Faculdade de Engenharia da Universidade do Porto

FEUP

Performance Management and Alignment on Collaborative Networks of SMEs

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Resumo

O contexto deste trabalho incide na observação das atuais formas de colaboração entre organizações que pretendem explorar novas oportunidades de mercado a atuar em conjunto com parceiros oriundos tanto das suas regiões de origem como também no ambiente global. Dentro deste novo modelo de negócios é cada vez mais expectável a criação de redes colaborativas que permitam aos seus participantes a partilhar conhecimento, recursos e objetivos estratégicos. A sinergia entre parceiros da cadeia de valor, sejam organizações complementares ou até mesmo concorrentes, permite enfrentar novos desafios de forma sustentável. O mercado torna-se continuamente mais exigente e rigoroso no que diz respeito aos aspetos relacionados à qualidade dos produtos e serviços, tempo de resposta e redução de custos. Entretanto, a gestão deste novo modelo é dificultada se houver baixa confiança entre parceiros, ineficiência dos processos interorganizacionais e da interoperabilidade dos sistemas. Assim, um caminho eficiente para ajudar os decisores a ultrapassar estas dificuldades é avaliar o desempenho dos processos interorganizacionais aplicando o conceito de alinhamento. Portanto, a medição e gestão do desempenho tornam-se, então, cruciais na gestão da rede pois permite determinar seus pontos fracos e implementar ações que viabilizem soluções de melhoria mais eficazes.

Em relação a estes desafios, esta Tese apresenta métodos para avaliação do alinhamento entre os resultados dos processos interorganizacionais e as metas de desempenho da rede colaborativa. Tais abordagens e métodos foram desenvolvidas e testadas por meio de estudos de caso exploratório onde foram consideradas as especificidades relativas aos diferentes ambientes empresariais e, então, diferentes abordagens para medir o alinhamento foram propostas. Aos resultados derivados dos métodos desenvolvidos aplicou-se o paradigma emergente da predição de desempenho em substituição à tradicional abordagem de recolha de dados de desempenho para posteriormente definir metas ou monitorar o desempenho. Esta abordagem inovadora é suportada por ferramentas de estimação que consideram a fusão de dados, tanto para a caracterização das medidas de desempenho quanto para o apoio à tomada de decisão. Estudos de casos acompanhados pelo autor em redes brasileiras de pequeno e médio portes permitiram testar os métodos de medição do alinhamento.

Em resumo, a principal contribuição deste trabalho é propor que a medição do alinhamento dos processos interorganizacionais usando medidas de alinhamento (indicadores chave de alinhamento) seja uma abordagem relevante para avaliar o desempenho em redes colaborativas. Assim, é possível avaliar a contribuição de cada participante para o alinhamento relativamente à consecução dos objetivos e metas da rede. Outra contribuição importante foi o desenvolvimento de métodos e ferramentas aplicadas na medição e gestão de desempenho em redes colaborativas, incluindo: método da distância Euclidiana, método de determinação de *benchmark* de desempenho (DEA) e do grau de alinhamento (*Fit Degree*) aplicado à predição do alinhamento.

Abstract

This work aims at the observation of existing forms of collaboration between organizations that are seeking to explore new market opportunities and to work with partners from both their native regions and also from around the world. This new business model is increasingly leading to collaborative networks that enable participants to share their knowledge, their resources and their strategic objectives. The synergy between partners in the value chain can help complementary organizations or even competing organizations to sustainably meet new challenges. In this context, market demands are continuously increasing and more rigorous with regard to the quality of products and services, response times and the ability to reduce costs. However, the management of this new model is hampered by the possible lack of trust between partners, the inefficiency of the inter-organizational processes and interoperability between systems as well as problems relating to the accomplishment of strategic targets. Therefore, an effective way to overcome these difficulties supporting decision-makers is to assess and manage the performance of inter-organizational processes by introducing the concept of alignment. Thus, performance measurement and management become crucial to managing the collaborative network helping their participants to determine their own weaknesses and ineffective actions and then implement the most effective solutions for improvement.

Regarding such challenges, this thesis presents approaches and methods for assessing the alignment between the results of inter-organizational processes and the performance targets established by the collaborative network. Such approaches and methods were developed and tested by means of exploratory case studies and the specificities related to different collaboration business environments had been taken into account, then different approaches for measuring alignment were proposed. Specifically, the emerging paradigm of performance prediction was applied to the results derived from the methods thus replacing the traditional approach of collecting performance data to set goals and then monitor performance. This innovative approach is supported by tools that consider estimation and data fusion, both to characterize performance measures and to support decision-making. Case studies accompanied by the author in small and medium-sized Brazilian companies made it possible to test alignment measurement methods.

In summary, the main contribution of this work is to propose that business motivational factors, performance indicators and alignment measures are determined to assess performance in collaborative networks. Therefore, it is possible to assess the efforts of each participant to the inter-organizational alignment related to the objectives and goals of the network. Consequently, methods and tools used in measuring alignment were developed, including: Euclidian Distance Method, Benchmarking Analysis and the proposed Fit Degree Metric used in alignment prediction.

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It is also dedicated to my family and friends

“Ephemeral organizations joined in ephemeral combinations to produce ephemeral products for ephemeral markets . . . FAST.”

Tom Peters

Summary

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List of Abbreviations

ANN – Artificial Neural Network

ARCON - A Reference Model for Collaborative Networks

ATHENA - Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Application

BASYS – Balanced Automation Systems

CATWOE - Customer, Actor, Transformation process, Weltanschauung (world view), Owner, and Environmental constraints

CD – Compliance Degree

CN – Collaborative Network

CNIM – Collaborative Network Inter-operations Measures

CNPMS – Collaborative Network Performance Management System

CNSM – Collaborative Network Strategic Measures

CSR – Case Study Research

DDA – Descriptive Degree of Alignment

DET – Digital Enterprises Technology

ECOLEAD - European Collaborative Networked Organizations LEADership Initiative

EFQM – European Foundation for Quality Management

ENEGEP – Encontro Nacional de Engenharia de Produção

GPM-SME – Global Performance Management-Small and Medium Enterprises

ICT – Information and Communication Technology

IDEF - Icam DEFinition for Function Modeling

INESC Porto – Instituto Nacional de Engenharia de Sistemas e Computadores do Porto

INTEROP - Interoperability Research for Networked Enterprises Applications and Software

IT – Information Technology

KPI – Key Performance Indicator

KAI – Key Alignment Indicator

LAN – Local Area Network

LOM – Local Operational Measures

LPMS – Local Performance Measurement System

LSM – Local Strategic Measures

LSOM – Local Shared Operational Measures

LSSM – Local Shared Strategic Measures

MOSAIC - Specific Support Action

OEE – Overall Equipment Effectiveness

PDA – Predictive Degree of Alignment

PDCA – Plan, Do, Check, Act

PKAI – Predictive Key alignment Indicator

PMF – Performance Management Framework

PMI – Project Management Institute

PMMS – Performance Management System

PMS – Performance Measurement System

PMS-EVE – Performance Management System-Extended Virtual Enterprise

PNQ – Prêmio Nacional da Qualidade

PRO-VE – IFIP Working Conference on Virtual Enterprise

PVE – Performance Value Estimator

RCED – Redes Colaborativas de Elevado Desempenho

SCOR - Supply Chain Operations Reference-model

SDA – Subjective Degree of Alignment

SMEs – Small and Medium Enterprises

SSM – Soft Systems Methodology

UML – Unified Modeling Language

VBE – Virtual Organizational Breeding environment

VE – Virtual Enterprise

VFF - Virtual Factory Framework

VO – Virtual Organization

Chapter 1

Introduction

This chapter presents the context and relevance of collaborative networks and highlights the main theoretical fields that lead to explore performance management and alignment. Thereafter, concepts and research methods used in research methodology, including research questions that are related to problem-situations in business management are dealt in this research. A work plan is then shown and finally the contents of the thesis are presented.

1.1 Context and Relevance

The rapidly changing business environment that has been observed over the past decades increased the collaboration among distinct entities that are geographically distributed and that effectively seek to combine a set of skills and resources, covering short-term and long-term projects.

Indeed, a collaborative network (CN) may constitute a strong basis for competitiveness, world-excellence and agility in uncertain market conditions (Chituc and Azevedo, 2005). This collaboration model has to follow some aspects, such as common strategies and goals, the level of mutual trust, inter-organizational processes and infrastructures and policies for business practices in collaborative networks. In fact, it is possible to achieve higher levels of integration and agility if the conditions for obtaining these basic challenges are met (Camarinha-Matos, Afsarmanesh and Ollus, 2005).

This subject is an important business area that has been recognized by the scientific community and the practitioners because it is co-related to the need to improve the competitiveness of every kind of organization. It is increasingly acknowledged by those involved as a new paradigm that includes interoperation of distinct organizational systems which seek effectiveness by aggregating the skills and resources of the network participants (Drissen-Silva and Rabelo, 2009). It has also an impact on the development of abilities, either within conceptual or technological and operational frameworks. Exploring this concept further, there is a fundamental importance in establishing a perspective of cooperation extended to the CN life-cycle (creation, configuration, reconfiguration and cessation) by monitoring performance and alignment in order to support the decision-making process.

Nowadays, the markets are increasingly volatile and uncertain. It means organizations must formulate effective strategies to survive and prosper (Kaplan and Norton, 1992). Driven by the need to achieve higher levels of productivity and quality in their products, processes and staff, they can use old paradigms derived from known success cases or seek to apply new concepts (paradigms) which are more adapted to current requirements in terms of cost, quality and responsiveness. Therefore, the companies are searching for different alternatives to improve the critical business processes in a way that they can meet the increasing demand and be more flexible, have greater delivery precision and lower production times.

If the collaboration strategy is intended to reduce uncertainty and increase the competitiveness of the organizations involved, then would it be advisable to use the performance assessment to support decision-makers in effectively managing this new environment? For this purpose, is there an appropriate evaluation system able to help them achieve the objectives that motivated the CN creation?

In order to face this challenge, companies need to know that strong interaction among all participants in the business chain is a fundamental requirement that will decisively contribute to their sustained competitiveness. In order to assess whether the goals outlined in the CN strategic planning will achieve the desired outcomes, there must be ways of measuring and monitoring the performance of the intra- and inter-organizational processes during the CN life-cycle. Therefore, it is important for the participants to preventively check whether it is worth staying in the CN or if it is time to leave.

Problems with inter-organizational alignment can certainly disrupt the objectives and targets set and agreed among partners. The alignment is relevant and essential to the success of the collaborative network, it is a pre-requirement for a successfully co-working (Abreu, Macedo and Camarinha-Matos, 2008). Furthermore, the design, creation and implementation of a collaborative Performance Management System (PMMS) are challenges to be faced by the CN decision-makers. This system should be based on a conceptual framework that makes it possible to address functionalities that enable performance measurement and management, and the alignment of inter-organizational processes. It should always observe whether there is an effective alignment between the results of inter-organizational processes and the performance targets established by the CN.

Since the alignment is an important requirement, is it possible to measure or even predict the degree of alignment in collaborative networks? Would this measurement help decision-makers in providing effective solutions to improve the performance of the CN?

According to Evans, Roth and Sturm (2004), a performance measurement system (PMS) can provide instances of performance and simultaneously lead to the alignment of CN participants. They believe the inter-organizational performance must be continuously improved and participants must align their goals and targets. Therefore, managers should be very careful to avoid making wrong decisions in the formulation of collaboration strategies.

In addition, it would be interesting to develop methods for measuring alignment in collaborative networks in order to support performance evaluation of inter-organizational processes. The intention is to help CN decision-makers achieve the strategic objectives that motivated the formation of CN, as well as ensure that this information can be used when the new networks are formed.

1.2 Objectives and Research Questions

In order to understand the problem-situations in the previously outlined business management, methodological issues were addressed to guide this research then some research questions were established. Thus, this task has four main objectives in providing consistent information and knowledge on the subjects addressed in this thesis:

- Understanding the benefits of organizations acting in collaborative networks and the factors that may guide them to improve the inter-organizational performance and alignment.
- Studying issues related to performance management in collaborative networks and the main aspects of the inter-organizational alignment.
- Observing the functionalities of current performance management systems used for collaborative networks, the approaches and tools used for performance measurement and see how they deal with the alignment of inter-organizational processes.
- Conceptualizing the alignment and developing alignment measurement methods related to inter-organizational processes of collaborative networks which can be tested and validated in order to become a management tool for real-life situations.

Furthermore, some research questions should be answered in order to guide this research along a scientific line that is sufficiently robust to generate effective results regarding the main objectives and contributions for the collaborative network subject. Therefore, a set of specific questions are directed towards achieving the abovementioned objectives being described as follows:

Question 1: How to assess performance in collaborative networks, and what network typologies, measures and performance management models must be considered?

Question 2: How to achieve alignment between participants of a collaborative network?

Question 3: How to quantify the inter-organizational alignment in a collaborative network?

In fact, these questions aim to deal with performance measurement and alignment enabling the development of alignment measurement methods for performance management in collaborative networks. Consequently, such questions are intended to cover research gaps and doubts with regard to the benefits related to the increasing competitiveness of organizations in a collaborative network.

In conclusion, the efforts that must be made to find appropriate answers to these questions should include a state-of-the-art review on the topics discussed herein. The principles and methods that can be used must also be explored to carry out practical applications enabling their analysis and discussion.

1.3 Research Methodology

One of the main concerns that were taken into account herein was to use a consistent methodology to guide this research in order to understand a specific problem-situation in business and thus generate solutions that can mitigate or solve it. Therefore, it has been a major challenge defining the research methodology for the investigated problem. This is relevant to correctly answer the research questions presented in the previous section.

1.3.1 Research methodology approaches

Research means, quite simply, to seek answers to the proposed questions (Silva and Menezes, 2001). This definition is corroborated by Gil (1999) who states that research, in not such a brief form, is "*a formal and systematic development of the scientific method. The primary goal of research is to find answers to problems through the use of scientific procedures*". These definitions propose the use of research methods and a systematic approach to answer the research questions.

Furthermore, there are other definitions that can more accurately explain what research means. According to Minayo (1993), research can be defined as *"the basic activity of science in their quest and discovery of reality. It is an attitude and a theoretical practice of constantly seeking to define a process inherently unfinished and permanent. It is an activity of successive approximation of reality that never runs out, making a particular combination of theory and data"*. It introduces the concept of processes to guide the inquiry, observation and reporting.

Seeking a more objective view, research is also defined by Parra and Almeida (2000) as *"the study should add something to what we already know about the issues and be a useful source of research, providing information to verify and challenge the hypothesis presented with a view to its continuation"*. This definition is related to a deductive approach. Moreover, if it is seen as a tool to investigate problem-situations in business management, as observed by Whitehead and McNiff (2006), research is defined *"such as shopping. Research however is purposeful investigation, which involves gathering data and generating evidence in relation to articulated standards of judgment, in order to test an emergent theory"*. This definition is regarding to an inductive approach.

According to Silva and Menezes (2001) it is advisable to classify research strategies according to the following two points-of-view.

How to address the problem - Focusing on quantifying numbers in order to translate the opinions and information observed to classify and analyze them, using resources and statistical techniques, such as <u>quantitative</u> research. Otherwise, the research can be seen as <u>qualitative,</u> when one considers there is a dynamic relationship between the real-life objectivity and the subjectivity of the real-life situation, in reference to the problem identified which cannot be translated into numbers and does not require methods and statistical techniques. Thus, the researcher is the key element to collecting the data directly in the natural environment in order to interpret the phenomena and provide the assignment of meanings. It is descriptive because researchers often analyze their data inductively;

How to determine the research objectives - It can also be classified into one or more of the following types, according to the specific characteristics of the problem:

- As exploratory research, it aims to provide for greater familiarity with the problem to make it explicit or build hypotheses. It involves a literature review, interviews with practitioners in the research problem, and analysis of examples that encourages understanding. It generally takes the Bibliographic Research form and Case Study.
- As descriptive research, it aims to describe the characteristics of a given population or phenomenon, or establish relations between variables. It involves the use of data collection standard techniques such as Survey and Systematic Observation, but it usually takes the Survey form.
- As explanatory research, it aims to identify the factors that determine or contribute to the phenomena occurrence, advances in knowledge of reality because it explains the reason or "why" of things. In the natural sciences uses of experimental method, and uses the observational method in the social sciences. It generally takes the Investigation and Experimental Research expost-facto form.

According to Gil (1999), scientific research is considered exploratory when it comes to conducting research in literature, interviews with stakeholders or other interested parties in the phenomenon under study, and analysis of case studies that promotes understanding of the phenomenon. This author considers an inductive approach stating that, *"this type of study is to provide a greater understanding for the researcher on the subject, so that it can make more precise problems, form hypotheses that can be searched for further studies"*.

Yin (1994) argues that many research strategies can be applied, such as case studies, surveys, history and experiments, but the "*more appropriated view of these different strategies is a pluralist one*". This author proposes that a case study can be used for all three purposes and so, there may be exploratory, descriptive and explanatory case studies. This method is still an appropriate form of social science inquiry that becomes appropriate when the phenomenon under investigation is not easily distinguishable from its context, including the situation of inter-organizational partnerships (Yin *et al.*, 1987), as investigated in this research.

Therefore, the research presented here can be considered as quantitative research, focusing on both exploratory and descriptive, aiming to introduce new knowledge through the integration of concepts and reality.

The conceptualization of this research is directed to hold a discussion about a little-known theme, suitable for academic and practical applications, using case studies covering multiple contextual conditions. Multiple sources of evidence are required to understand and properly describe the problem, and also find the theoretical concepts needed to study the phenomenon. In this thesis an action research is also used because it is applied in real-life settings and was developed through a case study method (Silva and Menezes, 2001), and it seeks to intervene in further applications proposing practical techniques and good practices in the issues covered. Using case studies, researchers hope to gain an in-depth understanding of situations and meaning for those involved in order to introduce improvements and solutions to the problem-situations observed (Hancock and Algozzine, 2006). An analysis of the problem is presented in Section 1.3.2 including requirements to verify and confirm the case study used as the research method.

In addition, a research can be conducted using the approaches of inductive and deductive reasoning that has different meanings regarding their adoption in distinct types of research processes. Although these approaches are being widely used in learning and teaching, they can also be applied in order to understand how to start the research cycle. Thus, the research is conducted not only in accordance with the assumptions and observations of the phenomena, but also in accordance with the theories used.

In the inductive reasoning, the individual writes down a series of observations of one or more cases that are classified into one concept or generalization. Only after observing and analyzing them, one can reach the abstraction, they can move from specific observations to broader generalizations and theories that can constitute a specific pattern. Inductive reasoning makes it possible to formulate some tentative hypotheses and then obtain theories that can describe the phenomena observed. However, the opposite occurs in deductive thinking. Inductive reasoning (Figure 1) begins with specific observations and measurements, detecting patterns and regularities, formulating some tentative hypotheses to be tested and analyzed, and finally, some general conclusions or theories are developed (Trochim, 2006).

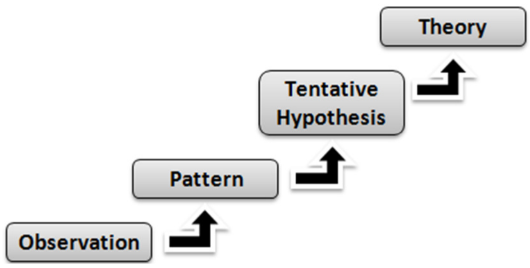

Figure 1. Inductive approach (Trochim, 2006)

Otherwise, the deductive reasoning (Figure 2), begins with theory and then formulates a hypothesis to be explored. Rips (Adler and Rips, 2008) presents two main ideas in the human nature of deductive reasoning. It merges to idealize theories developed from the more general (generalization) to a more specific observation. The first idea states that deductive reasoning involves the ability of making assumptions, even temporarily, in order to trace their consequences on the phenomena. There is a tendency to take these propositions to focus efforts on exploring the next steps. A second idea includes interim targets to prove the assumptions and to obtain conclusions that can be improved and then validated in order to confirm those assumptions once explored.

With regard to using this approach, after the assumptions are accurately defined, as well as the interim targets, Trochim (2006) argues that

> *"we might begin with thinking up a theory about our topic of interest. We then narrow that down into more specific hypotheses that we can test. We narrow down even further when we collect observations to address the hypotheses. This ultimately leads us to be able to test the hypotheses with specific data - a confirmation (or not) of our original theories".*

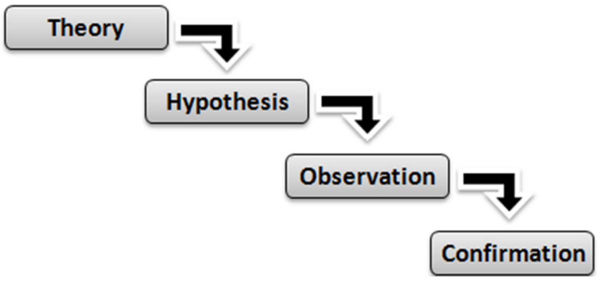

Figure 2. Deductive approach (Trochim, 2006)

According to Burney (2008), researchers are generally guided by the deductive approach to drive the actions of scientific research and technology development. Therefore, the deductive research approach is characterized from the more general to the more specific works. Sometimes this is informally called a "top-down" approach, and the conclusion is obviously followed by the premises (available facts).

In fact, with this approach, concepts are explored before the phenomena have been highlighted. In short, it looks for a theory and exploits it in order to confirm its assumptions. However, the proposal of this research contradicts this last approach since the phenomena are previously named (problem-situation) and then there is a move from specific observations to broader developments. Thus, these two approaches are related, as cited by Hill and Hill (2005), "*the data already known performs, through the inductive process, a theory which, through the deductive process, provides new data*". Thereby, an inductive-deductive approach is applied in this thesis.

Furthermore, when a reasoning approach requires an inductive method to establish hypothesis related to the comprehension of phenomena, the Case Study Research (CSR) is a qualitative research method to examine contemporary real-life situations and provide the foundations for the application of ideas and extension of methods.

Robert K. Yin (2003) defines the CSR method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used. If it is applied carefully and focuses on crafted studies of real-life situations, the research can be successful.

According to Gerring (2007), when referring to a "case study" this might mean that:

- "*the method is qualitative, small N;*
- *research is holistic and details a phenomenon;*
- *it is a particular type of evidence (ethnographic, clinical, not experimental, not based on surveys, participant observation, the process of tracking, historical, textual and field research);*
- *the method of evidence is naturalist (a "real-life context");*
- *the topic is diffuse (case and context are difficult to distinguish);*
- *employs triangulation (multiple sources of evidence);*
- *research aims to investigate the properties of a single observation;*
- *research aims to investigate the properties of a phenomenon, instance or example.*"

In order to explain the case study method appropriately, Gerring (2007) gave the following interesting example:

> *"There are two ways to learn how to build a house. One might study the construction of many houses - perhaps a large subdivision or even hundreds of thousands of houses. Or one might study the construction of a particular house. The first approach is a cross-case method. The second is a within-case or case study method. While both are concerned with the same general subject - the building of houses - they follow different paths to this goal. The same could be said about social research. Researchers may choose to observe lots of cases superficially, or a few cases more intensively. (They may of course do both, as recommended in this book. But there are usually trade-offs involved in this methodological choice)".*

It means that an important step must be done in order to establish the research method as well as the type of evidence, real-life context, single or multiple sources, data-collection technique, validation process and control over the behavioral events.

