(3), pp. 260-271.

SALTELLI, A., 2002. Sensitivity analysis for importance assessment. *Risk Analysis,* 22(3), pp. 579-590.

SANCHEZ, R. and HEENE, A., 2004. The new strategic management. *New York,* .

SANDERS, T.I., 2003-last update, What is complexity?. Available: http://www.complexsys.org.

SCHMIDT, R., LYYTINEN, K. and MARK KEIL, P.C., 2001. Identifying software project risks: An international Delphi study. *Journal of Management Information Systems,* 17(4), pp. 5-36.

SCHOCKEN, S. and ARIAV, G., 1994. Neural networks for decision support: Problems and opportunities. *Decision Support Systems,* 11(5), pp. 393-414.

SCOTT, W.R. and DAVIS, G.F., 2007. *Organizations and organizing: Rational, natural, and open system perspectives.* Prentice Hall.

SCOTT, W.G., 1961. Organization theory: an overview and an appraisal. *Journal of the Academy of Management,* , pp. 7-26.

SERRANO-CINCA, C., 1996. Self organizing neural networks for financial diagnosis. *Decision Support Systems,* 17(3), pp. 227-238.

SETIONO, R., THONG, J.Y. and YAP, C., 1998. Symbolic rule extraction from neural networks: An application to identifying organizations adopting IT. *Information & management,* 34(2), pp. 91-101.

SEXTON, R.S., DORSEY, R.E. and JOHNSON, J.D., 1999. Optimization of neural networks: A comparative analysis of the genetic algorithm and simulated annealing. *European Journal of Operational Research,* 114(3), pp. 589-601.

SHARDA, R. and WANG, J., 1996. Neural networks and operations research/management science. *European Journal of Operational Research,* 93(2), pp. 227-229.

SIMON, H.A., 1953. *Administrative behavior: a study of decision-making processes in administrative organization.* Macmillan.

SIMON, H.A., 1962a. The architecture of complexity. *Proceedings of the American Philosophical Society,* Vol. 106, No. 6, pp. 467-482.

SIMON, H.A., 1962b. New Developments in the Theory of the Firm. *The American Economic Review,* 52(2, Papers and Proceedings of the Seventy-Fourth Annual Meeting of the American Economic Association), pp. 1-15.

SIMON, H.A., 1976. How complex are complex systems? *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association,* 1976(, Volume Two: Symposia and Invited Papers), pp. 507-522.

SIMON, H.A., 1982. *Models of Bounded Rationality: Empirically grounded economic reason.* MIT Press.

SIMON, H.A., 1996. *The sciences of the artificial.* MIT press.

SIMON, H.A., 1999. Can there be a science of complex systems? In: Y. BAR-YAM, ed, *Unifying themes in complex systems: Proceedings from the International Conference on Complex Systems 1997.* Cambridge, MA: Perseus Press, pp. 4-14.

SKULMOSKI, G.J., HARTMAN, F.T. and KRAHN, J., 2007. The Delphi Method for Graduate Research. *Journal of Information Technology for Teacher Education [H.W. Wilson - EDUC],* 6, pp. 1.

SLOCUM, N., 2005. *Delphi: Participatory Methods Toolkit.* Retrieved from http://archive.unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf.

SMITH, K.A. and GUPTA, J.N.D., 2000. Neural networks in business: techniques and applications for the operations researcher. *Computers & Operations Research,* 27(11-12), pp. 1023-1044.

SMITH, K.A. and GUPTA, J.N., 2002. *Neural networks in business: techniques and applications.* IGI Global.

SMITH, P.A. and MITLETON-KELLY, E., 2011. A complexity theory approach to sustainability: A longitudinal study in two London NHS hospitals. *The Learning Organization,* 18(1), pp. 45-53.

SONG, H., MIAO, C., ROEL, W., SHEN, Z. and CATTHOOR, F., 2010. Implementation of fuzzy cognitive maps based on fuzzy neural network and application in prediction of time series. *Fuzzy Systems, IEEE Transactions on,* 18(2), pp. 233-250.

STABELL, C.B. and FJELDSTAD, ØD., 1998. Configuring value for competitive advantage: on chains, shops, and networks. *Strategic Management Journal,* 19(5), pp. 413-437.

STACE, W.T. and GOLDSTEIN, J.A., 2006. Novelty, indeterminism, and emergence. *Emergence: Complexity and Organization,* 8(2), pp. 77.

STACEY, R.D., GRIFFIN, D. and SHAW, P., 2000. *Complexity and management: fad or radical challenge to systems thinking?* Psychology Press.

STACEY, R. and GRIFFIN, D., 2008. *Complexity and the experience of values, conflict and compromise in organizations.* Routledge.

STERMAN, J.D., 2000. *Business dynamics: systems thinking and modeling for a complex world.* Irwin/McGraw-Hill Boston.

STEYVERS, M., TENENBAUM, J.B., WAGENMAKERS, E. and BLUM, B., 2003. Inferring causal networks from observations and interventions. *Cognitive science,* 27(3), pp. 453-489.