Dull and Ark (2008) separate the Case Study Research into two types: single and comparative case study. The first one is used in case of an instance to be sufficient to achieve the research objective and the other when two or more cases are necessary. They distinguish "case study" from "experiment" arguing that while in the first case there is no manipulation of the object of research or its environment, which occurs in the second. These authors state that the CSR method is basically an inquiry of only one single instance (the case), where the object of study and its environment are not manipulated (real-life context). Moreover, these two very distinct characteristics of the CSR method and the authors' experience in case studies led them to create their definition of case study. They define it as *"a case study is a study in which (a) one case (single case study) or a small number of cases (comparative case study) in their real life context are selected, and (b) scores obtained from these cases are analyzed in a qualitative manner"*.

The CSR method can be viewed as a research strategy and can be used in several research situations such as organizational and management studies, public administration, city and regional planning, but it frequently guides papers and theses. It is a different approach from the traditional focus on data collection or fieldwork directed to design, analysis and reporting issues.

In order to adequately explain this approach, Yin (2003) refers the main concerns that must be considered to plan research. He argues that the challenges to be faced are basically:

- how to define the case study,
- how to determine the relevant data to be collected, and
- what should be done with the data, once collected.

The first point will help researchers plan their case study and conduct their research more successfully. Therefore, according to Yin (2009), the success of this research method depends on of three basic conditions:

- The type of research question.
- The control the researcher has over actual behavioral events.
- The focus on contemporary as opposed to historical phenomena.

In this context, Yin (1994) claims this method is preferred when:

- Questions using "how" and "why" are imposed.
- The investigator has little control over events.
- The focus is on a contemporary phenomenon with a real-life context.

Furthermore, Hancock and Algozzine (2006) argue that there are seven questions to be answered in a case study to provide a consistent form that uses this scientific approach during research, as follows:

1. what we want to study (the research question)
2. how we want to study it (the design)
3. who we want to study (the "case," "cases," or "sample")
4. how best to acquire information (the data-collection techniques)
5. how best to analyze or interpret the information that we acquire (the data analysis)
6. how and with whom to share our findings (the dissemination process)
7. how to confirm our findings (the verification process)

These questions are appropriate to accomplish the planning of the research. However, it seems to be more important having the discipline to act on research than being able to determine the steps of a routine. Indeed, the questions and routines used must be understood, but in each research project, the authors should plan systematic methodologies and make it more appropriate for each case studied.

The CSR method basically comprises the following phases: design, data collection, analysis and reporting. However, this strategy can also deal with surveys and exploratory and explanatory research. Despite this, the exploratory objective is more present in the case studies, thus Yin (2003) argues that case studies can also be descriptive or explanatory. Choosing one or more of those strategies is the challenge that requires appropriate planning activities for each particular situation in a case study.

A systematic for organizing the research successfully, using the CSR method, is developed and proposed by Yin (2009).

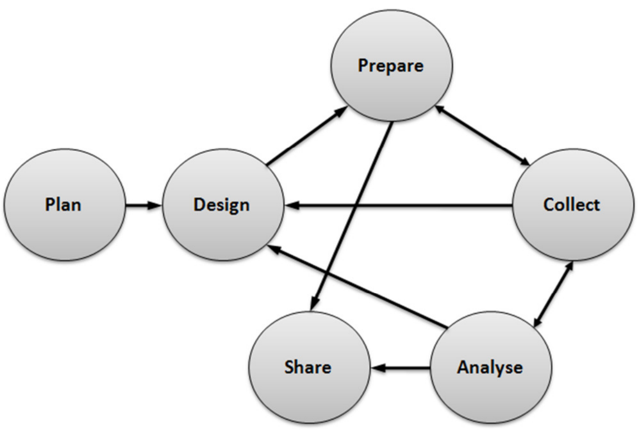

Figure 3. The interactive process in the CSR method (Yin, 2009)

Therefore, the CSR method consists of the following six steps:

1. Determine and define the research questions (PLAN)
2. Select the cases and determine daa gathering and analysis techniques (DESIGN)
3. Prepare to collect the data (PREPARE)
4. Collect data in the field (COLLECT)
5. Evaluate and analyze the data (ANALYSE)
6. Prepare the report (SHARE)

This sequence then ensures effective research. The researchers begin planning the work and focusing on the design for the case study. At this point, they identify and define the case(s) study and establish the study questions, its propositions (if there are any), the units of analysis, the logic linking data to propositions and the criteria for interpreting the findings (Yin, 2009).

The next step is preparing to collect the case study evidence. It is mandatory that the researcher has extensive knowledge in the studied area, or is prepared for it. Another important aspect is to deal with the case in the respective study to observe its characteristics, the creation of conditions to improve the reliability of case studies by developing protocols in order to conduct simulations and pilot cases (Yin, 2009).

Indeed, using data collection techniques to collect evidence is necessary to choose the most adequate source. Yin (2009) refers to six: documentation, archival records, interviews, direct observation, participant-observation and physical artifacts.

The researcher has to find answers to the analysis of evidence and possible alternatives. This includes several actions such as: examining, categorizing, tabulating, testing, or rearranging the evidence in order to empirically draw conclusions (Yin, 2009). This analysis is the key to increasing the accuracy of research outcomes.

Finally, it is necessary to compose the evidences and the results from the techniques used in the analysis of case studies. Summarizing and interpreting the information obtained will be possible to determine the information-based themes that address the research questions since this is a critical task of a case study researcher (Hancock and Algozzine, 2006).

Therefore, in order to obtain the necessary information about the phenomenon studied in the research, it is important to use some methodology to deal with the problem-situation that the researcher aims to understand and suggest hypotheses for their resolution. The Soft Systems Methodology (SSM) is a systematic form that uses a structured approach that basically intends to understand a problem, build a conceptual model and find feasible and desirable changes and implement them. The SSM is mostly used to respond to symptoms when the underlying problem is not yet understood (Eva, 2004).

According to Erdmann, Graelm and Graelm (2003), a methodology is frequently confused with method or technique when a situation must be described or solved. Methods describe what to do and their results are expectations previously defined. Methodologies lead to structured approaches that require considerations and analyses. It helps decision-makers improve their understanding of problems in the real-world by comparing people's perception to constructed theoretical models. Ferrari *et al*. (2001) explain that SSM is *"a methodology that tries to analyze, under a systematic focus, a real organizational problem, extracting from this analysis actions for the improvement of the real world"*.

To better understand the complexities that involve the current organizations, there is a change in the traditional systemic approach or "hard-systems", in which the control of physical systems of production of predefined objectives prevails, by a "soft-systems" approach that emphasizes the characteristic human relations found in the complex systems of human beings. It has some features (Table 1) that may be compared (Pinheiro, 2000).

Table 1. Hard- and soft-systems features

Hard-systems	Soft-systems
Focus on physical systems of production (and simpler objects) and on the control of the entrances aiming at to optimize exits.	Focus on the interactions of complex systems livings creature (above all human) and on the social construction of the decisions and action.
Belief in a unique and objective reality (to which science has privileged access).	It is given credit multiple realities (each individual interprets it differently).
Emphasis in the identification of the problem, in the solution technique and in the product to be obtained.	Emphasis in the process of formularization of the problems and its diverse interpretations.
Searching for an optimal solution for the problem identified.	The intention is to construct some alternative satisfactory solutions.
Only maximize an objective (e.g., economic and technical development).	Harmonization of several objectives (e.g., economic, social and environmental development).
Conflicts in general are ignored.	Consideration and handling of conflicts.
The local knowledge is valued, but the superiority of the scientific issues prevails.	All the knowledge forms are equally valid
Communication as transmission of knowledge and information.	Communication as dialogue. Knowledge is socially constructed.
Positive approach.	Constructive approach.
Multi-discipline.	Inter-discipline

The SSM is a learning process methodology which applies this concept to the entire entity as a whole. Ferrari *et al*. (2001) point out that, "*systematic practices are applications of systemic thought to start and to guide the actions of the real world*". In this context it is necessary to find an adequate systematic.

According to Checkland (1990), the SSM it is divided into seven distinct stages. This conceptualization, corroborated by Couprie, Goodbrand, Li and Zhu (1997), contains a reasonable explanation for a scientific application. These stages are as follows (Figure 4):

1 – problem-situation unstructured - It implies defining a problem that must be analyzed or reviewed. The problem is structured and the key players and processes are defined in order to initiate the analysis or review.

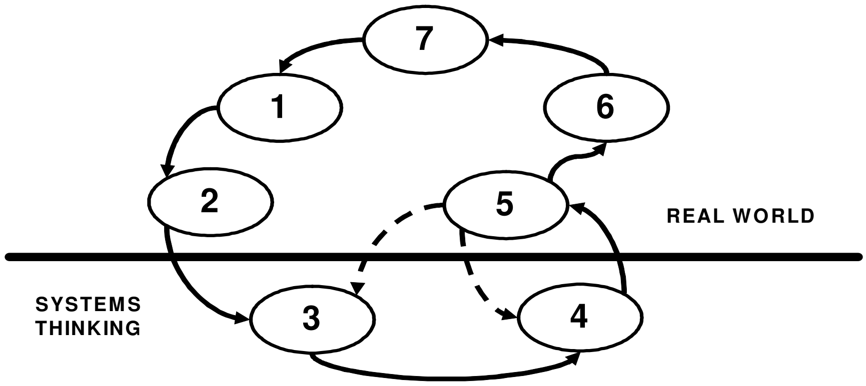

Figure 4. The seven-stage Soft Systems Methodology model

2 – problem-situation expressed - It aims to collect and sort information in order to provide an accurate description of the problem. It looks for the organizational structure and processes, and specific issues about management and hardware technologies using techniques that can illustrate the problem-situation and select the information to support the analysis, using rich pictures for instance.

3 - naming relevant systems – It aims to contribute in the construction of conceptual models.

a) Root definitions - It is the formulation of names for relevant systems that makes it possible to build a model based on these names. It aims to express the central purpose of the chosen activity system. It is necessary to think in a simpler way in order to build the system models.

b) CATWOE - Root definitions are written as sentences that are intended to elaborate some transformation. There are six elements that compose the formulated root definition, which are summed up in the mnemonic CATWOE (Customer, Actor, Transformation process, Weltanschauung - the German expression for world view, Owner, Environmental constraints) in order to understand the analysis of root definition sentences using these elements.

4 - conceptual models - It can be seen as a "human activity model that strictly conforms to the root definition using the minimum set of activities" that can be drawn by applying system thinking. A formal system model acts as a guideline to check the conceptual model once drawn.

5 - comparing conceptual models with reality - Back to the real world, thinking about the adopted line. The conceptual models (stage 4) must be compared to real world expressions (stage 2).

6 - implementing 'feasible and desirable' developments or/and changes - It must be identified and discussed to be put in action in the next stage. This comparison of the stages is intended to generate a discussion about possible solutions which might be implemented for the perceived problem.

7 - action to improve the problem - Then, recommendations are proposed to promote actions in order to resolve the problem and define how to implement the solutions proposed in step 6.

According to Bergvall-Kareborn, Mirijandotter and Basden (2004), the CATWOE technique brings together a combination of intuition, experience and willingness to deal with formal systems thinking. Indeed, the main objective is to properly understand the meaning of CATWOE elements and their inter-relationship in order to improve the analysis. These elements are: customer, actor, transformation process, weltanschauung (world view), owner and environmental constraint.

1.3.2 Research outline

Thereby, this research used case studies to find feasible and appropriated tools for measuring alignment in collaborative networks. Moreover, the methods were applied in a real-life environment through exploratory case studies. This strategy was applied in order to conduct research on a problem that has not yet been explored, considering the gaps found in the collaborative network subjects treated in this research.

To verify which research method is more appropriate for the case study research (CSR), the important conditions previously stated are observed in Table 2:

Table 2. Relevant situations for different research methods (Yin, 2009)

Method	Research Question	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	How, Why?	Yes	Yes
Survey	Who, What, Where, How many, How much?	No	Yes
Archival Analysis	Who, What, Where, How many, How much?	No	Yes / No
History	How, Why?	No	No
Case Study	How, Why?	No	Yes

With the aim of finding a better research method to be used in this research, the methods should be related with the research questions. Therefore, the answers to the research questions presented earlier can provide information on the most appropriate strategy that will achieve the research objectives. Observing the Table 3 it is possible to conclude that a case study is an appropriate method to guide this research.

Table 3. Answers related to the method validation

Questions	Answers
Form of Research Questions	How, Why?
Requires Control of Behavioral Events?	No
Focuses on Contemporary Events?	Yes

With regard to Yin's proposals (1994, 2009), it is possible to determine the conditions needed to conduct the research, and the path to effectively perform the research requires that:

- Questions such as "why develop a PMMS in collaborative networks" and "how to develop such a system" are raised to face the defined problem;
- There is a low level of control over events that provide information about the observed phenomena, for instance it is lower than in the event of experimental research. Thus, in this research, partnerships with existing CNs and groups of companies that desire to form a new collaborative network were built;
- The research focuses on the phenomena of contemporary business. This study sought to investigate the current stage of this subject, and in which direction it is being developed.

Since this method is used, it then makes it possible to plan the actions that will guide the research. The method applies the Hancock and Algozzine's proposals (2006) to answer the questions raised by these authors when the method used is the CSR method. This is a useful check-list, which provides a better understanding of how to conduct the research for a case study. Therefore, it decisively contributes to the research planning. The answers are as follows (Table 4).

Table 4. CSR Questions (Hancock and Algozzine, 2006)

CSR Questions	Thesis work answers
What we want to study (the research question)?	The necessary concepts and approaches for the development of a performance management system for collaborative networks of SME regarding the measurement of the inter-organizational alignment.
How we want to study it (the design)	Studying the main principles and methods that are relevant to the specific field, develop a performance management framework proposal, test practical applications in real-life environments, test and validate methods of measuring alignment, discuss and verify the feasibility of the outcomes.
Who we want to study (the "case," "cases," or "sample")	Studying small supply chain, commercial retail and wholesale and medium-sized industrial companies.
How best to acquire the information (the data-collection techniques)	Using papers review, fieldwork, projects reviews, questionnaires and interviews, direct observation, participant-observation.
How best to analyze or interpret the information that we acquire (the data analysis)	Through cross-comparison of results with theory, analysis of results of practical applications and expert opinions.
How and with whom to share our findings (the dissemination process)	Through the paper submissions in conferences and international journals in the areas concerned, as well as other forms of dissemination and exploitation.
How to confirm our findings (the verification process)	Through the results of the case studies conducted inducing a formal discussion confronting the current knowledge assumptions about the theme studied.

In fact, this research aims to validate the research questions using the concepts of the CSR method (Yin, 2003), considering that the characteristics of this research project are already well framed for this approach.

Moreover, this planning can be adjusted to complex systems derived from multiple cases and with different specificities. In fact, the CSR method includes planning for multiple case studies (Figure 5), as explained by Gerring (2007). This author states that a case study is an intensive study of a single case in which the objective of this study is - at least in part - to explore a larger class of cases (the population), allowing to incorporate several cases (multiple-case studies).

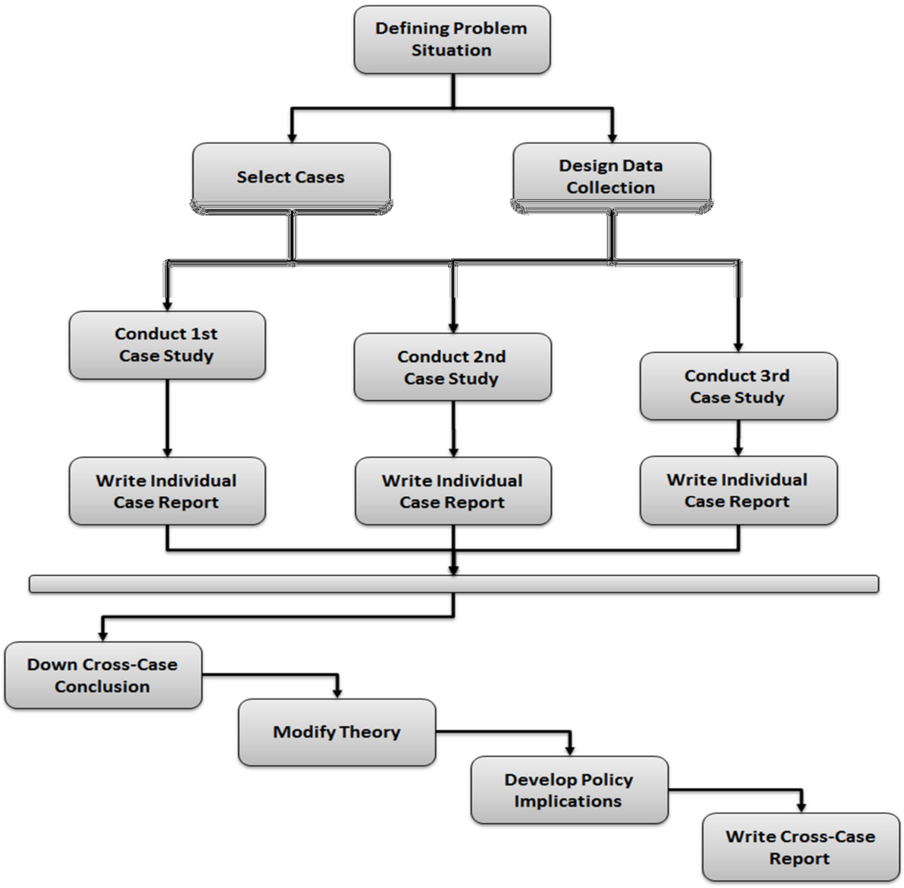

Figure 5. Multiple-case study diagram (adapted from Yin, 2009)

To help answer the research questions outlined in the previous section, Table 5 presents the respective investigation strategies related to the research questions.

Table 5. The research strategies proposed to be applied

Research questions	Research strategies
1 and 2	Explanatory research
2 and 3	Exploratory research

Different kind of actions to collect data supported the research in each investigation strategy, including the literature survey method. They are presented as follows (Table 6).

Table 6. Data collection for research

Investigation strategies	Data collection
Literature survey	Review papers, practitioner's magazines, research project reports, academic theses and dissertations
Explanatory research	Review papers, research project reports, questionnaires and interviews
Exploratory research	Fieldwork, direct observation, participant-observation.

In fact, this research focuses on the development of a method for measuring the alignment between the results of inter-organizational processes and the performance targets established by the CN. Thus, the ideal balance between the objectives and research questions must to be achieved. According to Busi and Bititci (2006), the priorities and a guide to developing a collaborative PMMS must be defined as follows:

- Understanding the structure and dynamics of collaborative enterprises;
- Understanding extended processes' structures and operations;
- Developing a structured methodology to design the PMS;
- Understanding what to measure (what are the differences between single enterprise and collaborative enterprise measures?);
- Developing a structured management process to use measurements to support decision-makers, set goals, allocate resources and inform management;
- Understanding the difference between leading and lagging indicators and proactive and reactive management;
- Specification of integrated/interoperable collaborative computing technologies.

These requirements are applied in this research, particularly in response to the third research question (see page 3), and also involve the following activities based on a PDCA - Plan, Do, Check, Act - model (Campos, 1992):

- Planning objectives and methods to be applied, search potentially feasible real-life situations, and look for partners that want to be included in the research;
- Creating a conceptual framework for performance management, improving and developing it during the practical applications;
- Checking if the framework developed is consistent with the theoretical rules and real-life situations investigated in order to enable the application of the alignment measurement method.
- Acting on the results in order to demonstrate the reliability of the alignment measurement method developed.

Therefore, to perform tasks with these characteristics, the performance measurement application scenario must consider business environments that are appropriate to test the performance management system. Indeed, previous academic or professional relationships with the researcher or their host educational institution can facilitate the research and contribute to a more efficient planning of the research project.

In this context, approaches and techniques to estimate performance values are presented in Chapter 3. It is a contribution to demonstrate new approaches and tools that can be used to assist CN managers who need to predict performance outcomes. This is the great contribution introduced by this thesis in order to orient and support CN decision-making during the design and operation phases.

For this research, partners were sought from different business areas, ranging from small to medium-sized companies, in order to observe their needs then developing a PMMS and help them to implement it. The case studies were conducted in a Brazilian business environment[2], including:

- A small Brazilian retail network of independent pet shop retailers interested in achieving benefits through the joint formulation of strategies and operations. They act under an entrepreneurial project that promotes the creation of collaborative networks composed of companies acting in the same business environment.
- Medium-sized industrial companies in a Brazilian industrial group, which provides raw materials to other companies in the supply chain, whose collaborative network agreement was created to improve their own productivity and quality in their inter-organizational processes and also the quality levels of their products by monitoring nonconformities.

Therefore, there are case studies (Table 7) covering different company sizes and business environments, which provide a challenge that can greatly contribute in testing the proposal of this research.

Table 7. Collaboration Characteristics

Case Study	Main Collaboration Characteristics
Pet Shops Retailers	Small enterprise network, fully connected mesh topology, dynamic virtual organization typology.
G3 Supply Chain	Medium enterprise network, linear bus topology, supply network typology.

1.3.3 Research strategy

The planning of this thesis follows a scheme that aims to cover the main topics as well as the methods and tools used in the research. The aim is to dictate the actions that will be undertaken during the research project. It comprises steps that must be performed in order

[2] The research was conducted by the author of this thesis acting as a consultant in these business environments.

to follow a consistent line of research. Therefore, this set of steps is included in the research process flow (Figure 6) as follows:

- Designing the research project, classifying the research method, defining the research strategy, designing the research report architecture, explaining purposes and outcomes;
- Investigating and identifying the characteristics of collaborative networks, performance management and inter-organizational alignment, as well as the respective relevant definitions used in these disciplines from a literature survey;
- Searching typologies of networks suitable for use in practical applications, creating a conceptual model for a performance management system in CNs;
- Applying exploratory research in real-life situations using a collaborative PMMS based on a conceptual model specially developed for measuring the alignment between the performance outcomes inter-organizational processes and the performance targets established for the CN;
- Developing alignment measurement methods to be tested in real-life situations;
- Writing the final research report.

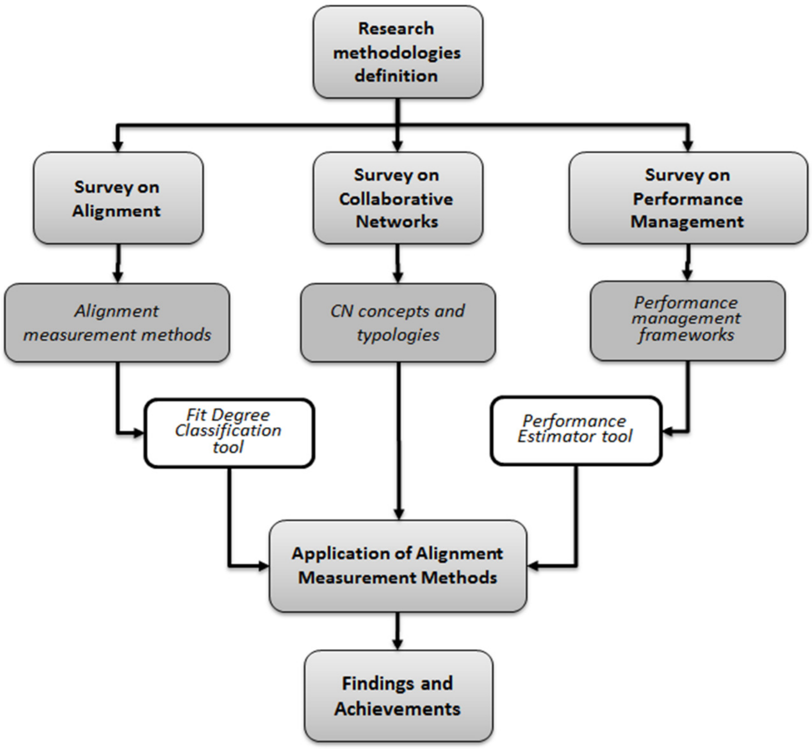

Figure 6. Research process flow

Supporting this process it is possible to observe in Figure 7 the development phases applied in this research, such as: the initial literature review, the application of exploratory research, an improvement phase for the proposals presented and a consolidation phase of the results dissemination.

1 STARTING PHASE

GOAL	Developing a performance management system to reduce uncertainty and increase competitiveness in CNs
THEORY	Collaborative networks; performance measurement and management
METHODS	Survey; Case Study Research; Soft System Methodology (SSM)
OUTPUT	CNPMS framework design

2 APPLICATION PHASE

GOAL	Validating the implementation of the CNPMS framework;
THEORY	Inter-organizational alignment;
METHODS	Questionnarie method; Euclidian distance method
OUTPUT	First application case (Pet Shop Retailers)

3 IMPROVEMENTS PHASE

GOAL	Proposing alignment measurement approaches and methods; CNPMS Manager application software development
THEORY	Performance prediction, neural networks, Kalman filter
METHODS	Estimator tool; DEA application tool
OUTPUT	Second application case (G3 Supply Network)

4 RESEARCH CONTRIBUTION PHASE

GOAL	Improving the alignment evaluation methods and creating a method for alignment prediction in collaborative networks
THEORY	Alignment prediction, Fuzzy Logic
METHODS	Classification tools
OUTPUT	Fit Degree as a tool for alignment prediction

Figure 7. Research development phases

Therefore, these thesis development phases are described as follows.

Starting Phase – In this phase the main concern was to develop a performance management framework to support decision-makers to perform a PMMS. The assessment of performance to manage a CN is related to the needs to improve competitiveness. At this moment, the relevance of the alignment of inter-organizational processes is still diffuse, but the performance measurement and management were considered crucial to manage CNs. The research method applied was based on literature reviews and research of explanatory case studies. Therefore, a conceptual framework to support the performance management in collaborative networks was designed and transformed into a proposal to be applied in real-life environments.

Application Phase - The Collaborative Network Performance Management System (CNPMS) model was designed as a conceptual framework and the PMMS implementation methodology was then applied in a collaborative network in order to evaluate and improve this model. In this context, the criteria, methods and tools that can be used to evaluate performance are discussed conceptually. However, this performance framework aims to help design and implement a PMMS that is more suitable for applications in real-life. In the collaborative network context, the specificities of the life-cycle phases of the CN must be addressed as well as the functionalities required for planning performance management and the real-time performance measurement. Moreover, the evaluation of performance over the life-cycle must be addressed in particular in order to save the performance data for future collaboration opportunities (e.g., data repository).

A questionnaire was simultaneously developed which was answered by the CEOs of participating companies to determine their perception on the degree of alignment of the CN at the moment of agreement and thereafter in the operation time. Following this application, which also included the assessment requirements for measuring the degree of alignment, an attempt was made to improve the alignment measurement.

The research method applied was based on exploratory case study research. Alignment measurement methods were tested using an appropriate questionnaire answered by the CEO's. Measurement techniques were used to determine a qualitative measure for the degree of alignment by using the Euclidian Distance method and classification criteria.

Thereafter, another approach was applied using a performance benchmarking analysis method. This approach consists of determining the benchmark of the performance between the partners.

Improvements Phase - In this phase a new interesting paradigm was adopted, the performance prediction paradigm, which seemed to be useful in decreasing the reaction time for process improvements. This approach then began to guide the research efforts towards developing an estimator tool which led to an application case for testing this tool. The so-called Performance Value Estimator (PVE) tool enhances the capacity of alignment measurement methods as it suggests ways to support decision-makers and help them manage the CN's performance effectively, visualizing the future behavior or performance of inter-organizational processes.

The research method applied was based on action research in which the PVE tool was developed and applied in a supply chain network case and preliminary conclusions were then drawn relating to their capacity to support the predictive performance management in collaborative networks.

Research Contributions Phase - After these application cases, the methods of assessing the degree of alignment proved to be somewhat subjective. This forced this research to look for other innovative methods and tools to assess the alignment of the CN. This meant it was possible to instantiate the degree of alignment using the KPIs that have already been collected and monitored to establish reference measures for measuring alignment. The research method was based on action research to develop the method of determining an alignment metric called Fit Degree, which was applied. Furthermore, these methods and tools were applied in CNs and preliminary conclusions were reached relating to their ability not only to predict the performance of processes but also to predict the future alignment of the CN. Fuzzy logic was applied to classify entities regarding alignment between the results of inter-organizational processes and the performance targets established by the CN

1.4 Structure of Dissertation

This thesis is composed of six chapters that include the concepts and tools presented and used to deal with the proposed theme (Table 8). An appropriate sequence was established to present the main topics of this study including an explanation of the phenomenon under study. Moreover, the visualization of the problem and the desired outcomes, the research form definition, the presentation of the proposal to build a model that addresses the problem and the discussion of practical results making it possible to apply the proposal were addressed as well. Finally, the conclusions and ideas for further work are presented.

In Chapter 1, the research approaches and methodologies are included that refer to the methods used to undertake this research. It contains a complete and guided vision about the Case Study Research method in order to define and guide the research. The Soft Systems Methodology is also presented to support a systematic implementation of the performance management framework held in practical applications.

In Chapter 2, the concepts of collaborative networks and performance management are defined on the basis of current definitions by contemporary authors. In order to define and lay grounds for the proposals that were made, these fields were addressed. The main findings guided decisions that were adopted in the development of the research.

Chapter 3 conceptualizes alignment in the context of performance management and addresses the relevance of alignment measurement when the objective is to measure performance of CNs. Research gaps are discussed and addressed to deal with the performance of inter-organizational processes that occur in collaborative networks. Requirements for measuring alignment are established and then some alignment measurement approaches are proposed taking into account the functional requirements, as well as the alignment factors, necessary to manage performance in CNs with different typologies and structures.

In Chapter 4, the alignment prediction paradigm is introduced which presents an innovative approach to measuring performance in collaborative networks using key alignment indicators for calculating the future degree of alignment.

Chapter 5 presents the application cases that were developed to validate the conceptual framework (CNPMS) for implementing a PMMS, as well as the alignment measurement methods for assessing performance in CNs. Thus, two cases were studied in collaborative networks of small and medium-sized Brazilian companies.

Chapter 6 focuses on the outcomes of the scientific research, translating the information obtained from the multiple-case studies that provided findings. Furthermore, it refers to the conceptual findings obtained in this research and suggests some situations that need to be further investigated.

Therefore, a sequence of issues was defined in order to construct this thesis. Thus, these steps are: introduction, research methods, the state-of-the-art of collaborative networks and performance management, alignment definition, application cases and conclusions. Complementing this, there are also bibliography references and complementary information.

Table 8. Thesis structure

Subjects	Main Sections	Contents
Research Objectives	**Introduction**	Theme, context and relevance, problem-situations in business, objectives, research questions, research methodology, work structure and planning.
State-of-the-art on Collaborative Networks	**Collaborative Networks**	Concepts, taxonomy and network typologies, network life-cycle.
State-of-the-art on Performance	**Performance Measurement and Management**	Performance concepts, performance management frameworks, key performance indicators, performance measurement taxonomy for collaborative networks.
	Performance Forecasting and Prediction	Forecasting techniques, predictive measures, prediction tools.
	Performance Benchmarking Analysis	Benchmarking concept, Data Envelopment Analysis (DEA).
Alignment Definition	**Inter-organizational Alignment**	Alignment concepts and approaches, fit concept, trust and other alignment factors.
	Alignment Measurement approaches	Requirements for assessing alignment in CNs, alignment measurement methods.
	Performance Prediction	Presentation of the Performance Value Estimator (PVE) tool.
	Alignment Prediction	Presentation of the Fit Degree alignment prediction method.
Application Cases	**Performance Management Framework**	Performance management models, performance functionalities, performance management system implementation process, ICT support technologies, alignment factors.
	Strategic Network (small-sized enterprises network)	Application case "Pet Shop Retailers".
	Supply Chain Network (medium-sized enterprises network)	Application case "G3 Supply Network".
Analysis and Discussion	**Final Conclusions**	Results obtained in the case studies in relation to the Research Questions.
	Main Contributions and Achievements	Findings obtained in the analysis of the results and concluding remarks.
	Future Works	Suggestions for future research.
Literature Review	**References**	Presentation of literature references
Complementary Information	**Annex**	Necessary information to complete some issues presented in this thesis.

Chapter 2

Literature Review

The aim of this chapter is to present a literature review on collaborative networks and performance management outlining the state-of-the-art of these subjects. The most relevant theories and approaches have been selected to serve as a conceptual basis to guide the researcher to answer the research questions posed in the previous chapter.

2.1 Introduction

A significant survey was performed on the concepts of collaborative networks, performance management and inter-organizational alignment with the aim of supporting this research using important contemporary authors who effectively contribute to providing information and substantial knowledge on these themes.

The concepts, models, frameworks and methodologies that already exist should be adopted by adapting their features to the purpose of this research and, if it is feasible, they should be used in order to generate knowledge for applying it to real-life situations. This would improve the understanding of collaborative network management and the practices involved. Furthermore, in order to observe and explain collaboration in business environments real-life, important concepts should be studied and applied within this research scope.

In fact, the literature review aims to extract information on the issues that deal with the problem-situations investigated in this work, focusing on supporting the development of performance management systems in CNs. Therefore, the procedures used to find and develop appropriate systems must refer to how knowledge is obtained of the concepts and methodologies that should guide this research. The type of documents that were consulted to analyze the works published by several authors is the following.

Books - Although several books devoted to the topics studied were read to get different theoretical perspectives, other sources of information were used. Nevertheless, the subject ‘collaborative networks’ is less mentioned in books than the subject ‘performance measurement and management', which was written about widely. On the other hand, the subject 'strategic alignment' is not referred to sufficiently, but is now increasing, as visible in the book "Strategic Alignment Process and Decision Support System" by Shimizu, Carvalho and Laurindo (2006).

As far as the collaborative network subject is concerned, the work entitled "Collaborative Networks: Reference Modeling" (Camarinha-Matos and Afsarmanesh, 2008a) is an epistemological milestone on this subject. This literature is the result of the ECOLEAD Project, which contributed to the configuration of CN typologies and provided a theoretical foundation for collaborative networks.

Another important source is the sequence of books by Kaplan and Norton (1999, 2001, 2006), where these authors contributed significantly to the measurement and management of performance subjects through the famous framework called Balanced Scorecard System (BSC). In this context, the explanation of performance measurement and management is a relevant part of this work referred by experienced relevant authors, such as Seifert (2009), Parmenter (2010) and Neely *et al.* (2002).

In order to understand even more the research methods contemporary works are referred, such as: Yin (2005, 2009) and Checkland (1990), respectively on CSR and SSM. Complementary subjects on performance prediction, neural networks, Kalman filter and fuzzy logic were surveyed in a few books because these topics are found mainly in papers.

Scientific Publishing - The paper "Collaborative Performance Management – Present Gaps and Future Research", written by Biti and Bititci (2006), was an important contribution to this research. These authors proposed to identify gaps in current research and also to define a performance management research agenda. This paper has practical implications because it helps researchers build a knowledge base in collaborative performance management so that they can focus their research efforts on the most relevant issues in performance assessment.

Another paper that has contributed significantly to this work is "Organizational Alignment and Performance: Past, Present and Future", written by Kathuria, Joshi and Porth (2007). This work, based on a survey on organizational alignment and performance management, encouraged further study on how inter-organizational alignment influences collaborative network management regarding forms of alignment. Simultaneously, the term "fit" has been referred to for a long time in the context of strategic management (Venkatraman and Camillus, 1984) and is still today (Silveira e Souza, 2010).

Moreover, the paper entitled "Foundations for Collaborative Performance Measurement", written by Verdecho *et al.* (2009), contributed with a relevant survey on performance measurement systems (PMS), explaining what is necessary in terms of collaboration characterization and relationship variables through a comparative study of several works in this area. The aim is to identify main strengths and weaknesses to take into consideration in future research.

Of course, other interesting papers of current authors have also provided a constructive approach to collaborative performance management research and interesting reports were found in conference proceedings, which allowed the author of this thesis understanding important aspects of the subjects addressed here. These conferences annals include PRO-VE, BASYS, DET, ENEGEP, and others. The aim with these conferences, which are becoming more and more frequent, is to provide a path to exchange information and modeling propositions in order to find about new perspectives to improve the collaborative networks knowledge, as well as the research challenges.

Furthermore, publications from conferences and specific paper calls also include a large amount of papers. Therefore, many subjects related to collaborative networks are provided by the Society of Collaborative Networks (SoColNet) specifically trough the IFIP Working Conference on Virtual Enterprises. A survey on conference topics between 2005 and 2009 years showed that the academic contributions are concentrated around three main subjects: Modeling, Management and Control. Surrounding these subjects were several topics related to collaborative networks (Figure 8), such as: ontology, topology, creation-configuration, value co-creation, competencies, human & social aspects, innovation, business processes, knowledge, governance, legal aspects, Virtual Organization Breeding Environment, coordination, partners selection, decision-making, procurement, negotiation, alignment, trust, infrastructures, interoperability, risk management, continuous improvement, change management, ICT and technological support, performance measurement and management. The latter has been referred to regularly. On the other hand, the topic "Control" is not yet very significant.

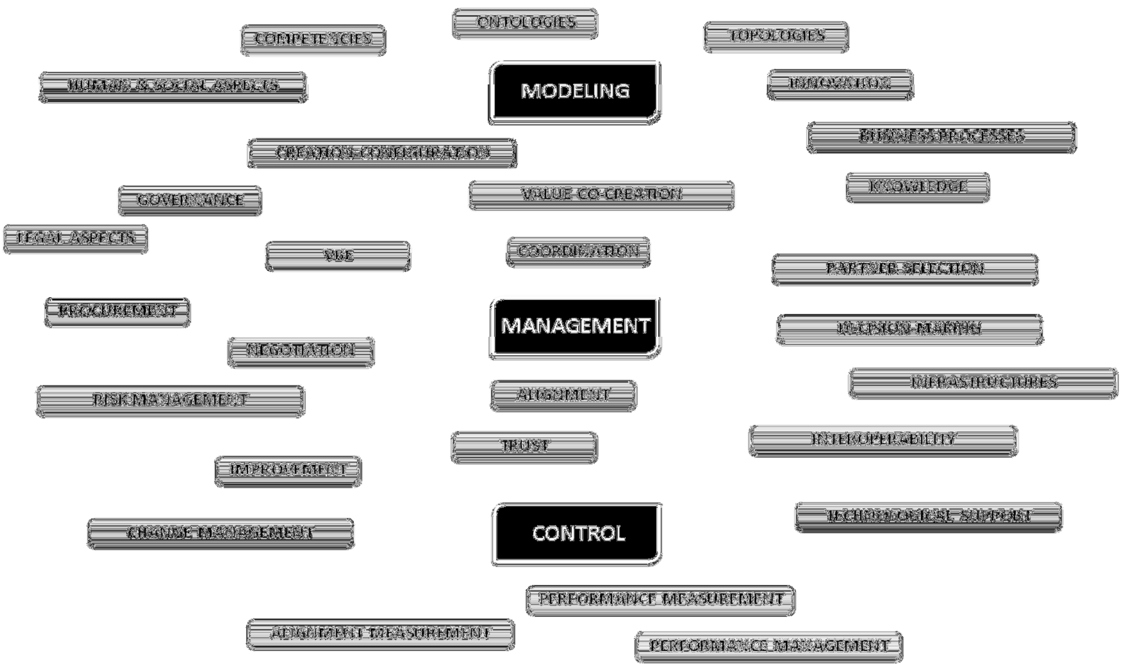

Figure 8. Collaborative Network subjects most explored in SoColNet conferences

Research Projects - It is also appropriate to refer important research projects on the “collaborative networks” subject in order to research this new business model in various specific areas. Projects on this area include: ECOLEAD (European Collaborative Networked Organisations LEADership Initiative), MOSAIC (Specific Support Action), INTEROP (Interoperability Research for Networked Enterprises Applications and Software), ATHENA

(Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Application). The last two projects were designed simply to improve interoperability (Camarinha-Matos and Afsarmanesh (2008a).

The outcomes of the ECOLEAD project were extensively used in this study for the collaborative network modeling process. The aim was to build a theoretical basis to perceive and understand new forms of collaboration focusing on three fundamental and inter-related areas, i.e. the ECOLEAD pillars. This is the foundation for dynamic and sustainable networked organizations including the Virtual Breeding Environment Organisations (VBE), Virtual Organization (VO) and Professional Virtual Communities (Camarinha-Matos, Afsarmanesh and Ollus, 2005). This project aimed to facilitate the configuration and creation of VOs, supporting their management process and introducing new approaches and methods to promote trust, defining a collaboration business culture and common value systems to be shared among independent organizations. This project was significantly important to explore actors and roles, life-cycle and management of VBEs, as well as to the VO's creation process, outlining activities from the collaborative opportunity to the VO launching.

Institutional Projects - The project "*Redes Colaborativas de Elevado Desempenho-RCED*" (Carneiro *et al.*, 2007), translated to English as High Performance Collaborative Networks, the RCED Project is an initiative proposed to investigate major models of collaborative networks and identify the most suitable models for the reality of the northern region of Portugal. Furthermore, the RCED project aims to identify and define the conditions for the establishment of an environmental enhancer for high-performance collaborative networks involving the business community in this region, and also to develop structures of socio-economic relationships and technological support for collaboration. In addition, this project aimed to identify the most appropriate instruments to promote and consolidate models based on collaboration among firms. The intention was to provide an analytical tool to the CN participants or designers involved in the collaborative network management that can be used as in the foundation for practical approaches or as an academic reference in research on this subject. Bearing this in mind, a reference model was created (see Section 2.2.1). The main contribution was a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis on the comparison between the collaboration approach and vertical integration in order to make recommendations to improve performance, such as: promote and develop VBEs, top-down networks, study cases, support technologies, collaboration knowledge, brokers, performance evaluation, governmental financing, method dissemination and executive training.

Another institutional project is the so-called "Projeto Empreender", translated to English as Entrepreneurial Project. This project was created by the Brazilian Support Service to Micro and Small Enterprises (SEBRAE). The aim of this initiative is to increase entrepreneurship actions in micro and small companies so that they can benefit from the synergy among competitors within the same branch business and addresses common problems related to suppliers, logistics services, marketing, asset security, employee training, among others, which can be engaged through aligned strategies. It intends mainly to reduce costs, increase bargaining power with suppliers. In conclusion, they work together towards an increase in competitiveness.

2.2 Collaborative Networks

2.2.1 Concepts

Nowadays, companies recognize that a strong interaction and coordination among participants in their business chain are key strategies to achieve be competitive and reduce uncertainty (Faria and Azevedo, 2006), and so this motivates them to act within a CN environment. This new business model requires an effective strategic alignment among membership organizations in order to achieve the planned objectives. Therefore, it involves interoperation of different organizational systems that must be integrated and orchestrated in order to guarantee effectiveness, leading to suitable performances according to the participants' expectations. In addition, this new vision requires technology and infrastructure support, management tools and appropriate performance measurement solutions that can ensure the alignment expected with regards to the strategic objectives defined in a business network environment. It must support quick decisions within the CN strategy to face the necessary changes and also to achieve feasible and desirable improvements for the inter-organizational processes.

Conceptualizing the term "collaboration" is the key to defining "collaborative networks". Camarinha-Matos and Afsarmanesh (2008a) argue that this term is often confused with cooperation. There are other types of interactions between firms, such as coordination and networking, which can be outlined as follows:

- Networking is the interaction, communication and information exchange by network participants for their own use. This can occur without the need for common goals among participants;
- Coordinated Networking: while maintaining the previous premise that there are no specific common goals, coordination of information sharing may involve the alignment of activities so that the results achieved are more effective;
- Cooperation means that specific activities are ascribed among participants. Information exchange and redirection of activities occur similarly to the previous definitions. However, resources are also shared so as to make it possible to achieve feasible and desirable goals while working together;
- Collaboration occurs when participants not only share information and resources, but also jointly plan, implement and evaluate the intra- and inter-operational processes as well as the interoperability among participants in order to achieve common goals and strengthen each participant’s capacities. Acting under a single identity implies not only sharing risks, resources and responsibilities, but also to achieve benefits.

Therefore, the interactions (Figure 8) could change from simple cooperation between organizations to a level where there is coordination of inter-organizational processes for exploiting information and communication between them. On the other hand, there may also be cooperation where responsibilities on the inter-organizational processes and respective resources are shared, and can progress to an even higher level that requires an agreement on common strategic objectives, i.e. collaboration.

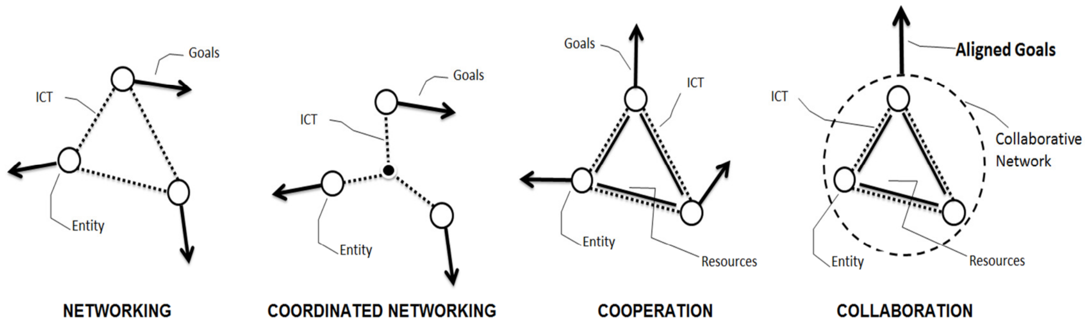

Figure 9. The inter-organizational interactions

Such definitions make it easier to understand the forms of interaction among organizations in order to correctly define the network typology to be adopted in different business environments.

The RCED Project Report (Carneiro *et al.*, 2007) presents a definition for these concepts, exploring their requirements, including articulated strategies, interoperations, benefits, trust, labor forms, specific management methods, technological support (information and communication) and governance (rules, frameworks). In this report, the definitions of the terms “cooperation” and “collaboration” in the context of inter-organizational networks are presented as follows.

> *“Cooperation refers to the organizations’ ability to articulate strategies and activities to achieve objectives agreed among them and to gain mutual benefits for organizations to cooperate through mutual trust, dividing labor and eventually adopting common methods. If cooperation does not exist, organizations are working alone (competing or not);*
>
> *Collaboration is the process of two or more organizations achieving collective results, accomplishing tasks together. It can be very difficult (or impossible) to achieve these individually, and so a coordinated and joint action by individuals should be promoted and supported by the communication in a demonstration of cooperation. However, in a context of collaboration, the process of interaction between autonomous agents through formal and informal negotiation entails the creation of rules and structures to govern their relationships and how they act or decide on which aspects to keep them together. It is a process that involves common standards and mutually beneficial interactions (Thomson and Perry, 2006).”*

Therefore, cooperation implicates not only sharing resources in order to achieve compatible goals through some tasks carried out by organizations involved, but also information exchanges and operational fit (Camarinha-Matos and Afsarmanesh, 2008a). Differently, collaboration is the process in which participants work together in order to plan and solve business problem-situations. This strategy involves trustworthiness, resource sharing and strategic alignment. Normally, it includes separate entities with different competencies, sometimes with different interests, but acting symbiotically in a same breeding environment (Chituc and Azevedo, 2005).

The collaborative business environment is an interaction among organizations that cooperate in order to reach common goals for their own strategic purposes. This new paradigm has been encouraged by rapid innovations in information and communication technologies (Chituc and Azevedo, 2005). Academics and practitioners are increasingly focusing on this matter in order to define the appropriate theories and their modeling tools for managing CNs, and also for education and training on this new discipline. In this context, the initiatives of the Society of Collaborative Networks (SoColNet) have been adding fruitful relationships between researchers in this area.