STROGATZ, S.H., 2001. Exploring complex networks. *Nature,* 410(6825), pp. 268-276.

STULA, M., STIPANICEV, D. and BODROZIC, L., 2010. Intelligent modeling with agent-based fuzzy cognitive map. *International Journal of Intelligent Systems,* 25(10), pp. 981-1004.

STYLIOS, C.D. and GROUMPOS, P.P., 1999. Mathematical Formulation of Fuzzy Cognitive Maps. *Proceedings of the 7th Mediterranean Conference on Control and Automation.* Haifa, Israel: MED99, .

SUNDARAM, A.K. and INKPEN, A.C., 2004. The corporate objective revisited. *Organization science,* 15(3), pp. 350-363.

TAN, D. and MAHONEY, J.T., 2005. Examining the Penrose effect in an international business context: The dynamics of Japanese firm growth in US industries. *Managerial and Decision Economics,* 26(2), pp. 113-127.

TARRIDE, M.I., 2013. The complexity of measuring complexity. *Kybernetes,* 42(2), pp. 174-184.

THORELLI, H.B., 1986. Networks: Between markets and hierarchies. *Strategic Management Journal,* 7(1), pp. 37-51.

TOWN, J.S. and KYRILLIDOU, M., 2013. Developing a values scorecard. *Performance Measurement and Metrics,* 14(1), pp. 7-16.

TWOMMEY, P. and CADMAN, R., 2002. Agent-Based Modelling of Customer Behaviour in the Telecoms and Media Markets. info, 4, 56-63.

VAN AKEN, J.E., 2004. Management research based on the paradigm of the design Sciences: The quest for field-tested and grounded technological rules. *Journal of Management Studies,* 41(2), pp. 219-246.

VAN HAM, F. and VAN WIJK, J.J., 2004. Interactive Visualization of Small World Graphs. *IEEE Symposium on Information Visualization.* . IEEE, pp. 199-206.

VELLIDO, A., LISBOA, P.J.G. and VAUGHAN, J., 1999. Neural networks in business: a survey of applications (1992–1998). *Expert Systems with Applications,* 17(1), pp. 51-70.

VOINOV, A. and BOUSQUET, F., 2010. Modelling with stakeholders. *Environmental Modelling & Software,* 25(11), pp. 1268-1281.

VON BERTALANFFY, L., 1950. The Theory of Open Systems in Physics and Biology. *Science,* No. 2872(New Series, Vol. 111), pp. 29.

VON DER GRACHT, H., 2012. Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technological Forecasting and Social Change,* 79(8), pp. 1525-1536.

VON NEUMANN, J. and MORGENSTERN, O., 1947. *Theory of Games and Economic Behavior.* Princeton University Press.

WARNER, B. and MISRA, M., 1996. Understanding neural networks as statistical tools. *The american statistician,* 50(4), pp. 284-293.

WASSERMAN, S. and FAUST, K., 1994. *Social network analysis: Methods and applications.* Cambridge university press.

WATTS, D.J. and STROGATZ, S.H., 1998. Collective dynamics of 'small-world' networks. *Nature,* 393(6684), pp. 440-2.

WATTS, D.J., 2004. The" new" science of networks. *Annual review of sociology,* , pp. 243-270.

WEAVER, W., 1991. Science and complexity. *Facets of Systems Science.* . Springer, pp. 449-456.

WELTER, F., SMALLBONE, D. and VAN GILS, A., 2012. *Entrepreneurial Processes in a Changing Economy: Frontiers in European Entrepreneurship Research.* Edward Elgar.

WENG, G., BHALLA, U.S. and IYENGAR, R., 1999. Complexity in biological signaling systems. *Science,* (284), pp. 92-96.

WERNERFELT, B., 1984. A resource-based view of the firm. *Strategic Management Journal,* 5(2), pp. 171-180.

WILLIAMSON, O.E., 1969. *Managerial discretion, organization form, and the multi-division hypothesis.* University of Pennsylvania, Department of Economics.

WILLIAMSON, O.E., 1975. *Markets and hierarchies: antitrust analysis and implications.* New York: The Free Press.

WILLIAMSON, O.E., 1985. *The Economic Institutions of Capitalism: Firms, markets, relational Contracting.* Free Press.

WILLIAMSON, O.E., 1996. *The Mechanisms of Governance.* Oxford University Press, USA.

WOODALL, T., 2003. Conceptualising'value for the customer': an attributional, structural and dispositional analysis. *Academy of marketing science review,* 2003, pp. 1.

YOUNG, S.M., 1999. Field research methods in management accounting. *Accounting horizons,* 13(1), pp. 76-84.

ZARANDI, M.H., HADAVANDI, E. and TURKSEN, I.B., 2012. A hybrid fuzzy intelligent agent-based system for stock price prediction. *International Journal of Intelligent Systems,* 27(11), pp. 947-969.

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