Today, the social and business environment is characterized by constant change, ephemeral markets, volatile demand, short life-cycle of products and services, change of standardization to customization approaches, time-to-market, flexibility in production, delivery of complex products and processes, and others. These aspects motivate the process-oriented organizations for cooperation and collaboration. This is a valuable and effective business model to achieve the strategic objectives in a low cost and low response time, where participants work together to achieve goals that would not be possible or would have a higher cost if undertaken individually. It can provide a high delivery service level that must be compatible with the expected levels of customer satisfaction.

The process of creating and delivering products to the market requires networks to temporarily join their core competencies for collaborative value-creation. Sometimes these networks are dynamic, with the order specifically configured, and exist only for the duration of that order (Katzy, Zhang and Löh, 2005). In fact, with the focus only on business opportunities, aspects such as time for alignment, process optimization and corrective actions become highly critical in terms of the time variable.

Nowadays, organizations believe they need to perform in network environments in order to be prepared to face the market where changes in business-oriented environments are noticeably one of the main concerns of the enterprises. They look for solutions that may keep them safe from more and more unpredictable changes in business environments and reach a stable and successful existence (Grudzewski, Sankowska and Wantuchowics, 2005). This is clear in global production systems or in situations where there is co-operation within global networks.

These assumptions lead to find better solutions that make it easier to achieve higher levels of agility and flexibility through virtual and/or collaborative production, and are very important in competitiveness strategies (Faria and Azevedo, 2006). Indeed, a key feature is the participation in collaborative networks via a common strategy which should be aligned to strategic goals, while guaranteeing the independence of the legal partners.

A CN is managed according to the type of organizational structure, allocation and coordination of resources and activities, as well as interoperability. Thus, it is possible to achieve objectives within the required time, cost and quality frame (Karvonen, Salkari and Ollus, 2005). Thus, knowledge and skills on specific subjects relating to the management of collaborative networks should be encouraged to support CN decision-makers in achieving their strategic objectives.

According to Verschoore and Balestrin (2008), collaborative networks lead to the generation of economies of scale, and thus guaranteeing higher bargaining power. Such strategy helps companies solve problems not only through solutions provided by the network, but also through products or services, and physical or digital infrastructure. By sharing ideas and experience becomes possible to improve learning and innovation conditions. Innovative actions developed jointly by CN participants make it possible to reduce costs and risks associated with certain actions and investments that are common to all participants. Furthermore, it is also important to generate and maintain social relations in order to increase levels of trust.

Although organizations seek first to achieve their own strategic purposes and financial results, the benefits they can achieve in a network environment is more comprehensive and generates impact on all processes of the organization. In fact, the participants of the collaborative networks seek some expected benefits, including: increase flexibility, reduce costs, increase responsiveness, improve capacity, increase asset utilization, enhance customer satisfaction, increase market share, reduce time-to-market, enhance design innovations, increase quality, improve skills and knowledge, decrease risk of failure, support technology upgrades and promote complementary skills.

These benefits may result from effective strategies undertaken by the CN to overcome difficulties and requirements that must be taken seriously during the CN life-cycle. For this purpose, at least the following requirements must be considered:

- technological aspects (e.g., innovative process, hardware integration and software interoperability)
- business aspects (e.g., different business models, different business approaches, business complexity, etc.)
- Competency level, entity coordination
- Legal structure, cultural and geographical aspects
- Alignment and trust

These requirements should contribute to a concerted effort to obtain knowledge on the concepts, methodologies and tools that can help the CN decision-makers manage performance and simultaneously help participants align their targets.

As referred before, one of the most important projects addressing the collaborative network subject is ECOLEAD (Camarinha-Matos, Afsarmanesh and Ollus, 2008). This project addresses organizational collaboration issues in order to define the foundations required by this new business model. Although the expressions “inter-firm organization”, or “inter-firm collaboration” are used, this new organizational model is now called "collaborative network", an expression that covers the specific concepts of collaboration between the organizations discussed in this research. So, the collaborative network

> *“is a network consisting of a variety of entities (e.g., organizations, people, machines) that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, thus jointly generating value, and whose interactions are supported by computer networks” (Camarinha-Matos and Afsarmanesh, 2005).*

Understanding the particularities of collaborative relationships makes it possible to characterize collaborative networks and therefore define a set of characteristics or requirements to distinguish them from other events with different characteristics and typologies. For instance, if the object of a collaboration agreement among organizations is a single project, or an emerging business opportunity, then this characteristic determines the existence of specific collaboration demonstrations called: Virtual Enterprise (VE), which represents a temporary alliance between companies supported by information and communication technologies (ICT); Virtual Organization (VO), when an organization is not limited to an alliance; and Dynamic Virtual Organization (Dynamic VO), which is formed to respond to opportunities in a short period of time, and adapted to face the challenges of unstable markets (Afsarmanesh and Camarinha-Matos, 2005).

Virtual Organizations (VO) aggregates a group of distinct organizations that share resources and skills to achieve specific objectives and goals. This is true when a group of organizations agree to adopt cooperation rules, common best practices, and mainly to share ICT infrastructures. Moreover, when a VO is established on a short-term to respond to an emerging market opportunity, during a short life-cycle, and dissolves when the purposes are achieved, this is a Dynamic Virtual Organization (Camarinha-Matos and Afsarmanesh, 2008a).

Therefore, it creates highly dynamic organizations in accordance with the needs and market opportunities, operating while these opportunities persist (Camarinha-Matos and Afsarmanesh, 2005). Nevertheless, this is really feasible whether it occurs within a Virtual Breeding Environment Organization (VBE). This means that organizations and other supporting entities that adhered to a cooperation agreement based on medium- and long-term objectives aim to increase their ability to form, design and implement temporary collaborations on the short-term (e.g., Dynamic Virtual Organizations). The VBE concept is expressed in such forms as: industry cluster, industrial district, business ecosystems, inter-continental enterprise alliance, disaster rescue networks, virtual laboratory (e-science laboratory) and professional virtual community. Many of VBE initiatives come from governmental policies or industrial conglomerates. Although the establishment of VBEs is increasing, there are still few initiatives with proven experience and mature (Camarinha–Matos and Afsarmanesh, 2008a) in providing good conditions to seize business opportunities.

Naturally these forms are successful if a breeding environment can support or even register individual skills and competences. A Breeding Environment can be seen as a strategic alliance to create an outlined business environment to seek and take opportunities for participants to work together. The participants are hosted in this environment and their characteristics maintain special conditions to launch potential CNs. This can be considered as a long-term strategic network that usually occurs in restricted geographic regions like industry districts, taking advantage of common business cultures and focusing on regional abilities.

In fact, when organizations want to combine their resources and expertise, this collaborative relationship seeks to achieve a Collaborative Advantage (Huxham and Vangen, 2005). This means that positive synergies are created in order to reduce gaps in relation to market requirements. Therefore, according to Dyer (2000),

> *"The winners of the next decade and beyond will understand how to create collaborative advantage. They will understand the key trends that continue to push firms to focus on an ever narrower set of core competencies and develop closer partnerships with other firms in their value chain. They will recognize where and when to make investments in dedicated assets in order to optimize the value chain in which they are embedded. They will develop routines to share knowledge with their partners in the extended enterprise, thereby enhancing the competencies of all enterprise members. They will know how to develop trust with those partners so that the extended enterprise can swiftly and flexibly respond to opportunities and*

threats, while maintaining very low transaction costs. And they will also understand that strategy is no longer an individual firm phenomenon but will increasingly carried out in harmony with the firm's partners in the extended enterprise."

In Section 2.2.2 various typologies and topologies of collaborative networks are displayed in order to provide evidence on distinct features and the relations between the CN's participant. Indeed, in the last decade, several formal and informal networks were constituted in all regions of the world presenting different typologies and topologies, always seeking to improve competitiveness and to face new market challenges. CN modeling approaches were also developed to consider several aspects, such as: typology and topology, the life-cycle phases, purposes and leadership aspects which characterize the interaction between participants.

After configuring the CN, there are other aspects that need to be taken into consideration, including: brokerage or leadership actions; inter-organizational alignment; measurement and management performance; and other emerging concepts. Such aspects may translate the objectives and targets that induce to the appearing of the CN and also motivate how this collaboration strategy must be managed in order to reach those purposes.

Camarinha-Matos and Afsarmanesh (2008) consider that the current knowledge on the various forms of collaborative networks is still very fragmented and therefore it is necessary to promote the integration of concepts and tools and use them in formal models. Therefore, a reference model[3] should be used in order to explain the approaches used so that it is possible to understand and manage the types of collaborative networks. It must include the necessary terminology and taxonomy in order to find directions and guidelines to help CN's decision-makers design adequate systems and inter-operational processes.

For these tasks, the reference model RCED (Carneiro *et al.*, 2007) associates some collaboration elements to characterize the collaborative network, including: relationships (types of connections between network nodes); context (background information on the network context); motivation (strategic target of the network); actors (type of network nodes); resources (content of the links between network nodes); activities (added-value activities performed by the network). These attributes are grouped into six dimensions to assess the performance of collaborative networks (Figure 10).

This model includes some referential aspects that promote the formulation of the CN's typology, the principle and criteria of performance, the requirements to achieve the goals and types of collaborative technologies to be adopted. This approach seeks to facilitate the study of the characteristics of collaborative networks prior to defining or classifying them during the network formation.

[3] A reference model is a generally accepted framework for understanding the significant concepts, entities, and relationships of some domain, and therefore a "foundation" for the considered area (Camarinha-Matos & Afsarmanesh, 2008).

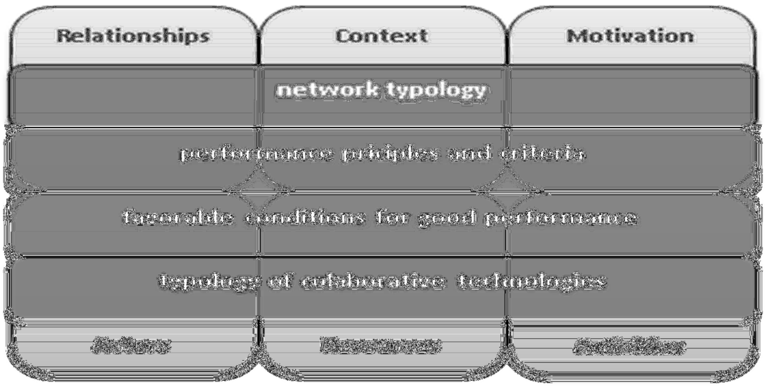

Figure 10. RCED Framework

Therefore, modeling can be considered a relevant activity to effectively understand, design, implement and operate systems. Therefore, three important tasks are suggested:

- define and structure the collaborative network;
- develop procedures and define targets of the inter-organizational processes;
- integrate performance evaluation processes.

According to Chituc and Azevedo (2005), the CN emerges as a powerful mechanism that can help organizations achieve their strategic objectives in order to reach effective response times, quality and cost savings using targets and performance indicators. Otherwise, organizations can be led to wrong directions. Furthermore, some measures must be created, organized, monitored, analyzed and improved in order to instantiate the actual performance and understand the benefit of using these measures, by using an effective PMMS. According to Paszkiewicz and Picard (2009), performance measurement is a difficult task that is commonly neglected, maybe because the used approaches are not sufficiently wide to cover all organizational aspects. As a consequence, performance indicators lack ontology and only recently models and performance management systems have been developed and implemented to use in the decision-making process of collaborative networks.

2.2.2 Collaborative network characterization

In order to correctly configure a collaborative network, it is relevant to define the proper shape and structure. Thus, the taxonomy may consider categories of current collaboration demonstrations in order to make easier to recognize which one is more appropriate characterization to designate the typology or topology of a CN. Therefore, this taxonomy may assist in defining the type of CN under study, such as: joint ventures, strategic alliances, virtual enterprise, virtual organization, holdings, franchises, dynamic network, value-added network, extended enterprises, supply chain, enterprises networks, outsourcing, partnership, clusters, collaborative networks, industrial districts and integrated logistics (Fusco, 2005). Therefore, each type of collaboration should be characterized in order to provide a conceptual view suitable for modeling the CNs. This has been properly studied and defined by Camarinha-Matos and Afsarmanesh (2008a) within the ECOLEAD Project where the taxonomy for collaborative network forms was defined as depicted in Figure 11.

In this approach, it is important to note that the long-term strategic network refers to VBE and professional virtual communities. On the other hand, the goal-oriented network implies an intense collaboration both to grab opportunities usually seized to the opportunities of the market in the short term and to the continuous production-driven net which occurs in a long-term duration such as supply chain and virtual government. However, although this taxonomy is based on the purposes of the network, it is influenced by the duration.

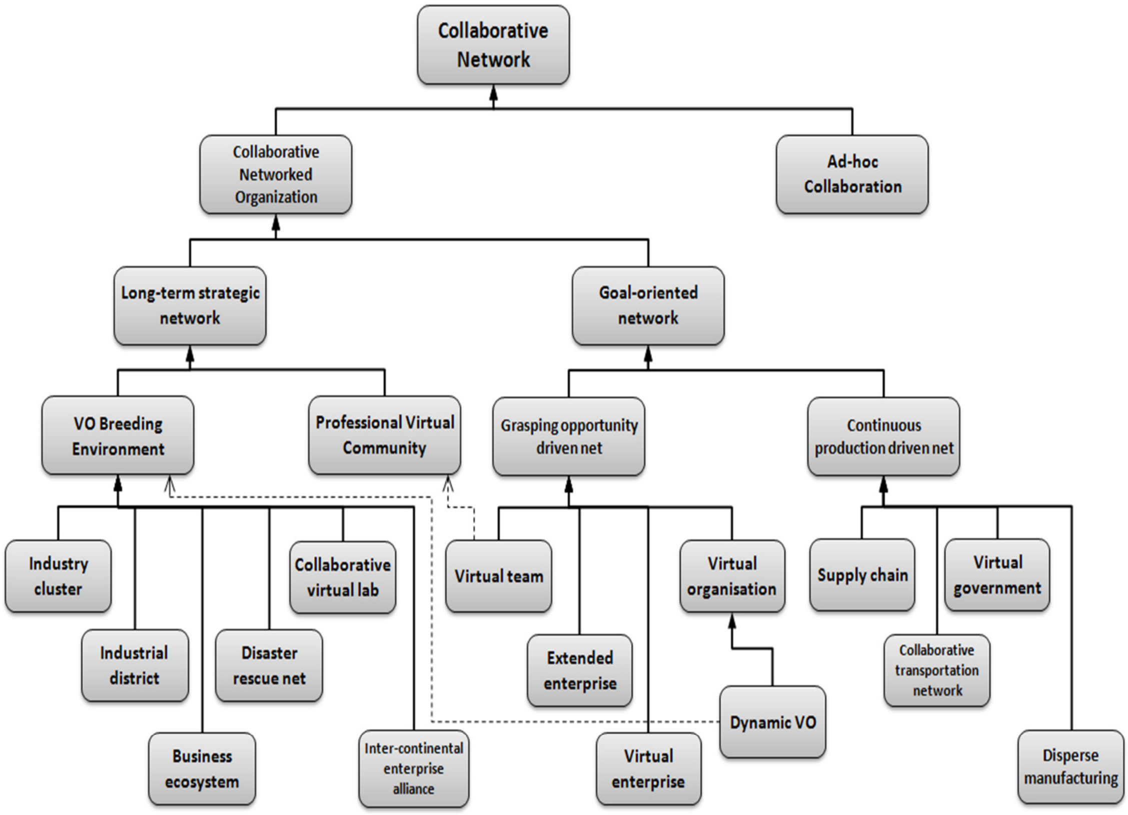

Figure 11. Examples of forms of CNs (Camarinha-Matos and Afsarmanesh, 2008a)

Similarly, the RCED Project (Carneiro *et al.*, 2007) proposes two classifications to conceptualize collaboration: collaborative networks and organization networks. The first class can occur as a collaborative network of individuals or a collaborative network of organizations according to the actor dimension. The second can be considered a collaborative network of organizations where the inter-organizational relationships are supported by collaborative processes. Therefore, focusing on inter-organizational relationships, there are operational synergies, technological and functional synergies, and strategic synergies network which are defined as follows:

Operational synergies network - Network of organizations cooperating to achieve synergies in the production processes of products or services (primary activities of the value chain).

Functional/technology synergies network - Network of organizations cooperating to achieve functional synergies in Research and Development (R&D), marketing, distribution, and other functions in order to support the activities of the value chain.

Strategic synergies network - Network of organizations (firms and supporting institutions) that cooperate on a long-term basis in order to increase their opportunities of participating in the operational synergies network or also in the technological/functional synergies network.

In line with this, some network typologies are presented, such as: supply network, Virtual Organization (VO), production network, purchases network, distribution network, R&D+I network, cluster and the Virtual Organization Breeding Environment (VBE). According to the RCED Project (Carneiro *et al.*, 2007), these typologies are also used to classify collaboration forms, although other typologies are presented in the report, such as: Procurement and Purchase Networks; Virtual organization Breeding Environment (VBE) where two or more independent organizations operate in a supportive environment (trust, social relations, technological mediation), articulated in a more or less informal, formulating some strategies and/or activities to help them achieve their objectives; Virtual Community sponsored by Organizations as a community (of practice, professional, project, or hybrid) supported by collaborative technologies, involving individuals from different organizations in order to satisfy individual and organizational objectives, and this participation is fostered by the organizations they belong to. Such classifications aim to characterize networks to better understand the requirements for their design and implementation. Complementing this, Cândido (2001, cf. Ernst, 1994) also presents types of networks studied by him including the following denominations of networks.

Supplier Networks - This network typology involves subcontracting and agreements between a client and its suppliers of intermediate inputs for production.

Manufacturing Networks - This network topology covers the arrangements for co-production, offering the possibility of competing producers to join their production capacity and financial and human resources in order to broaden their product portfolios, as well as its geographical coverage. Manufacturing networks are becoming increasingly highlighted due to technological advances related to rapid prototyping, virtual factory planning, product development, remote control for production, etc.

Customer Networks - Contracts and agreements are signed between the industries and distributors, the marketing channels, the retailers with value and also the end users in major export or domestic markets.

Standard Coalition Networks - These networks are formed by organizations that define global standards to press other companies as much as possible for using its proprietary product or to standards interface.

Technological Cooperation Networks - The aim with these networks is to facilitate acquisition of technology to design and manufacture products, to enable joint development and production processes, and provide shared access to scientific R&D. These networks were also mentioned in the RCED Project (Carneiro *et al.*, 2007) as R&D+I Network, with Innovation aspects added.

Furthermore, according to Lipnack and Stamps (1994), cited by Cândido (2001), other networks may be included, such as: Service Networks, which are the classic distribution networks operating in various supplies. Core Firms, which emerge in specific ventures or in alliance, looking to foreign markets, but with the intention of simplifying their relationships with common suppliers and distributors. Alliances related to relationships between companies or enterprise groups can be created by multinational firms, small businesses or associations formed by large and small enterprises, and others. The most common alliances are the "joint ventures" that create new businesses and it means that each one's best competencies are combined. Finally, the mega-groups represented by those with cooperation and competition competences on a large scale that focus on a particular geographic region and business.

Furthermore, a time-based classification can also be used to operate networks, classifying them as into short-, medium- and long term networks. Thus, considering that time-based aspects would be the most suitable choice for classifying collaboration in dynamic markets, Afsarmanesh, Marik and Camarinha-Matos (2004) considered three different CN types: "*long-term partnership of SMEs with one dominant participant; dynamic project-based partnership without a dominant participant; temporary partnership for one organization to explore short-term market opportunities*". To easily adapt itself to the dynamics of the market, temporary networks seem more suitable for typically short business opportunities, while long-term organizations focus more on investments in common infrastructures and practices and on the trust building process (Camarinha-Matos, Afsarmanesh and Ollus, 2005). An example of short-term collaboration is the virtual enterprise, while an example of long-term collaboration is a supply chain. Therefore, these typologies were proposed to refer to life time, partner dominance, motivation and roles, as follows.

Long-term partnership of SMEs with a dominant partner - It occurs when supply chain or enterprise networks are integrated and organized mainly in buyer/supplier relationships. The sponsor, motivator and/or facilitator are the dominant partners because of their decisive role in defining the cooperation rules that own the core knowledge, trademark, activities procedures, etc. This is also true for a few dominant partners. Industry clusters are typical examples.

Dynamic project-based partnership - This type of partnership is not driven by one dominant player. It is normally organized in democratically and favors more stable structures of participants with complementary skills. The type of agreement between partners requires prior experience on cooperation and ability to achieve consensus in the early design and start-up stages. Alignment with the project's objectives is crucial for effective inter-organizational processes. Generally, an organization can act as broker or facilitator for directing the efforts of the CN's participants.

Temporary partnership to explore short-term market opportunities - This type of partnership is usually composed of SMEs operating in specific business areas that join temporarily (or occasionally for several times) to meet certain business opportunities on the short term. Usually, participants are governed by poorly defined guidelines and rely on an agreement prior to the operation and also on default rules occurring spontaneously according to breeding environment, market characteristics and cultural traditions. Also, in this situation an organization can act as broker or facilitator, to direct the participants' efforts.

Otherwise, a collaborative network can also be seen according to the interaction with competitors and non-competitors as horizontal (competitors) or vertical (along a partner chain). There is a Vertical Network when the cooperation takes place between a company and the components of the different links along the production chain. Horizontal networks are those in which cooperation between companies include the production and supply of similar products within the same branch of business activity (an agreement between a company and its competitors). In this network typology, special care is necessary in order to avoid conflicts that may occur. This typology appears when isolated participants find it difficult to acquire and share scarce resources in production, to serve the markets, as well as to launch and sustain a new product line (Gerolamo, 2007).

With these considerations, a graph-theoretic definition analytical approach has been presented by Chituc (2007) in order to better understand a CN and its environment. The aim is to understand the CN, as well as its character and measure its performance. This combined approach assumes that a CN has several properties. A CN is characterized as a directed multi-graph, which is a finite set of nodes (vertices) and directed edges. The notation $(CN)_n$ will be used to represent an n-dimensional CN, where ***n*** is the number of nodes (participants) in the CN (***n*** finite and ***n***>=2). Then,

$(CN)_n$ = (O, E, BP, T) [1]

O – a set of vertices or nodes representing the organizations in the CN

E – a set of edges representing directed lines connecting two nodes of the CN, representing the set of relationships between two nodes (organizations)

BP – a set of public business processes for the CN

T – the analysis time (e.g., implied by the CN's dynamic structure)

n – the dimension of the CN, this is the number of organizations participating in a certain CN

where $\boldsymbol{n} \in N^*$ $\boldsymbol{n} \geq 2$, if ***n***=0 and ***n***=1 are trivial cases (e.g., if *n*=0 then (CN) is a null graph, if ***n***=1, the CN only contains one participant this means that, in this situation, it is not a CN).

Furthermore, to define the CN typology, aspects related to the mechanisms of interaction can also be observed which exist through a topology classification. Even though the presented typologies can explain the main characteristics regarding different events of collaboration, integration strategies among CN's participants can be properly defined by a perspective of the network's physical formation. In computer science, a mathematical approach (geometry) derived from the study of the geometric figures' properties are currently adopted to configure a communication network. This approach is called "Local Area Network" (LAN) and it consists of arranging the nodes of a local area network that are connected to each other. Thus, if a topology of communication network that uses this mathematical artifice to study the arrangement or mapping of network elements, such as nodes and links of the interconnections between nodes relating to physical flow (real) or logical flow (virtual), then it can be applied in the context of collaborative networks to represent both the physical flow of inter-organizational processes and the direction of the information data flow.

Picture representations can describe the different forms that the CN may have in real-life situations. They comprise the physical interconnections of the elements (links, nodes, etc.) of the organizations' interaction. Therefore, various types of network topologies can be named according to the type of link between participants (nodes), such as the following:

Linear bus network topology - For data to be exchanged within the network nodes, a common means of transmission between two nodes is established. The data are transmitted in a chain and received by the nodes that follow. In the case of physical flow, effects on delays should be considered. According to Katzy, Zhang and Löh (2005), delivery delay occurs usually in cases of supply chain in manufacturing industry specifically regarding process-oriented approaches. This network topology (Figure 12) comprises components which are connected such as in a busbar.

Figure 12. Linear bus network topology diagram

Distributed bus network topology - Unlike the previous topology, this case presents nodes connected to a common transmission medium with more than two endpoints. Although all nodes share a common means of transmission where branches are added to the main section of the transmission medium, the physical flow is distributed similarly to linear bus topology. This network topology (Figure 13) occurs usually in cases of supply chain in the manufacturing industry specifically regarding process-oriented approaches.

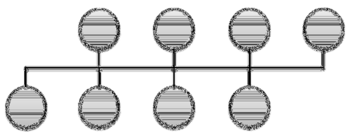

Figure 13. Distributed bus network topology diagram

Star network topology - The characteristic of this case is the connection between all nodes through a central hub that allows a physical flow within the network points. This is intended to facilitate the flow between the nodes because the network allows point to point connections using the central hub. However, this topology is more dependent on the hub that cannot fail. According to Katzy, Zhang and Löh (2005), this usually occurs in cases of dominant member (main contractor), specifically in the construction and automotive industries because is the easiest to design and implement, other than allowing other components to be added without new rules. This network topology (Figure 14) comprises components which are connected to a hub.

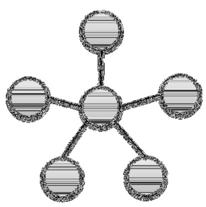

Figure 14. Star network topology diagram.

Ring network topology - In this topology, components are connected individually creating a closed loop. This means that components are connected in such a way that the last component is connected to the first. The physical and information flow follow a certain direction and only one component can pass these flows to the next network node. The components act as signal boosters or repeaters that can enhance the signals that crossed the network. However, failure in one component can cause the entire network to fail. This topology (Figure 15) may occur in creative and knowledge industry (e.g., knowledge networks).

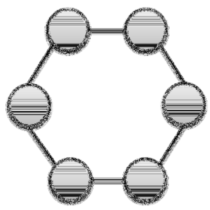

Figure 15. Ring network topology diagram

Fully connected mesh topology - The network components are connected to each other making it possible for the physical flow and information to occur simultaneously from any single node to all other nodes. The components are all connected directly to all other components, for example in local clusters and social networks, although some links may be interrupted if necessary (Figure 16).

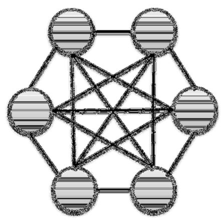

Figure 16. Fully connected mesh topology diagram

Partially connected mesh topology - Network components are connected to more than one network node with a peer-to-peer link and can have multiple relationships with all nodes without hierarchy when referring to the information data flow (Figure 17). It is highly dependent on each component, especially those with greater involvement in physical or information flows. It occurs mainly in service networks and knowledge networks. For example, in Hollywood, a number of distinct agencies provide specific solutions for each task while filming and editing a movie (Katzy, Zhang and Löh, 2005).

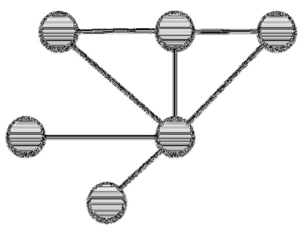

Figure 17. Partially connected mesh topology diagram

Tree network topology - This is the type of network topology where a node that represents the highest level of the network's hierarchy is connected to one or more nodes that are one level below in the hierarchy (i.e. the second level), connected point-to-point to the central 'root' node (Figure 18). On the other hand, the second-level nodes are also connected to one or more nodes that are a lower level in the hierarchy (i.e. the third level), and so on. The central 'root' node at the highest level "core" is the only node that has no other node above it in the hierarchy (the hierarchy of the tree is symmetrical). For each network node, there are a certain fixed number of nodes connected, in a lower level in the hierarchy. This hybrid approach bus/star supports the future expansion of the network much better than a bus network, which reduces the number of nodes due to the amount of interaction that it generates, or a star network, which is limited by the number of hub connection points (Mitchell, 2011). It is possible to infer that this topology is found in demonstrations of collaboration within project and process oriented networks, with a top-down coordination, broker or project bureau.

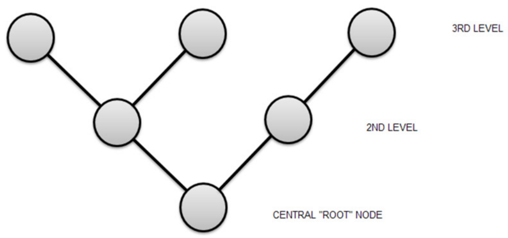

Figure 18. Tree network topology diagram

2.2.3 Life-cycle paradigm in collaborative networks

The life-cycle concept provides an idea about the transformation events that can happen during the organization's existence. It can assist in the planning process of various activities that occur in the collaboration environment. Thus, defining the life-cycle phases is very useful in determining the specific activities that happen at each stage, which tasks must be undertaken, what are the requirements to be met, which indicators should be used to monitor performance, which data and information are important, among others.

Projects carried out with collaborative relationships may have different lifespan (short-, medium- and long-term) because different times and characteristics are necessary to define the life-cycle phase. Moreover, different principles and methods are applied in each phase when the life-cycle paradigm is used in planning processes. However, in short-term projects, it is important to note that the time periods vary widely depending on the type of business, as stated by Katzy, Zhang and Löh (2005). For instance, these periods may vary from seconds (or fractions) in electronic media to years in the aerospace industry.

The CN life-cycle paradigm helps determine the activities of the entire CN planning. Thus, the definition of the life-cycle can be simple (design, formation and operation), as indicated by Petersen (2005), or more complex (partner search, partner selection, start-up, optimization, evolution and dissolution).

ARCON - A Reference Model for Collaborative Networks – is a modeling framework developed by Afsarmanesh and Camarinha-Matos (2008), within the ECOLEAD project. This model introduces three perspectives: environment characteristics, life-cycle phases and modeling. The aim is to model all features of the collaborative networked organizations (CNO) participants. Therefore, the life-cycle perspective helps us define and plan the efforts required during the CN existence. For different situations and complexities that determine the CN development, certain phases require different efforts and skills. In the structure of the ARCON reference model, some phases are considered, including: creation, operation, evolution, dissolution and, additionally, metamorphosis, which means there is an evolution to different objectives.

Therefore, it is important to establish the phases that will be established for the CN planning. In this research, five periods are suggested for the collaborative network life-cycle, which are: ideation, formation-configuration, run time, extinguishing and memory. Moreover, seven phases are proposed for composing the CN life-cycle in order to plan specific activities that may occur, such as:

1. Business opportunity detection;
2. Partner search and selection;
3. Design & setup;
4. Operation;
5. Evolution;
6. Dissolution;
7. CN's performance information.

The formation-configuration period may consist of searching and selecting partners detected before the business opportunities that promoted the creation of the CN. Particularly, during the formation and configuration processes, two important decision-making moments occur: partner selection and the agreement on collaborative policies and strategies. Thereafter, the design and start-up phases of the CN interoperations are addressed.

Therefore, the proposed life-cycle phases can be represented in a timeline view, as depicted in Figure 19.

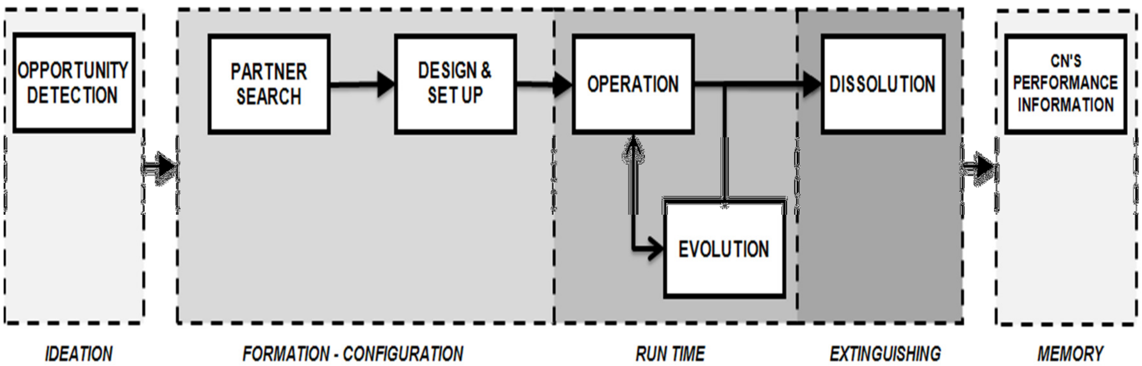

Figure 19. Periods and phases proposed for the collaborative network life-cycle

The next phases are the operation and evolution phases, which occur simultaneously. This happens because nowadays markets are characterized by rapid changes, especially due technological innovations. This situation urges organizations to continuously change their strategies and processes and may provoke the occurrence of the metamorphosis phase.

After performing these previous phases, when the purpose of forming the CN is no longer justified, the CN is dissolved then the network's performance memory should be kept.

The activities in every life-cycle phase must be planned according to specific CN characteristics. Thus, each phase proposed in Figure 19 above is described as follows:

Business opportunity detection - Throughout history, although the formulation of strategies often derives from who has the most power, cooperation and collaboration between armies and nations were used as a way of achieving the intended goals. In addition, the process modeling is often based on moral, environmental conditions of performance, leadership, discipline and method (Sun Tsu, 2007), but their adaptation to the present day imposes a more complex characterization based on specific approaches to delimit thinking on patterns to be established.

Mintzberg and Quin (2001) define strategy as a pattern (or plan) that integrates the major goals, policies in a sequence of actions in a cohesive way to help the organization. It is driven by policies which are rules or procedures that express the limits within which actions must occur. Then the purpose of determining what must be achieved and when results must be obtained should be defined.

The best known authors on this subject propose different approaches, ranging from general principles (Sun Tsu, 2007), strategic positioning in the market (Porter, 2001) and alliances with his less powerful neighbors to face potential opponents (Machiavelli, 1976), to the current descriptive and prescriptive approaches (Mintzberg, Ahlstrand and Lampel, 1998). Strategy concepts and basic principles have existed from the beginning of human civilization. These resulted from the need for survival, from the greed and ambition of nations and peoples to overcome the others in armed conflicts. Who was more engaged then had the better military-strategic knowledge for overtaking their rivals. Concepts such as goals, assessment of enemy strengths and weaknesses, cunning, morale, use of intelligence systems, discipline, hierarchy, etc., are present on the legacies left by them.

Nowadays, the fight to survive in the business environment is constant and leads with permanent changes, which requires continuous improvement in the products, processes and staff. These challenges are crucial and require matured business knowledge, and also the necessary competence and experience in order to support organization management.

Porter (1980) describes rivalry among competitors, the threat of new entrants, the threat of substitute products or services, the bargaining power of suppliers, and the bargaining power of buyer. Many concerns found within this approach based on the concept of Competitive Strategy have been addressed in order to understand which factors may contribute to the success of this type of market strategy. Within this scope, the degree of rivalry among competitors depends on the their maturity level, market sector growth, volume of fixed costs or storage, amount of differentiation or switching costs, volume of investment, types of competing risks, strategic stakes, and size and type of barriers. Substitute products offer alternatives to the market and limit profits. It also depends on the price and ease of replacement costs. Moreover, the bargaining power of buyers depends on the demand for shopping over selling capacity, the fraction of the cost on the purchase, the degree of purchase standardization, the amount of switching costs, the level of profits, possible threats in the integration, as well as the expected quality level. The same occurs for the bargaining power of suppliers (Ankli, 1992).

Competences, such as flexibility, agility, quality and others, require organizations to be more holistic and process-oriented. While some brokers or enablers could manage the process of finding opportunities, a marketing policy-oriented approach makes the network more pro-active and thus prepared to face the market challenges.

Thus, it is possible to make an analogy (Table 9) between various aspects of warfare tactics and current market tactics.

Table 9. Warfare tactics versus Current Market tactics (adapted from Mintzberg and Quin, 2001)

Warfare Tactics	Current Market tactics
War and conflict between civilizations	Competition between firms
Military reconnaissance	Market evaluation
Morale of a soldier or military	Employee and stakeholder satisfaction
Surprise attack on military objectives	Surprises in releases of new products to market
Logistical support to troops	Logistical support to supply and delivery
Concentrated military attack	Large commercial and marketing campaigns in specific sectors of the competition
Counterintelligence	Marketing and advertising in the business
Invading enemy territory	Conquest of new markets
Regrouping of forces	Concentration of production units or investment for expansion
Territorial expansion	Globalization
Military alliances	**Cooperation (or collaboration) between enterprises**
Military conquest of the enemy	Acquire controlling interest of competitors
Blitzkrieg[4]	Speed in the research, production, launching and expertise in the product marketing
Espionage	Search data and information on competitors
Military betrayal	Take key human resources in competitors
Technological military upgrade	Research and Development of new products

[4] Blitzkrieg is a German word that means a swift intensive military attack, esp using tanks supported by aircraft, designed to defeat the opposition quickly (www.thefreedictionary.com, Farlex, 2011).

Therefore, capturing market opportunities that bring benefits to develop or maintain an organization is a constant struggle. The detection of market opportunities depend on various tactics and resources that derive from effective strategies. In fact, collaborative relationships can be an excellent strategy for successful organizations to emerge. Those concerns can reduce the constraints between sellers and buyers and originate "win-win" solutions, reducing costs and risks in the value chain.

Partner search and selection phase - The efforts required to search and select partners to create the CN participants group are strong. While in a VBE it is not a great problem, in other collaboration demonstrations this is more difficult and unpredictable when planning the CN. The more times a VO is created within a VBE, the more data and information of potential participants become reliable when participants are choosing to join the VO (Jarimo and Korpiaho, 2009). However, in many cases supported by a VBE there is an important element which is the integration of the processes supported by computer networks. This brings benefits such as quick response and flexibility, but can be a heavy problem to face if the VBE it is not mature or does not exist (Crispim and Sousa, 2009).

The focus on partner search and selection is concentrated mainly on trust, reliability, competency (skill level), know-how and experience, and the process comprises basically the:

- Definition of areas of expertise and skills for the partners to be selected;
- Search for partners (within a breeding environment, by outsourcing, or both);
- Definition of the requirements for commitment;
- Analysis of the performance of potential participants;
- Selection of partners.

Some requirements that contribute decisively to collaborative advantage should be considered in the selection of CN partners, such as (Huxham and Vangen, 2005):

- Access to resources
- Shared risk
- Efficiency
- Coordination and seamlessness
- Learning

These requirements are considered in terms of their priority or their importance to performing the tasks required for managing the CN. Two main actors are responsible for initiating and developing this process. These actors are the motivator entity and the brokers that begin the partner selection process in order to carry out a specific project or seize a market opportunity.

Some analytical methods are proposed for partner selection, normally a mathematical decision-analysis, mainly through multi-criteria approaches and methods. An example of that is the Robust Portfolio Modeling (RPM) addressed by Liesiö *et al*. (2007) on project selection and referred by Jarimo and Korpiaho (2009) for networked partner selection. This solution is capable of matching the core competencies of partner candidates with the requirements of a project, and thus is an ideal VO in order to serve the customers. It is modeled as a multi-criteria binary programming problem comprising the subjects that deal with punctuality, partnership synergy, cost and economic situation.

Some modeling techniques can provide results that deal with ambiguities captured, including: fuzzy logic, neural networks, Bayesian network, rough sets, AHP framework, meta-heuristics, others.

In the context of collaborative networks, a variety of tools are found in several approaches and methods for selecting partners, such as multi-criteria decision-making problem (Crispin and Sousa, 2007), analytical hierarchical process (Bittencourt and Rabelo, 2005), service federation based approach (Camarinha-Matos *et al.*, 2005), modeling collaboration preparedness assessment (Rosas and Camarinha-Matos, 2008), stochastic combinatorial optimization problems (Crispin and Sousa, 2009), market-based solution approach (Kaihara and Opadiji, 2009), multi-agent platform (Angulo and Martín, 2009), strategic procurement planning approach (Seifert and Wüst, 2009), and others. A number of issues related within the collaboration formation context are considered in these approaches, including: economic situation, reliability, adaptability, flexibility, agility, partner size, risk profile, creativity, prestige and preparedness level.

Another very interesting approach is the prospective performance measurement (Seifert, 2009). This approach was developed to support the CN promoters in the initiation phase. This phase is divided into three steps: preparation, search and partner selection, and agreement (Thoben and Jagdev, 2001). The intention is to evaluate the partner potential in order to compose the participants of a VO. Therefore, this approach imposes five criteria or orientations that should be followed, which are: network structure, integrated-processes model, multi-level orientation, ICT support and competency of partners. Then, forecasting tools are used for predicting the performance that can be achieved by the CN's potential participants so that it is possible to choose the most suitable to be part of the VO.

In fact, these approaches and tools can contribute to improve methodologies to select partners for collaboration. Assessing the potential participants concerning the decision-making processes and the respective criteria is an extremely important task.

Design & Setup phase - According to Chituc and Azevedo (2005), the CN is formally set up when its member organizations conclude an agreement for business collaboration, which can be seen as a commitment between participants of the CN. It may stipulate the obligations and benefits of each participant, the allocation of functions and roles, the CN duration, the outcomes, among others. This means that the participants of the collaborative network are committed with a formal or informal contract to validate the agreement.

Complementing this, maybe the most important moment in the CN's life-cycle occurs during this "agreement" phase when participants make an agreement on planning and operations management. It is expected that a well-planned and mutually beneficial relationship already exists, formalized by the membership organizations, which contributes to accomplish the targets.

According to Winer and Ray (2003), a collaborative network must beget a rapid growth and high energy, exploring and discovering competencies in order to: uncover personal creative potential; blend ideas, make choices, focus on a collective vision; focus on productivity, administration, record keeping, policies and procedures; and bequeath love to tell stories, impart wisdom, and give resources for others to carry on the necessary changes and improvements for facing market challenges.

The planning process focuses on selecting resources that should be used while implementing a project. It is sometimes overlooked, or treated without necessary knowledge, causing gaps when the systems are performed because there isn't a sequence of activities, from the search and acquisition of materials to the creation of a finished product or service. Therefore, the planning process for a CN, using known planning methods, makes it possible to assess the criteria for formulating plans, and also structuring a project by organizing the functions and collaborative tasks.

In an assessment situation multiple criteria can be used, but the decisions are often based on incomplete and/or inaccurate information (Rosas and Camarinha-Matos, 2008). In the other hand, in a VBE a common infrastructure is usually provided, as well as the mechanisms and framework for the collaboration, allowing members to be more agile in finding business opportunities, and thus become more prepared to make assessments.

Therefore, in order to design a CN, some concepts and requirements must be considered including performance management.

Operation phase - During this phase inter-organizational processes starts with CN participants performing their functions and roles. Seeking to accomplish the objectives defined and agreed by the partners, the designed activities are then performed. Basically, the business processes should be integrated, covering product development, operation planning, production, distribution and the after-sales services (Faria and Azevedo, 2006).

Many factors must be considered within the Operations Management scope. In fact, the concepts, methods and tools currently used in manufacturing and service companies have been improved over the last decades. It is possible to find a great amount of literature that explains and characterizes different management areas on this subject, specifically in the Strategic Management (Slack, Chambers and Johnston, 2007), Planning and Control (Graves, 1999), Continuous Improvement (Masaaki, 1997), Quality Management (Juran and De Feo, 2010), Human Resources Management (De Cenzo and Robbins, 2009), Logistics (Ballou, 2004), and others.

In fact, expertise in operations management in the collaboration business environment is fundamental and crucial for the CN to succeed. Then, each participant should try to continuously improve their performance in the intra- and inter-organizational processes. Very different levels of expertise among participants should be avoided. In this case, certain requirements with regard to the quality of their management systems, technological standards, or even the fulfillment of specific legislation can align them in order to improve the performance of their inter-organizational processes.

Emerging concepts should be properly used in collaboration, for instance, the Change Management (Kotter, 1997) to support the challenges to be faced in the process of implementing the CN, the Decision-Making process (Roth and Mullen, 2002), which makes it possible to formulate better strategies and to solve problems more efficiently, and Leagility (Katayama and Bennett, 1999) to increase the time response for the market.

Therefore, in this phase, performance management is carried out in order to monitor and evaluate if there is compliance with the stipulated targets. So, there may be improvements in inter-organizational processes and the overall result of the CN, triggering the evolution of performance status regarding the previously designed targets.

Evolution phase - The structure and the process patterns of a CN may change over time, for instance: improvements in the technology used in intra- and inter-organizational processes, amendments in the CN topology, outputs and inputs of participants to perform specific tasks, implementation of new solutions to the customers, and others. The establishment of plans and actions for co-creating value can transform the processes and methods adopted. In this context, the value creation to the customer can be more effective and makes it possible to develop new goals and targets.

Indeed, it is crucial to develop methods and tools to support the analysis of processes and decision-making that makes it possible to redesign intra- and inter-organizational processes in order to improve performance and reach new patterns and establish new targets. Therefore, many approaches in Operations Management may be used in order to properly manage the operational systems of the CN.

Dissolution phase - Usually the CN dissolves when its goals are reached, or when the collaboration agreement terminates due to poor performance or because of market contingencies. This does not mean that the participants of the CN do not continue their business in other forms of cooperation. Sometimes, a new CN arises with new purposes and goals - the metamorphosis (Afsarmanesh and Camarinha-Matos, 2008a).

In the Dissolution Phase, contractual obligations stop between CN's members. This means that the CN ceases to exist. However, some organizations may still play specific roles in the relationship between them such as providing specific services, technical assistance, training or supporting activities for the products or services made by the CN in the Operation Phase, as well as dismantling factories and/or facilities.

CN Performance Information - Throughout the CN life-cycle, the performance should be assessed. In this context, the information and data obtained can be used in the future for new demonstrations of collaboration involving the current participants, especially those coming from VBEs. Thus, such information and data obtained by the PMMS and applied to a given CN can be saved in a performance repository.

Then, the process performance that is monitored during the Operation Phase, as well as the Evolution Phase, can provide data to the Performance Repository. Also, in the Dissolution Phase, the data from the reports and its respective analysis provides general information about the overall performance.

2.3 Performance Measurement and Management

2.3.1 Concepts

Measuring processes performance is very important if the company wishes to survive and prosper in the current business environment. In fact, the companies must use performance management and measurement systems derived from their strategies and capabilities (Kaplan and Norton, 1992). Seifert (2009) argues that "*performance is the degree of target achievement of a process regarding pre-determined and application-dependent criteria*", extending this definition to argue that performance measurement can be "*understood as the measuring, analyzing and communication of the performance of business processes*".

In fact, performance measurement is a fundamental function in business management as they make it possible to detect failures or variations in processes. It indicates where processes must be improved in order to solve or ameliorate these problems, and thus increase the overall performance. Measuring performance is much more than tables of numbers and scorecards. Although it uses numbers, it is not about numbers; it is perception, understanding and insight which, if done efficiently, can have a huge and positive impact on the organizations (Spitzer, 2007). In line with this statement, performance management deals with how to relate the measurement results of the differences between current performance and desired performance, and then redesigns the processes in order to improve them.

If there is operational effectiveness and strategic fit, a state of sustainable competitiveness can be reached (Porter, 2001). Deductively, for a collaboration strategy application, it is possible that this is equally true. In order for organizations to manage their collaboration strategy, it is important to understand how effective systems that can integrate and align inter-organizational performance can be implemented. Indeed, the participants must understand the importance of creating integrated systems to measure and manage the networks' performance. Therefore, a PMMS helps organizations provide instances of performance, contribute to decision-making and lead to the alignment of all participants towards to the defined strategic assumptions (Evans, Roth and Sturm, 2004). Furthermore, if a PMMS is required in helping to monitor the outputs/results of a collaborative network, then this should be supported by a conceptual framework for the configuration and implementation of performance measurement and management systems. This framework can support the application of specific methods, methodologies and tools in order to improve the systems management and decision-making process.

According to Camarinha-Matos and Abreu (2007), if the CN is able to measure the performance of each member and the overall CN performance, participants will understand and accept the benefits that this new paradigm can offer.

Furthermore, performance measurement makes it possible to know if the investments are amortizing (effectivity), if the external and internal processes are obtaining the expected results (effectiveness) and also if the operational activities are functioning within controlled and defined parameters (efficiency). It requires knowledge on performance measurement, which is generally a complex task. To manage efficiency and effectiveness, the measurement outputs of processes must enable improvement actions on the causes of poor performance. According to Franceschini, Galetto and Maisano (2007), efficiency "*means getting the most (output) from your resources (input), whether they are people or products (doing things right)*", it is therefore the relationship between process performances and the resources applied. On the other hand, effectiveness is seen in terms of the structural and conceptual causes that make it possible to conveniently plan objectives that should turn into the expected results of the formulated strategies, or the degree to which predetermined goals and objectives are achieved. In addition, according to these authors, effectiveness "*means setting the right goals and objectives, making sure they are properly accomplished (doing the right things)*", that means comparing the achieved results with targeted objectives. Furthermore, effectivity relates the applied resources with the results reached at the end, admitting there is efficiency and effectiveness in the process (Chiavenato, 1997). To explain the definition used for effectivity, first it can be inferred that efficiency is seen as the efficient management of resources during processes in order to obtain optimized results. Effectivity can also be seen as "*do what must be done, well done, with the lowest cost and prepared for improvement of processes*" (Francisco, 2003).

In this research, the focus on performance measurement and process management refers to different areas of operations, such as manufacturing, purchasing, internal logistics, distribution and sales. In fact, companies are typically more concerned with financial performance. However, according to Gunasekaran, Patel and McGaughey (2001)

> *"As suggested by Maskell (1991), for a balanced approach, companies should bear in mind that, while financial performance measurements are important for strategic decisions and external reporting, day-to-day control of manufacturing and distribution operations is better handled with non-financial measures."*

According to Lardenoij, Raaij and Weele (2005), performance measurement should be seen as the activity of quantitatively evaluating the efficiency and effectiveness of processes. The authors define performance measurement (referring Neely *et al*., 1995) as the "*process of quantifying the efficiency and effectiveness of actions in order to compare results against expectations with the aim of motivating, guiding and improving decision-making*". In addition, a performance measurement system is defined as "*the set of metrics used to quantify the efficiency and effectiveness of actions, and the corresponding guidelines for linking these metrics to strategy and improvement*". For an organization to make effective use of the performance measurement outcomes, it should be able to make the transition from measurement to management. This is corroborated by Taticchi (2010) who states that performance measurement and management system, which is a broader system, is developed to collect, integrate and analyze performance measures in order to enhance decision-making processes, while evaluating strategy effectiveness and promoting alignment at the same time. Complementing this, Evans, Roth and Sturm (2004) state that:

> *"Performance management may be used during strategic and operative (tactical) planning, execution (or implementation) and communication stages activity. As part of the communication activity, performance measurement is the process that gathers and records the effectiveness and efficiency of the execution (action) and planning stages. Thus, performance measurement can be considered a subset of performance management."*

Complementing this, Busi and Bititci (2006) argue that measuring performance is just the practical and technical instrument for performance management, which is broader. It helps monitor performance, identify processes and/or areas that need more attention in order to implement proper solutions to improve them. Amaratunga and Baldry (2002) explore baselines for moving from performance measurement to performance management stating that

> *"the use of performance measurement information to effect positive change in organizational culture, systems and processes by helping to set agreed-upon performance goals, allocating and prioritizing resources, informing managers to either confirm or change current policy or programme directions to meet those goals"*

In fact, many authors that deal with the subject "performance" still apply the expression "performance measurement" as a management tool to the process of the retrospective analysis of data and facts on past performance (Seifert, 2009). Therefore, if the objective is simply to gather information to support control activities, instead of forecasting and planning, then it is not possible to take advantage with the implementation of a PMMS as an oriented tool to plan strategies and establish strong links between strategy and operations (Taticchi, 2010).

Many authors prefer the expression "performance measurement", including Kaplan and Norton (1992), Neely *et al.* (1995), Wagooner *et al.* (1999), Adair *et al.* (2003), Evans, Roth and Sturm (2004), Graser *et al.* (2005), Saiz, Rodríguez and Bas (2005), Bentley (2005), Westphal, Thoben and Seifert (2007), Spitzer (2007), Matheis *et al.* (2008) and Seifert, Wiesner and Thoben (2008). Our intention is not to criticize these authors but to highlight the fact that a transition is occurring in the traditional performance measurement approach. A new one is emerging which consists of measurement functions and "performance management". These are specific and yet complementary, and so this approach is increasingly in evidence (Kaplan and Norton, 2001), as argued also Neely, Adams and Kenerly (2002), Amaratunga and Baldry (2002), Lardenoij, Raaji and Weele (2005), Alba *et al.* (2005), Busi and Bititci (2006), Azevedo and Francisco (2007), Paszkiewicz and Picard (2009), Verdecho, Alfaro-Saiz and Rodriguez-Rodriguez (2009) and Taticchi (2010).

According to Adair *et al.* (2003),

> *"The literature reviewed revealed that the components of performance measurement and performance management have become so interwoven that the two are largely inseparable. Naturally, management aspects were emphasized more in the sections on strategy and use, and less in the sections on data collection and analysis. Attempts were not made to distinguish them specifically in this report and, for communication purposes, the acronym PM will always stand for performance measurement."*

The acronym used in this research for specific performance management systems is PMMS. This differs from the abbreviation used for performance measurement, i.e. the PMS, which is usually found in the literature on this subject.

According to Bentley (2005), the information of a process is required by the observers to improve this process, or even the strategies. The purpose of the performance measurement system is to link the observer to the process. Therefore, it is necessary to design and implement this system for providing accurate information to the processes' decision-makers in solving problems.

2.3.2 Performance measurement and management frameworks

A PMMS is an important management decision support tool that represents a prerequisite to assure effective network inter-operations. Nevertheless, defining a proper set of categories of performance measures that meet the needs of a particular network represents a critical step towards the establishment of an effective PMMS. In order to contribute to supporting the CN decision-makers, it is necessary to establish how to plan, configure and implement an effective PMMS for a collaborative network (i.e. collaborative PMMS).

Therefore, it is important to briefly define that the performance measurement is the process of quantifying the efficiency (process monitoring) and effectiveness (results achieved) of actions taken; remembering that performance measure is the metric used to quantify this, and yet, this set of metrics is the performance measurement system (Neely *et al.*, 1995). The proper use of these performance measures, including its accuracy, provides instances of performance that can be evaluated by the PMMS criteria in order to determine solutions to improve the processes that are not reliable or has poor performance.

Currently, the most famous performance management model is the Balanced Scorecard System proposed by Kaplan and Norton (1992). This is a performance management approach which intends to create a system that aims to monitor current performance and to simultaneously focus on future performance. It consists of a set of specific measures to evaluate strategic objectives and goals which should be capable of channeling energies, abilities and the knowledge of the individuals. The measures are thought in lined up perspectives: financial, customer, internal process, innovation capabilities and learning. The intention is to align individuals, organizational and inter-departmental initiatives in order to identify new processes and solutions meant to meet the clients' demands and the stakeholders' objectives. The main principle is to integrate the goals with strategies and thus design better processes. There are other models that are being applied and adapted to specific applications, for instance, the Performance Prism (Neely, Adams and Kenerly, 2002), SCOR Model (Cabral *et al.*, 2006), and also some excellence models developed by national standardization systems.

In such models, specific perspectives are addressed. For instance, the Performance Prism model (Neely, Adams and Kenerly, 2002) compares interests of organization and its stakeholders, taking into consideration what the stakeholder wants and needs from the organization and *vice versa*. Basically, this framework is based on some aspects (two facets), such as the stakeholder's satisfaction and contribution, establishing an axis whose three sides are strategies, processes and capabilities.

The Supply Chain Operations Reference-model (e. g., SCOR model) researches the enterprise processes and the necessary reconfiguration, evaluates the internal process performance and redefines targets, besides proposing the best practices to improve performance, and imposing standard alignment to features and functionalities. It contemplates an integration of the well-known concepts of business process reengineering, benchmarking and process measurement into a cross-functional framework (Cabral *et al.*, 2006). According to Supply-Chain Council, the SCOR model is *"a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities".*

Complementarily, the excellence models developed to be used in all types of organizations combine results, which must be ready to measure and instantiate the individual organizational performance related to a specific market or territory requirements. Some examples can be pointed out, including the EFQM (Europe), PNQ (Brazil), Malcom Baldridge Price (USA) and Deming Price (Japan).

Specifically, the EFQM Excellence Award is a European excellence model that assumes specific concepts to configure a model which aims to reach excellent performance in some aspects, such as relationship with customers, people and society, considering that there is a leadership figure establishing policies and strategies that are delivered to people, participants, resources and processes.

Thus, an effective PMMS needs to define a proper set of categories of performance measures that meet the needs of an organization or collaborative network. It includes proper key performance indicators (KPIs) in order to instantiate the CN performance. Therefore, it is necessary to understand that a PMMS is a system that provides information (indicators) to instantiate (or estimate) the level of achievement with the objectives and goals (adapted from Franceschini, Galetto and Maisano, 2007, cf. UNI 11097:2003 Standard and UNI-11097, 2003).

The development of performance management systems over the last four decades can be sequenced as follows: Skinner (1974), Johnson and Kaplan (1987), Keegan *et al.* (1989), Fry and Cox (1999), Lynch and Cross (1991), Eccles (1991), Kaplan and Norton (1992, 2001, 2006), EFQM (1999), Schwenker (1999), Medori and Steeple (2000), Neely *et al.* (2002), Cabral *et al.* (2005), among others. They covered diverse subjects, such as: hard-problem approaches, optimization, forecasting and soft-problem approaches, concerning to operations management, business strategy formulation processes, marketing performance evaluation. The BSC model was widely used initially, but is being replaced by the SCOR model in supply chain context. Using these models has contributed to improving the organizations' processes and aligning their business units or companies in their supply chain.

These models for performance measurement and management are basically characterized as process-, quality- and cost-oriented (Hronec, 1993). In fact, there are many approaches and specifications to each one of them and they have different criteria to be adapted to the main objectives that motivate their choices (Seifert, 2001).

Therefore, for Bititci *et al.* (2005), referring various authors, performance measurement systems should:

- *"be balanced in terms of the requirements of the various stakeholders (shareholders, customers, employees, society, environment);*
- *be integrated in terms of understanding the relationships between various measures;*
- *report performance results in order to support the strategy attendance;*

- *deploy a dissemination strategy. The organization's strategic goals for its critical areas should be translated;*
- *focus on business processes that deliver value;*
- *be specific to business units;*
- *include competencies that determine how values are created and maintained;*
- *include stakeholders' contributions because they are crucial to the success and failure of a business."*

According to what was explained, these characteristics are valid and appropriate for performance management. In this research, it means that a PMMS is more than the definition of performance measures and should be developed to manage organizations. Indeed, to measure performance, it is clearly necessary to choose forms of measurements that can instantiate the performance of the monitored process. In these measurements, the KPIs should be established in a simple and conscientious manner in order to illustrate the relevant aspects that will be assessed.

After that, a performance measurement system (PMS) can manipulate information and data relating to the process outputs in order to become in input data of KPIs used to instantiate the performance within the selected perspectives and approaches. Therefore, using problem solving methods makes it possible to obtain reliable results in performance. Furthermore, for a PMMS to be effective it should be practical, easy to measure, reliable, comparable to other organizations' systems, and should have low operating costs (Gunasekaran, 2001).

The evaluation results become the starting point for the decision-making process, particularly regarding the planning for the implementation of defined solutions to improve processes. Thereafter, internal criteria, regulation criteria, benchmarking for process performance, customer requirements and predicted constraints must be considered for obtaining reliable abstractions to improve process performance. Therefore, the established improvement actions are performed within business processes and the performance management process is undoubtedly an evolving concept that addresses several issues that are crucial to the improvement of the organization. However, they seem to depend very strongly on two factors: design a performance management framework (or conceptual model) and define the KPIs.

In fact, traditional measuring methods are not always effective because performance indicators do not derive from the organization's strategy (Kaplan and Norton, 1991). Such performance indicators do not help decision-makers to improve processes, nor how to determine the causes of poor performance and therefore they do not contribute to the management of evaluated processes (Hronec, 1993).

Furthermore, there is a tendency to create sophisticated performance measurement and management models to be applied in CNs because they have more complex tasks. Moreover, many organizations that implement measurement systems start strong, identifying the most important or apparent measures, but they do not transform them into change instruments (Becker, Huselid and Ulrich, 2001). Thus, it is crucial to develop conceptual frameworks for supporting the design of performance management systems in order to support decision-making processes.

What is more, in order to design, implement and update performance management systems, it is necessary to define the conceptual bases that establish the concepts, methods and practices to implement these systems. Thus, it is important to remember the specificities that should be considered for the processes of measuring and managing performance separately (Figure 20). Therefore, in performance management it is more important to define how the results of the measurement process should be used in order improve monitored processes. However, the various conceptual frameworks in the literature generally do not establish a border between these two distinct processes.

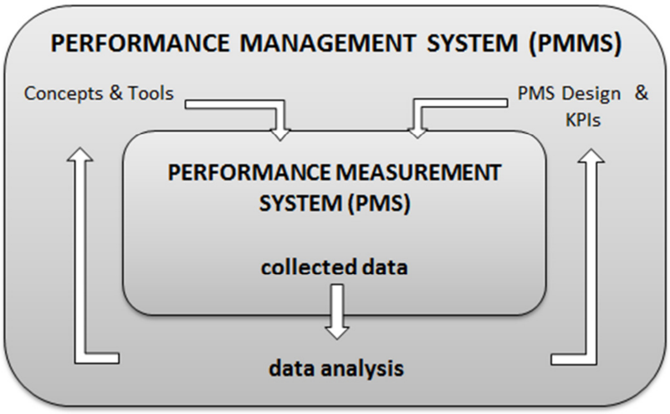

Figure 20. Performance measurement *versus* performance management

The difference between a performance management framework and a performance management system (PMMS) may not be clear. Therefore, were compiled and adapted the definitions found in English dictionaries (Farlex, 2010): a *framework is a set of assumptions, concepts, values and practices that constitute a way of viewing reality, and system is a group of interacting, interrelated or interdependent elements forming a complex whole that comprises an organized set of interrelated ideas or principles*. Furthermore, a *model is a schematic description of a system, theory or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics*.

In fact, in the current literature about this subject it is possible to find some frameworks that intend to provide a set of assumptions, concepts, values and practices that constitute a means of expressing ideas to be implemented in real-life environments. Several authors have presented models to schematically describe the characteristics, properties, and methods to measure and manage performance. For collaborative networks, specific models are becoming more and more frequent. Some conceptual frameworks are proposed for applications in CNs, including SC PM (Gunasekaran *et al.*, 2001), SCOR model (Cabral *et al.*, 2005), GPM-SME (Alba *et al.*, 2005), PMS-EVE (Saiz, Rodríguez and Bas, 2005), a Performance Measurement System for Extended Enterprises (Bititci *et al.*, 2005), CNPMS (Azevedo and Francisco, 2007), pmColNet (Carneiro *et al.*, 2007), VOPM (Seifert, Wiesner and Thoben, 2008), a prospective performance SCOR based model (Westphal, Thoben and Seifert, 2007) and COL-PMS (Verdecho, Alfar-Saiz and Rodríguez, 2009).

The GPM-SME (Alba *et al.*, 2005) can be highlighted, which was designed by a consortium of European automotive industries and named Global Performance Management. The aim is to combine “extended performance management” and “enriched performance management”. The first concept means an increase in visibility with clients, benchmarking with competitors and assessment of current suppliers or new ones. The second is directed towards new business paradigms such as innovation and agility, environmental care and green operations, ethics and corporate social responsibility, subjects that can be considered new business assets (Alba *et al.*, 2005).

The aim of the PMS-EVE, i.e. Performance Measurement System for Extended and Virtual Enterprises (Saiz, Rodriguez and Bas, 2005), is to propose a PMS for virtual enterprises (VE) and extended enterprises (EE) with regard to concepts on trust and equity. This approach differentiates the network level (global) from the individual level (local). Goals, objectives, strategies, plans, policies, critical success factors and KPIs are established as components of the PMS with four different perspectives: organization, resources, information and function inspired by the Architecture of Open Systems, CIMOSA (Amice, 1989).

Furthermore, the objective of the conceptual framework pmColNet (Carneiro *et al.*, 2007) is to design a performance evaluation system for collaborative networks that is supported by multi-criteria decision methods. This framework intends to provide methodological support for collaboration and negotiation between partners in a network so that it is possible to support the creation of a shared conception of performance management. This framework proposes the establishment of criteria and indicators to measure performance following constructivist logic and states that the opinions of members, individual performance system and a common language created by network members (Strauhs *et al.*, 2010) should also be considered.

In the new business context dominated by the concepts of quality and productivity, manufacturers are looking for suppliers to work cooperatively in order to provide better services, technological innovation and product design. As stated by Gunasekaran, Patel and McGaughey (2004), this development has allowed us to expand the scope of Supply Chain Management (SCM) through higher integration between suppliers and their customers. Therefore, these authors have made efforts to design a framework that deals with the identification of measures and metrics related to planning, sourcing, manufacturing/assembly decisions, delivery, and customer service level in order to achieve a fully integrated supply chain (Gunasekaran, Patel and Tirtiroglu, 2001). This framework, designed for supply chain performance management (SC PM), classifies metrics in three levels of management: strategic, tactical and operational management. These key measures then correspond to processes: planning, purchasing, production, delivery and customer satisfaction. As assessed by Verdecho *et. al.* (2009), this framework could consider the alignment of the supply chain (SC) with the individual performance measurement systems of each link in the SC. Indeed, some measures must be considered to evaluate performance in supply chain collaborative networks which refer to product cost, quality, agility, as well as delivery reliability and flexibility.

In sum, in the last decades some enterprises created competitive advantages by improving their processes of design, production, sales and delivery, technical assistance, and others. Especially, the increasing demonstrations of collaboration between organizations aim to enable competitive advantages in their business environments, primarily through resource, skills and knowledge sharing. Therefore, to measure performance, it is appropriate to properly select and define the KPIs that could accomplish the necessary information to analyze, develop and propose solutions to improve processes.

2.3.3 Key performance indicators

The measurement system captures the performance indicator values for the process outputs and the KPIs are then used as inputs for the performance evaluation process. The aim with the results obtained from this evaluation is to provide reliable information for decision-making processes, including the necessary actions to solve problems, to achieve continuous improvement, as well as for process reengineering or innovation. In fact, the KPIs should be selected in order to support decision-makers so that they can improve the performance of processes (Parmenter, 2010). Furthermore, there are key results indicators (KRI) which present how actions are conducted from a perspective or critical success factor. There are also the result indicators (RIs), or outcomes, which tell us what has been done. Finally, there are the performance indicators (PIs) that tell us what to do. Therefore, according to Parmenter (2010), the KPIs "*represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization*".

These assumptions establish the foundation to understand the relevant aspects on which performance measurement and management are based. Therefore, it is important designing the performance management process with regard to the information and data obtained from performance measurement. It suggests this process there are five stages: process output, measurement inputs, results evaluation, decision making and improvement actions. In Figure 21, it is possible to observe which activities can be related to each stage in order to carry out the performance management process.

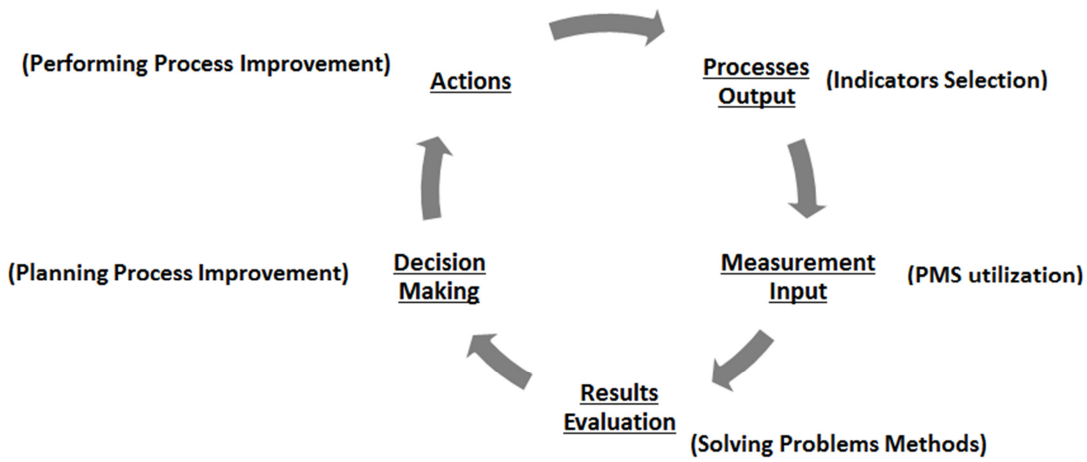

Figure 21. Performance Management Process

Furthermore, activities such as selection of indicators, use of performance measurement systems, use of problem-solving methods, improvement of planning processes and improvement of the process implementation lead to better performances in the management cycle.

According to Franceschini, Galetto and Maisano (2007), the selection of indicators should be performed taking into consideration whether the results of the processes meet the needs of the stakeholders and if it is essential to set up an evaluation system to test this condition. This may support decisions on which strategies will be implemented. According to the authors, they are:

- *quality policy*
- *quality targets*
- *the area of interest, within the organization: market competitiveness; customer satisfaction; market share; economic/financial results; quality, reliability and service; flexibility of factory systems and services supply; research and development; progress and innovation; management, development and enhancement of human resources; internal and external communication*
- *performance factors*
- *process targets*

Therefore, the selection of KPIs seems to be the most complex activity for planning a PMMS in order to face performance challenges and reach expected results and benefits for the organization or a collaborative network.

In this context, Parmenter (2010) proposes seven characteristics of KPIs, which are:

1. *Nonfinancial measures (e.g., not expressed in dollars, yen, pounds, Euros, etc.)*
2. *Frequently measurements (e.g., 24/7, daily, or weekly)*
3. *Acted on by the CEO and senior management team (e.g., CEO calls relevant staff to enquire on what is going on)*
4. *Clearly indicate which action is required by staff (e.g., staff can understand the measures and know what to fix)*
5. *Measures that tie responsibility down to a team (e.g., the CEO can call a team leader who can take the necessary action)*
6. *Significant impact (e.g., affecting one or more of the critical success factors [CSFs] and more than one BSC perspective)*
7. *Appropriate action is encouraged (e.g., they have been tested to ensure they have a positive impact on performance, whereas poorly thought-through measures can lead to dysfunctional behavior).*

Therefore, choosing the KPIs that meet consumer expectations, regulation standards and goals, become interesting to use the “process” concept using the following definition: “*an integrated system of activities that uses resources to transform inputs into outputs*” (Franceschini, Galetto and Maisano, 2007, referring ISO 9001:2008). By adapting it to establish and specify the inputs and outputs of the definition of the KPI, and replacing the term "resources" to "requirements", it is possible to design a framework based on IDEF

(Integration DEFinition) principles and methods (Michel, 2002) to choose KPIs. In Figure 22, the IDEF0 function modeling is presented as an example in order to explain this approach.

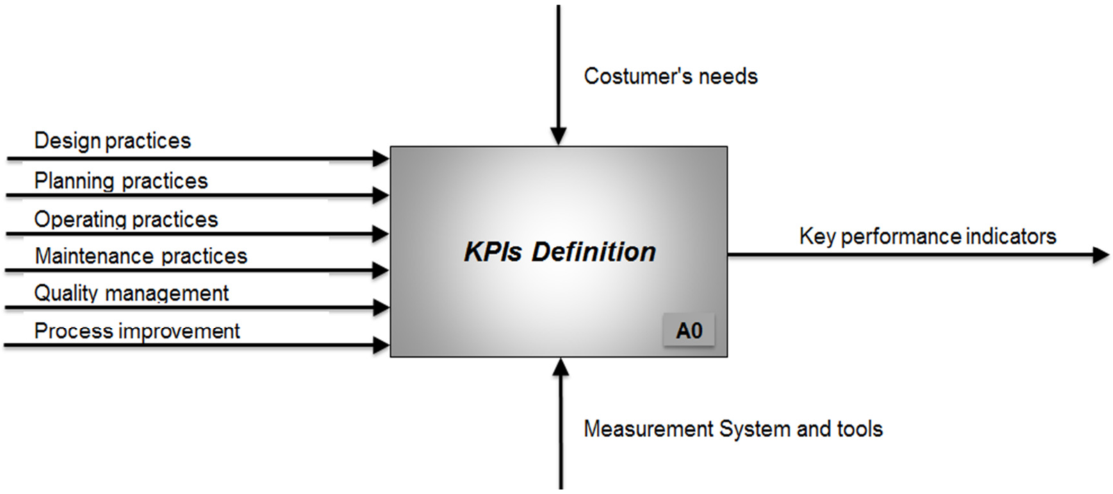

Figure 22. Definition of KPIs through the process concept

According to Franceschini, Galetto and Maisano (2007), the definition of indicators, the acceptance of the indicators by stakeholders, and indicators' abilities in terms of traceability and verifiability are critical aspects. Generally, each indicator refers to a specific class and is used as a basis for comparison. The reference values derive basically from the experience of the organization or benchmarking measures. These authors also argue that the indicators can support the control, communication and improvement actions implemented by decision-makers.

Furthermore, the use of appropriate KPIs could naturally support decisions to accomplish these goals. However, another approach establishes the management levels as strategic, tactical and operational levels (Gunasekaran *et al.*, 2001) stating that performance measurement is an obligatory activity to support supply chains in increasing organizational effectiveness. The authors also present several KPIs for these levels in a Supply Chain framework for performance measurement, including financial and non-financial metrics, such as:

- Strategic level – total supply chain cycle time, order lead time, delivery lead time, variations against budget, and others;
- Tactical level - purchase order cycle time, delivery reliability, effectiveness for master production schedule, and others;
- Operational level - capacity use, cost per operational hour; quality of delivered goods, supplier rejection rate, and others.

At all levels of management, the KPIs that show the results (efficiency and effectiveness) derived of the strategy should be used to evaluate if the process results complies with the performance expectations of the supply chain. This idea leads us to conclude that the use of a performance management system can support the decision-makers so that they can anticipate possible problems, optimize processes that have already been implemented, meet market needs, and also improve the relationship with the stakeholders of the supply chain.

With regard to the KPI selection some examples are presented in the following tables (10 to 12). There are others which are not explicit here. They are basically classified according to the approach defined by Hronec (1993) in which the classification is composed by aspects referring to time, cost and quality obtained from the monitored process. It is presented taking into consideration KPIs for different operations, such as: design, production, logistics and maintenance.

Table 10. KPI classes (Cost)

Operations	KPI Class (COST)
Design	• Cash to cash cycle time • R&D costs as percentage of total costs • % of R&D cost related to new product development • % of new product/service development launched on budget • % of R&D cost related to product improvements and extensions • % of R&D resources by total resources • Ratio of actual to projected unit production costs
Production	• Cost of managing process • Average wage for production employees • Work-in-Progress turns (COGS/Average value WIP) • Finished Goods Turns (COGS/Average Value Finished Goods) • Cost of goods sold (COGS) • Direct Product Cost • Raw material turns (COGS/Average raw material) • Warranty Cost as % of Revenue • Average Unit Cost
Logistics	• Total supply chain management cost • Direct Material Cost • Direct Labor Cost • Cost to schedule product deliveries • Warranty Cost per Unit Shipped • Freight cost per unit shipped
Maintenance	• % of preventive maintenance cost • % of corrective maintenance cost • Maintenance cost per unit • Ratio corrective versus preventive maintenance cost • Maintenance cost over asset value

Although many perspectives could be used, the following two tables only show examples from the availability and quality perspectives, considering the operations stated in the previous table.

Table 11. KPI classes (Availability)

Operations	KPI Class (AVAILABILITY)
Design	• Time-to-Market of new products/service • Time-to-market of changes to existing products/services • Average number of prototypes per new product • Average release cycle of engineering changes • Average days per engineering change • Test cycle time • % of new product/service developments launched on time
Production	• Average days per schedule change • Schedule production activities cycle time • Production cycle time • Manufacturing cycle time • Finished product cycle time • Manufacturing Schedule Adherence • % of hazardous operational waste • Production schedule attainment • Rate of damaged material due errors caused by workers • Production Plan Variance • % lost manufacturing capacity
Logistics	• Perfect Order Measure / Fulfillment • % of orders delivered to customer in the committed date • Quantity per shipment • % of schedules changed within supplier's lead time • % of orders delivered in full • Order fulfillment cycle time • On time delivery and pickup (Load, stop and shipment) • % of orders delivered with damaged products/items • Inventory replenishment cycle time • Transit time • Empty miles or kilometers
Maintenance	• MTTR (Mean Time to Repair) • Mean-time between failure (MTBF) • % of maintenance hours of operating time (maintenance efficiency) • Corrective maintenance to preventive maintenance ratio • Preventive maintenance hours as a percentage of total maintenance hours • % of preventative maintenance tasks completed by due date • Ratio of downtime to projected operating time

A huge amount of KPIs can be established to monitor the performance of processes. In this context, the concept of Total Quality Management has assumed an important role in defining and configuring of KPIs. Thus, examples of quality indicators are presented in the following table.

Table 12. KPI classes (Quality)

Operations	KPI Class (QUALITY)
Design	• Number of new requests (DPMO) • Test coverage % of software specifications • Must-Have Effect • Software Development Quality
Production	• Defects per million opportunities (DPMO) • Yield variability % • Overall Equipment effectiveness % (OEE) • Loss ratio of material per order • Rate of rejects
Logistics	• Service level • On time in full (OTIF) • % of orders delivered with damaged product • Optimize load fulfillment (OLF) • Supplier quality performance
Maintenance	• Backlog of maintenance work • % of maintenance rework • Corrective Actions Right First Time

Furthermore, other classes can be introduced in this approach, such as: environmental, safety & health and financial. For instance, reportable accidents (including fatalities) per hours worked, percentage of construction and recycled demolition waste, percentage of hazardous operational waste, percentage of suppliers that affirmed business code of conduct, percentage of energy used from renewable sources, percentage of materials used that are recycled input materials, and others.

In fact, the establishment of KPIs is an important task to be performed in order to make an effective PMMS. Finally, it is possible to conclude that it is important to use a PMMS for supporting the decision-makers referring to anticipate predictable problems, optimizing problem solving methods, achieving higher levels of knowledge on processes and effectively instantiating the organization's performance (Casarotto and Pires, 2001).

Furthermore, many approaches are introduced in this context for improving the performance evaluation. There are those who wish to formulate strategies and plan tactical actions through the use of performance management systems based on the BSC or the Performance Prism, while others want to focus on operational activities. For manufacturing environments there is one that is currently well accepted, which is the OEE-Overall Equipment Effectiveness (Gibbons and Burgess, 2010).

Therefore, some inputs may be explored, for instance, those originating from design, operation, maintenance and improvement practices, in order to achieve the key performance indicators. In fact, inputs and outputs of defined primary functions and processes should be identified and related with the KPIs. Furthermore, in a manufacturing approach, there is an expressive amount of KPIs that are applied regularly according to specific manufacturer organizations.

2.3.4 A taxonomy of collaborative performance measures

In order to understand the meaning of "measure", it is currently defined in the English dictionary as "*a reference standard or sample used for the quantitative comparison of properties*" (Farlex, 2010), or "*a basis or standard for comparison*" (Merriam-Webster, 2010). Therefore, the choice of indicators that can be used to compare results with targets is crucial for evaluating operational systems. According to Franceschini, Galetto and Maisano (2007),

> *"A good indicator set directs and regulates the activities in support of strategic objectives and provides real-time feedback, predictive data, and insights into opportunities for improvement. In addition, indicators need to be flexible in recognising and responding to changing demands placed on the operating system due to product churn, heterogeneous customer requirements, as well as changes in operating inputs, resources, and performance over time".*

A performance indicator is designed to understand the context they intend to measure performance and make tangible the operating system, as well as properly define the representation-target of the respective context (Franceschini, Galetto and Maisano, 2007). In the context of collaborative network environments it is possible to state that:

- the context is the inter-organizational processes
- the representation-target is the performance and alignment measurement
- the performance indicators are, for instance, the degree of alignment and the predictive measures

An indicator can be considered a map of the empirical system that represents the real world that is transformed into a symbolic system that can be represented by a numerical system. When empirical expressions (operations) occur, they often have relations which are conditioned by the context (Franceschini, Galetto and Maisano, 2007). According to Graser *et al*. (2005), cf. Eschenbaecher and Seifert (2004),

> *"Generally, the challenge in Performance Measurement is the necessity to transfer highly complex real-world processes to a simplifying processes model, to derive performance information from the model, and to transfer these results back to the real world."*

Furthermore, according to Franceschini, Galetto and Maisano (2007), the indicators are classified as objective, subjective, basic and derived. The objective indicator aims to link empirical manifestations to symbolic manifestations. For example, the quantity of orders delivered represents the symbolic manifestation derived from the empirical manifestation of production and distribution. Moreover, subjective indicator represents the symbolic manifestations derived from subjective perceptions or opinions of decision-makers allowing different organizations to have different maps for symbolic manifestations of the same empirical manifestation. This can be exemplified by the perception on inter-organizational alignment in collaborative networks when the representation-target can be associated with different symbolic manifestations, for instance, by using a 5 level scale consisting of 1-lowest, 2-low, 3-medium, 4-high, 5-highest. Furthermore, when the indicator is obtained through the observation of an empirical expression it is denominated as a basic indicator or "level zero" indicator, for instance, the number of orders delivered or the number of products with non-conformities in the production line. In addition, the derived indicator is obtained by the synthesis of two or more indicators, for instance, the ratio between products with non-conformities and good products.

Furthermore, the performance indicators that more adequately represent the process performance are called Key Performance Indicators (KPI). It is usually a derived indicator that represents a symbolic manifestation for measuring performance under the strategic and operational processes targets. Indeed, to create indicators which reflect the performance of processes, classes of indicators that deal with different aspects such as cost, availability, quality, safety & health and environmental must be established. Using the information modeling IDEF1 (Figure 23) to describe the relevant aspects that are used to establish the classes of KPIs, it is possible to present the KPIs representations.

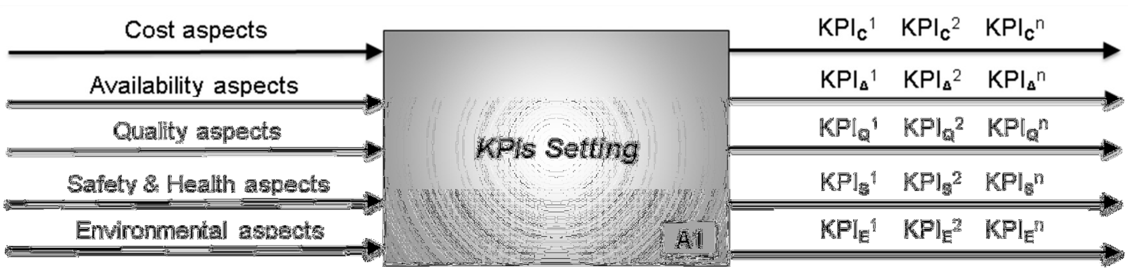

Figure 23. Key performance indicator settings

The KPI selection implies that the objective and/or subjective indicators must be established in order to supply the PMMS requirements such as indicators of effectivity (e.g., market share, product value), effectiveness (e.g., customer satisfaction, ramp-up time, increase of new clients) and efficiency (e.g., downtime, waste).

In fact, the collaborative measures that can be used in the PMMS which will be applied in collaborative network environments must be duly characterized. Hence, the metrics that can be chosen to be used in the PMMS must be consistent and trustworthy. Indicators that instantiate the individual performance of each partner must be identified along with performance indicators for inter-organizational processes. KPIs can be created and collected to measure performance of inter-organizational processes in order to improve performance throughout the cooperation or collaboration life-cycle. And yet, to measure this in a more efficient way, the business processes that cover several organizations in a collaborative network have to be monitored by relevant KPIs, thus making it an applicable and reliable process for performance management (Matheis *et al.*, 2008).

According to Hronec (1994), the traditional output measures are not efficient because they do not explain to the decision-makers how to improve the method. Typically, they focus on results and effects, not on processes or causes. In a worst case scenario, they are not related to the organizational strategy. In order to reach its optimum performance these output measures must consider the relationship between cost and quality and also between quality and time response. In collaborative networks this affirmation may be essential to defining the measures to whom it can be applied.

The performance measurement is a toolkit providing methodologies, directives and indicators for measuring and evaluating the performance of processes. Applying a detailed set of measures offers quick identification and assessment of weak points, for instance, of inter-organizational operation's processes in order to improve the processes efficiency (Graser *et al.*, 2005).

In order to establish metrics for the performance measurement in CNs, two kinds of different measures can be used to extract the data from the participants, the local performance measurement system (LPMS), which are transferred and compiled as useful data for the collaborative PMMS. These are the individual enterprise measures (enterprise scorecard) and the inter-organizational measures (collaborative network scorecard). They can be seen in Figure 24 with the following explanation.

Figure 24. Local performance measurement system (LPMS)

Enterprise scorecard - A set of measures can be used by the CN´s individual participants to assess their own performance. Some measures do not need to be presented or transferred to the collaborative PMMS because each participant is independent. However, there are some measures that relate to strategic objectives and also to the operations of the individual enterprise participant that should be disseminated. These measures are called Local Strategic Measures and Local Operational Measures (e. g., LSM and LOM). However, there are others that are both strategic and inter-operational, that can be shared and must be transferred and compiled for the collaborative PMMS. These are called Local Shared Strategic Measures (e.g., LSSM) and Local Shared Operational Measures (e.g., LSOM).

In fact, an approach is proposed in which these "local measures" are distinguished from strategic measures and the measures related to the inter-organizational processes. This approach corresponds to the targeted measures for performance management of each partner. Furthermore, there are measures for composing the set of measures of the collaborative PMMS that can be shared. These measures (e.g., LSSM and LSOM) are related with local performance indicators, for strategic KPIs (KPI^{st}) and operational KPIs (KPI^{op}) they are respectively expressed in the following expressions.

$$LSSM = f\,(KPI^{st}{}_{1}, KPI^{st}{}_{2},\ldots, KPI^{st}{}_{n-1}, KPI^{st}{}_{n}) \qquad [2]$$

In this situation it can be seen that the various KPIs used to measure whether the strategy is effective make it possible to support the calculation of the LSSM measure.

$LSOM = f\ (KPI^{op}{}_{1},\ KPI^{op}{}_{2},\ldots,\ KPI^{op}{}_{n-1},\ KPI^{op}{}_{n})$ [3]

Furthermore, it can be seen that the various KPIs, used to measure whether the inter-organizational processes become efficient and effective, allow us to support the calculation of the LSOM measure.

Collaborative network scorecard - The measures transferred to the collaborative PMMS by every individual organization are used in order to constitute the measures that make it possible to evaluate the global performance. These are measures that arise from inter-organizational processes (Figure 25). The first measure is related to strategic objectives (e. g., CNSM) and the other measure is related to the inter-operations (e. g., CNIM) which must both be transferred and compiled for the collaborative PMMS.

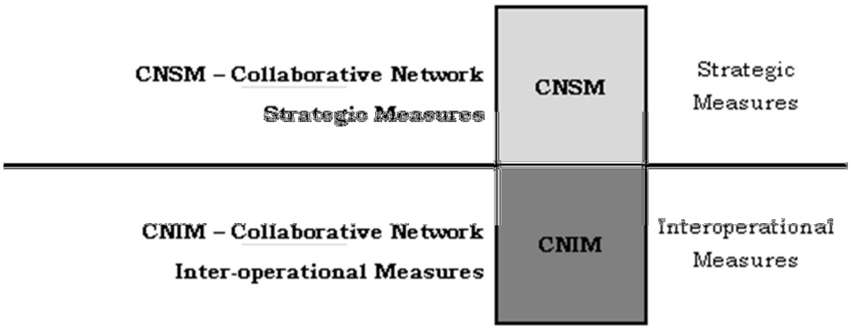

Figure 25. Collaborative network performance management system

These measures (e.g., CNSM and CNIM) are a function of inter-organizational performance indicators for strategic KPIs (KPI^{CNst}) and inter-operational KPIs (KPI^{CNop}). These measures represent the set of indicators extracted from the inter-organizational processes of the CN which make it possible to instantiate its overall performance, as expressed in the following formulas:

$CNSM = f\ (KPI^{CNst}{}_{1},\ KPI^{CNst}{}_{2},\ldots,\ KPI^{CNst}{}_{n-1},\ KPI^{CNst}{}_{n})$ [4]

In this situation it can be seen that the various KPIs used to measure whether the CN strategy is effective then make it possible to support the calculation of the CNSM measure.

$CNIM = f\ (KPI^{CNop}{}_{1},\ KPI^{CNop}{}_{2},\ldots,\ KPI^{CNop}{}_{n-1},\ KPI^{CNop}{}_{n})$ [5]

Furthermore, it can be seen that the various KPIs used to measure whether the inter-operational processes become efficient and effective, make it possible to support the calculation of the CNIM measure.

The performance of the CN's inter-organizational processes have many direct and indirect positive effects on productivity that, according to Mayer (see Cabral *et al.*, 2005), can be summarized in two levers of efficiency, when they bring solutions for integration and its respective reduction of costs, and when they become agile through business process automation.

2.3.5 Performance forecasting and prediction

Organizations are constantly facing changes in their business environment, looking for competitiveness and attempting to prevent uncertainty. This implies that they must develop strategies that enable organization systems to be more flexible and agile. Therefore, decision-making processes are crucial in order to reach a robust positioning in the respective business environment. They require increasingly more forecasting and data fusion methods and tools within the systems to measure and manage the performance.

According to Harbour (2009), forecasting measurement is used to predict the future or to extrapolate from one environment or scene to another through performance measures. This prediction of what might happen, but has not yet happened, is often based on what has already happened, i.e. with descriptive measures. Therefore, these measures are also called leading indicators, suggesting that they represent types of predictive measurements.

Forecasting techniques have attracted a great scientific interest and are constantly requested by industry in order to support sales, scheduling and performance management. According to Seifert (2009), there are basically three main forecasting methods, which are the deterministic, the stochastic and heuristic methods, with different approaches (Figure 26) and various methods for practical applications.

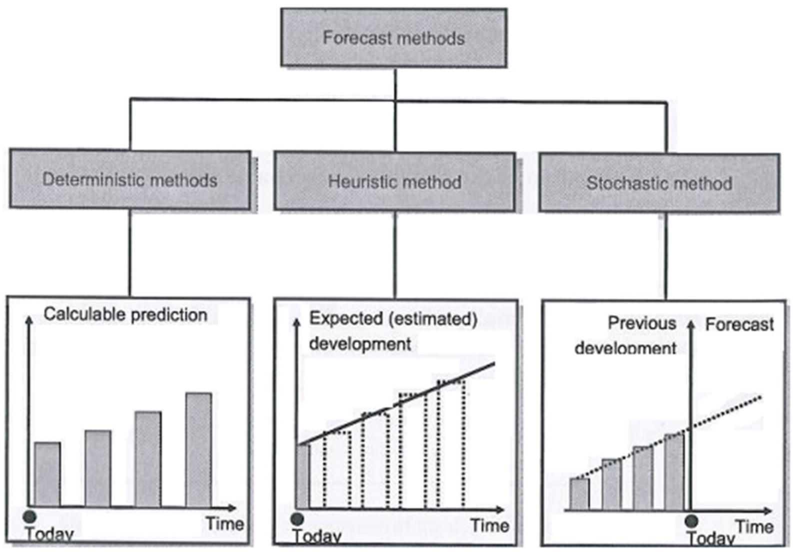

Figure 26. Basic methods for forecasting (Seifert, 2009)

Performance forecasting and predictive measures require distinct methods and tools for forecasting and data fusion techniques. These are constantly requested by industry in order to support sales, scheduling and performance management. These mathematical forecasting methods aim to provide results with low error and they have varying degrees of difficulty in relation to structuring, computing and application. The deterministic methods are supported by credible sources and know the future values in advance, meaning that they are good for quantitative planning. On the other hand, stochastic methods and heuristics are characterized by being based on past data. Heuristic methods require a high level of knowledge on the system under study and are usually associated with large uncertainties. Nevertheless, they are simple to implement and have low computational costs. In turn, the stochastic methods are based on mathematical methods in regression analysis, moving averages or exponential smoothing, allowing the mathematical extrapolation of known data. Therefore, when properly applied, these methods make it possible to generate estimates that meet planning, analysis and monitoring process needs.

According to Busi and Bititci (2006), new terms are being used as performance management measures, including "proactive" and "passive", "feedback" and "feedforward" control, or "lagging" and "leading" measures. This is reflecting a strong change in performance management that has occurred in the last decades, transforming concepts and points-of-view on the importance of performance measurement and management, as follows:

- *"From performance measurement to performance management;*
- *From individual to collaborative performance measurement;*
- *From lagging to leading performance management."*

Using leading measures of real-time performance, it is possible to do a feedforward control on the development and deployment of plans and objectives (Figure 27). Otherwise, through a feedback control the comparison of actual performance with proposed targets is based on historical lagging measures. Therefore, proactive performance management, using feedforward and feedback control, tries to predict future performance while treating processes with poor performance. It is necessary to provide a proper mix of leading and lagging measures, thus enabling the use of forecasting methods and tools to obtain good predictions.

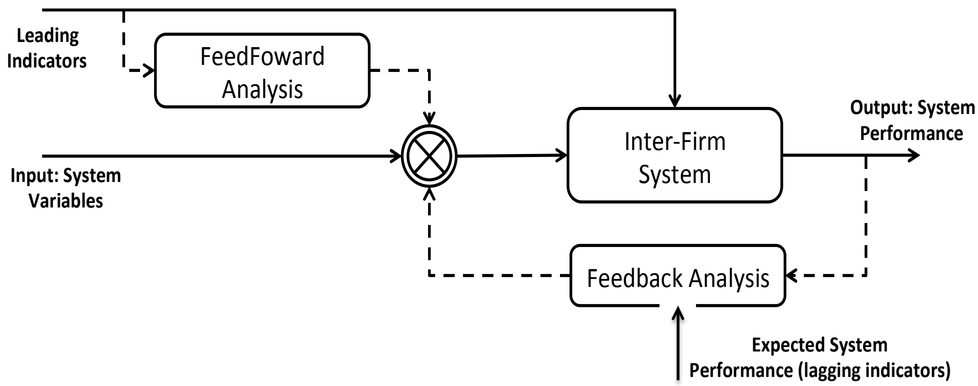

Figure 27. Feedback and feedforward control

According to ICPM (2008), "*lagging indicators are those measures that for the most part can be associated with previous event(s) and a leading indicator is an individual measure, or collection of measures, that are predictive of future system performance before this performance is realized*".

Performance management systems have been developed to identify areas of poor performance and areas where processes could be improved. However, the measurement causes the systems to fail because the measures that are traditionally used are based on feedback from past activities and have not changed. As it is possible to perceive, this approach is changing to a predictive control (Amaratunga and Baldry, 2002).

Furthermore, obtaining reliable predictive measures can be facilitated by systems with a large quantity of performance data, as opposed to very little performance data and high variability. In many cases the best data to predict performance can be data on past and present performances. A predictive model consists of a number of predictors with variables that are likely to influence future behavior. The statistical analysis and/or data mining, which deal with extracting information from data, should be used to support predictions for future behavior patterns. Therefore, predictive measures should be applied in measurement systems and should be designed to create a balanced set of performance measures to monitor the intra- and inter-organizational processes, as well as external and extended processes. These measures can then support proactive management based on feedback and feedforward control.

Even though performance prediction is a highly explored issue in computer engineering, mainly in software performance models, some initiatives have used this to infer the future or extrapolate the performance measure in one setting or environment in another. Predictive measures are also sometimes called leading indicators, suggesting that they represent types of feedforward measures (Harbour, 2009). In this context, the Prospective Performance Measurement (Westphal, Thoben and Seifert, 2007), a SCOR-based model that introduces the performance prediction for partner selection, is one of the pioneers in this approach for collaborative networks. In fact, this means planning preventive actions to make improvements before it is necessary to take corrective actions.

Performance indicators should be relevant and meaningful in relation to the emerging business model based on collaboration. In this context, the measurement systems should be designed to use a balanced set of performance measures that will make it possible to monitor the external relations as well as the efficiency of internal and extended processes. This will then support the proactive management based on feedback and feedforward operational control (Busi and Bititci, 2006).

This approach normally requires extrapolation and interpretation. Therefore, a mature system with precise control and abundant performance data is easier to perform prediction measurement than the immature system with little historical performance data. Predictive measures may help extrapolate data to instantiate the future. In many cases, it makes it possible to find better predictive performance values using descriptive measures that instantiate the current and past performance data. This kind of measure only describes what is happened and has happened.

Furthermore, using predictive metrics it is possible to achieve better results when methods of analysis for process improvement are applied, including Lean Six Sigma and Failure Method Effects Analysis (FMEA), among others. The predictive measures can assist decision-makers (Figure 28) in dealing with the following tasks:

- Predicting and improving performance of future tasks assigned;

- Preventing problems that could cause delays in the schedule of activities, as well as in the cost of operations;
- Supporting prediction process management and preventing the appearance of bottlenecks;
- Reporting possible future outcomes in order to keep managerial and operational teams alert. Therefore, the process of establishing performance targets change from an approach where average values obtained by calculating traditional forecasting is used, to another where values are used close to reality that may exist in the future if, in this moment, the variables considered in the calculation of prediction occur;
- Helping learning teams to conduct proactive planning;
- Support decision-makers so that they can learn how to drive proactive planning.

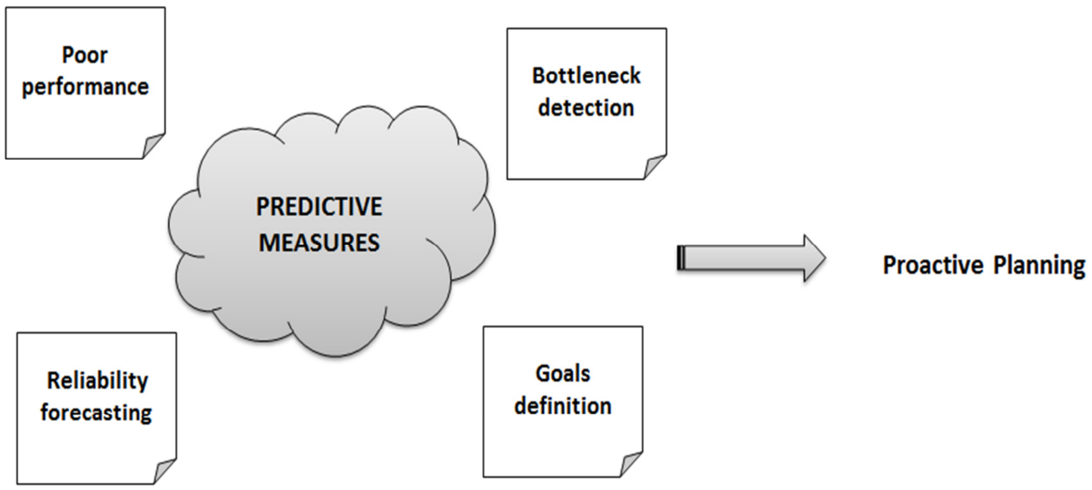

Figure 28. Consequences of using predictive measures

Therefore, predictive measures can bring some benefits, such as preventing bad outcomes, focusing management on key drivers, saving time in process planning, presorting the magnitude of possible bottlenecks and achieving higher quality to the definition of targets. It can be a useful approach to deal with uncertainty and provide a strong support for face the market challenges.

Indeed, one of the main contributions of this research was developed a tool to forecast performance values using a mathematical estimator, supported by Artificial Neural Networks, which will permit complex system modeling in a simple and intuitive manner. This approach is improved by the Kalman Filter, a modeling error filter, which makes this proposed tool immune to noise from internal and external disturbances. A mixture of deterministic and heuristic methods characterizes the proposed tool.

The Artificial Neural Network (ANN) basically imitates how the human nervous system processes information to take action. In the human brain, neurons communicate using short duration electrical signals. Neurons send and receive a huge amount of information between them. The neurons are interconnected by branching fibers called axons. The voltage pulse travels along these paths carrying information, so that a threshold value of signal is exceeded

(Minin, 2006). Here, the term "network" refers to the system of artificial neurons that range from a single node to a large number of nodes that are connected to each other.

Furthermore, the ANN is important in a wide range of applications. The tool's characteristics include: a continuous learning capability, which enables it to continuously adapt to different conditions, respond to new situations and more common and complex modeling systems with non-linear behavior; fit tolerance to structural and parametric changes; reject input noise and finally, offer a faster processing capacity. Hence, one of the major applications of the ANN is forecasting. In fact, there are a series of characteristics which make the neural networks an attractive and valuable tool for forecasting tasks (Farahat, 2005).

According to Minin (2006), the ANN

> *"it is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process."*

The ANN is a nonlinear tool used to support system modeling because it has data-driven self-adaptive capabilities that allow for the use of any continuous function with the desired accuracy. It can also use non-complex examples from the past to emulate the system's behavior without prior knowledge of the relationship between input and output variables. Thus, as it considers the factors that can be anticipated and envisaged, this modeling approach makes it easier to predict future performance.

According to Farahat (2005), the ANN architectures that are most commonly used and offer the best results in terms of demand forecasting, performance, cost, risk and other factors in manufacturing are: back-propagation (BP) and radial basis function networks (RBFN). In the forecasting domain, the RBFN is considered more accurate and less time consuming. As the input variables go directly to the hidden layer without weights, the RBFN models are simpler when compared to the BP architecture. In fact, the main problems of the back propagation architecture are the slow convergence, the difficulties of generalization and the arbitrary nature in network design. In fact, the RBFN has overcome these limitations and can provide better results. Almeida's (2010) ANN training process to determine the predictions is presented in the Appendix A.

In order to adjust the system more accurately and increase its emulation capability and reliability, neurons are linked together in the form of a network. This network may range from a single node to a large collection of nodes, in which each one is connected to every other node in the net. In the image below a circle represents each node and the weights are implicit in all connections (Figure 29). The nodes are distributed in a layered structure where signals flow from an input to an output, passing through a series of hidden layers.

Although the RBFN can be used to forecast performance the development of a neural network predictor is not simple and obvious. It is very important to consider the structure and number of layers, the number of nodes in each layer and the number of arcs that connect with the nodes. Furthermore, other aspects should be studied and selected, such as the activation functions of hidden and output layers, the training algorithm, standardization methods, training and test sets and performance measures.

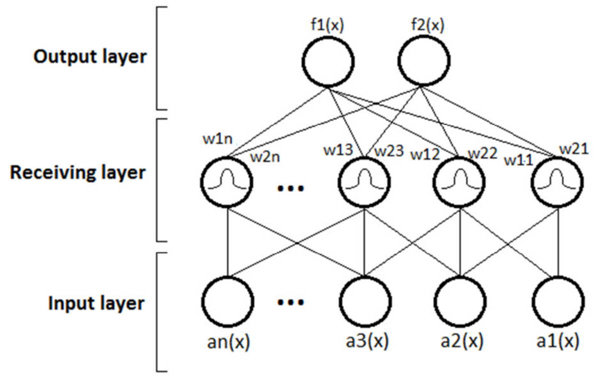

Figure 29. Simple example of neural network (RBFN)

As outlined by Camarinha-Matos and Afsarmanesh (2008a), it is possible to use two modes of operation for the neuron's approach: the learning mode and the using mode. The learning mode is characterized by training to trigger (or not), by finding the right synaptic weights to guarantee that the output matches the desired output, according to particular input patterns. In the using mode, when an input pattern is detected, an output is generated according to the set of weights the network learned in the previous phase.

These features will be explored in the following sections on task prediction due to the speed of processing and the ease of transformations. Furthermore, this tool presents a continuous learning capability which allows it to respond to new situations (generalization). It tolerates parametric and/or structural changes, thus making this tool very robust (Almeida, 2010).

ANN can be used successfully in conjunction with other applications to deal with several types of problems. With reliable historical data to train the network is possible to develop applications that can include information to classify VBE participants according to their availability and suitability for emerging collaboration opportunities, their historical data (data mining) on cases of past collaboration and the likelihood of success of potential consortiums (Camarinha-Matos and Afsarmanesh (2008a).

Indeed, with the ANN modeling approach it is possible to emulate and anticipate the expected performance of a complex system. Nevertheless, it is necessary to be cautious with the use of ANN since there are a lot of causes and factors that can affect the performance of a ANN tool. In relation to estimation and including the use of computer applications, the generation of noise in measurement creates unknown states where the representation of estimates usually have noise derived from measurements. In many complex systems control is not able to measure every variable. Consequently, the Kalman filter can infer the missing information using indirect (and noisy) measurements and also predicts the likely future course of dynamic systems that people are not likely to control (Almeida, 2010). This mathematical tool was developed by Rudolf Emil Kalman (Kalman, 1960) to optimize the estimation of state models and is important in modern control and system theories because it significantly improves applications in the field of control engineering and management areas.

According to Welch and Bishop (2006), the Kalman filter is

> *"a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean of the squared error. The filter is very powerful in several aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modeled system is unknown."*

Basically, the Kalman filter is designed to help estimate the "state" snapshot of a linear dynamic system perturbed by white noise. On a higher level of mathematical abstraction, the measures linearly related with the state that are corrupted by white noise can be defined (Bolland and Connor, 1997).

According to Libonati, Trigo and DaCamara (2007), the advantages of using the Kalman filter when compared to other statistical techniques include that fact that it recursively updates the regression coefficients. For instance, it makes it possible to adapt to changes in the model of numerical weather predictions and also to different weather situations which may vary significantly throughout the year. And yet, when compared with other techniques, the Kalman filter does not require a large data set. Therefore, the Kalman filter was used in order to eliminate the possibility of non-controllable errors (where possible) that can originate from the modeling system or from the leading and lagging factors measured. However, only sometimes it is possible to accurately extract the mathematical model that describes the system's dynamics. It is then essential to express gaps in the knowledge more precisely and use them to estimate the state of the dynamics. Due to the fact that this filter is capable of supporting estimations for past, present and future states, even when the system modeling accuracy is unknown, this tool is normally applied to optimize the estimation of state models. Consequently, by incorporating these two significant approaches, both ANN and the Kalman filter, it was possible to develop a tool that was able to predict the evolution of the behavior of complex systems, minimizing the different errors and noise that can disturb the normal assessment of the performance of the system. A mathematical explanation and the model of the Kalman filter are presented in Appendix B.

The Kalman filter, basically, addresses the general problem of trying to estimate the state of a discrete time controlled process that is governed by a linear stochastic difference equation. However, when a process is estimated to be non-linear, a mathematical filter must be used to linearize the current mean and covariance (Welch and Bishop, 2001). This is not useful when analyzing complex non-linear systems that are not Gaussian. According to Almeida (2010) "*this filter, gives an approximation of the optimal estimate, and so the system's non-linearities turn into a linearized version around the last state estimate. For this approximation to be credible, it is necessary for this linearization to be an efficient approximation in the entire uncertainty domain associated with the state estimate*". In addition, according to Welch and Bishop (2006), the Extended Kalman Filter (EKF) it is an *ad hoc* state estimator that uses the linearization to approximate the optimality of Bayes' rule. However, the EKF may diverge if the consecutive linearizations are not sufficiently efficient within the associated uncertain domain.

2.3.6 Performance benchmarking analysis

Benchmarking is a management approach used to observe and implement the best practices adopted by similar organizations, especially industry, to improve their performance although this approach can also be applied in different industries (Joo, Nixon and Stoeberl, 2011). Benchmarking is defined by business dictionaries (Businessdictionary.com) as "*a measurement of the quality of an organization's policies, products, programs, strategies, etc., and their comparison with standard measurements, or similar measurements of its peers*".

The objectives of benchmarking are to determine what and where improvements are used for analyzing how other organizations achieve their high performance levels and to use this information to improve performance.

Camp (1989) defined benchmarking as *"the continuous process of measuring products, services, and practices against the toughest competitors or those companies recognized as industry leaders"*. According to Choy, Lee and Lo (2002), "*benchmarking is the systematic comparison of elements of performance in a company against those best practices of relevant companies, obtaining information that will help the observing company to identify and implement improvements*". Therefore, the analysis of performance benchmarking aims to compare the results and best practices of competitors or other organizations with high levels of excellence to improve the processes and knowledge of an organization.

The use of this approach can be described as a continuous process of measuring and comparing key performance indicators of products, services and processes with reference to organizations recognized as market leaders. Then, it becomes interesting to determine performance values which compare the performance of companies, business units and internal units of production.

The benchmarking process may consist of steps from the definition of what will be compared, data collection and processing, until the availability of the output data. In this context, Araujo (2000) presents a typology of benchmarking forms. This author applies the concepts of Camp (1989) to describe the types of benchmarking: internal, competitive and generic. Furthermore, adds the forms "shadow", functional and collaborative which mean:

- Shadow - it is the study to make comparisons with competitors without them knowing, but nothing to do with espionage.
- Functional - the study compares similar cases, but not equal, since the same business environment.
- Collaborative - is the study conducted among a group of companies, or within an enterprise network (e.g., collaborative networks).

Therefore, for comparing performance in collaborative networks an interesting technique can be used that is the Data Envelopment Analysis (DEA) which is a mathematical programming technique developed to evaluate the performance of homogeneous units in a number of practical applications, such as a set of hospitals, a number of schools, a set of banks, others (Ramanathan, 2003). This technique has been successfully used to evaluate the performance related to a number of companies that use a variety of identical inputs to produce a variety of identical outputs.

The DEA is a linear programming technique that measures the performance efficiency of Decision Making Units (DMU) which has their performance evaluated using the concept of efficiency or productivity. These concepts mean looking at the ratio of total outputs and total inputs.

The DMUs considered efficient by the DEA are rated as 100%, while the remaining must have a lower classification. Therefore, the possible improvements for a particular DMU are suggested, not in an arbitrary direction, but based on the performance of the most successful DMU with similar characteristics.

Following is presented an example (Table 13), adapted from Ramanathan (2003), that briefly explains the DEA method. Considering:

Efficiency (E) as the ratio of outputs/inputs (5)

Table 13. DMU imputs and outputs

DMU	Inputs	Outputs	Efficiency (E)
A	8.6	1.8	0.209
B	2.2	0.2	0.091
C	15.6	2.8	0.179
D	31.6	4.1	0.130

In this case, the DMU "A" has the highest efficiency, while DMU "B" has the lowest note as it is possible to follow in the graph (Figure 30).

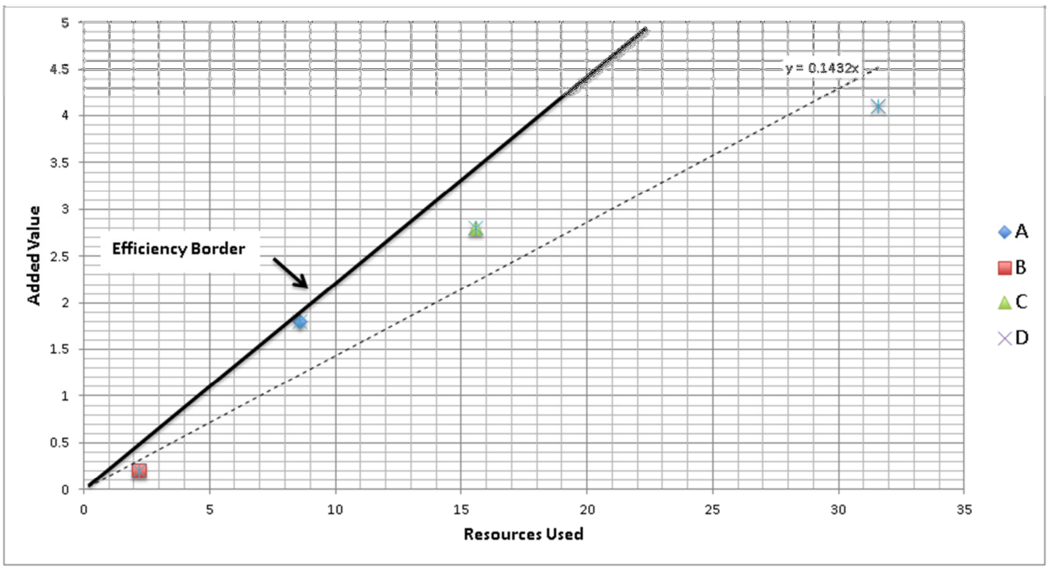

Figure 30. Efficiency border of DEA approach

In the represented image above, the dotted line represents the average line that passes through all points and that can be calculated by statistical means. This line could conclude that the points above could be considered satisfactory as the low point could be considered unsatisfactory.

On the other hand, the efficient frontier line defines the best performance of the DMU (A) and measures the efficiency of using the remaining deviations from this line. Thus, the analysis by DEA identifies the point A as an example to be followed in future improvement actions, thus serving as a "benchmark". In this case, we can determine the performance goals for DMUs with lower efficiency so that they reach at least the same efficiency of DMUs with better efficiency. For example:

Target for Inputs = Current Relative Efficiency/100 [6]

Table 14. DMU's current relative efficiency

DMU	Efficiency	Relative efficiency (%)
A	0,209	100,00
B	0,091	43,40
C	0,179	85,80
D	0,130	62,00

Thus, for DMU B:

Target for the used resources = 2.2/0.434 = 0.955

That is, company B would use $0,955 million in funds invested for obtain the same value as $0.2 million currently earned (Table 13). So, for this company, the savings to be made should be $1.245 million.

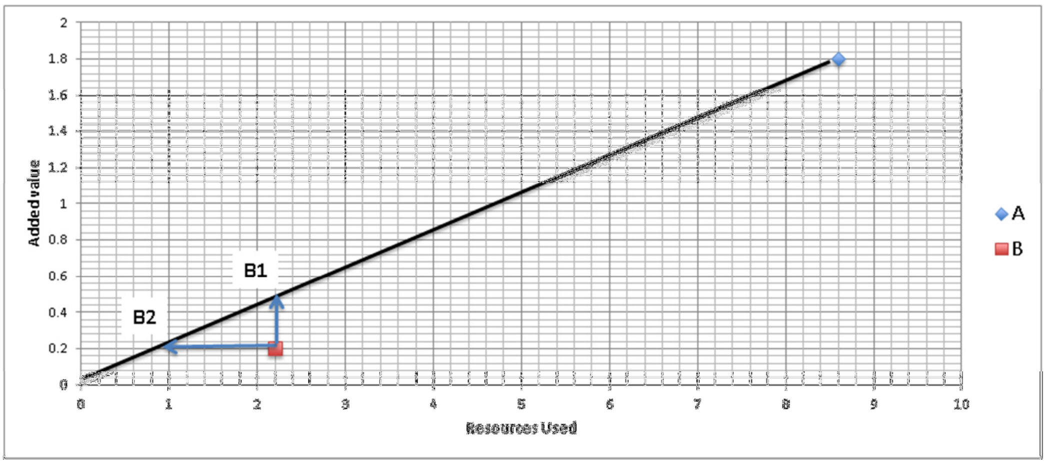

Figure 31. Strategy by improving process using DEA approach

Similarly, it is possible to identify another strategy to be followed by company B. In fact, if it is able to improve its processes in order to increase the added value of $0.2 million to approximately $0.48 million, then the position of DMU B on the graph would shift to the efficient frontier, the would represent an increase of productivity, while maintaining the resources used.

Subsequently, various approaches can be employed according to the type of DMU's that will be measured. Hence, the efficiency of distinct DMUs in the CN can be compared in terms of the types of efforts (inputs) that are determined to measure the success of these DMUs.

Therefore, the challenge is to find performance indicators based on data from "inputs" and "outputs" to measure the overall efficiency of each DMU and then compare them in relation to improvement of that has the worst performance.

2.4 Concluding Remarks

In this chapter the aim was to explore the main issues of the subjects "collaborative networks", and "performance measurement and management". The state-of-the-art of these subjects was surveyed, specifically focusing on the collaborative network environments in order to identify the main features, benefits and morphologies currently existing. Also, a set of theoretical concepts applied to this subject were considered.

Subsequently, the main characteristics of collaborative networks were addressed, including the existing typologies and proposed topologies, considering the different approaches of several authors and projects in this field.

Furthermore, issues relating to performance measurement and management were presented to clarify the difference between 'measurement' and 'management'. Distinct performance management systems were also presented in a manner that made it possible to explain their approaches and main features. In particular, the need to establish conceptual frameworks in the development of a PMMS was discussed. In order to support this development the steps taken in the process of establishing KPIs were described and both the characteristics and classes of KPIs were addressed with examples.

The concepts and approaches used for performance prediction were discussed, stressing the relevance of predictive measures for performance management and also highlighting the effect of forecasting on the proactive management of organizations.

Finally, the performance benchmarking analysis was addressed and the DEA method was explained in order to use it in to assess the performance of CNs of similar business areas by determining a benchmark which may be useful in the evaluation of the participants' performance.

In line with these explanations, the following chapter presents a proposal for developing alignment measurement approaches and methods towards to support performance management in collaborative networks.

Chapter 3

Defining and Measuring Alignment

This chapter aims to conceptualize the alignment in the context of performance management. In order to accomplish this it is necessary to define why measuring alignment could be used to assess the effectiveness of the inter-organizational processes of CNs. First, such an approach needs to define precisely the concept of alignment. Furthermore, it is necessary to verify research gaps and to establish requirements for alignment measurement. Then, some alignment measurement approaches are proposed taking into account the functional requirements, as well as the alignment factors, necessary to manage performance in CNs with different typologies and business environments.

3.1 Alignment Definition

3.1.1 An overview of the alignment issue

According to Mintzberg and Quin (2001), strategic decisions are those that determine the overall direction of an organization in light of predictable and unpredictable organizational changes in all environments that influence this organization. In fact, in order to support decision-making systems, it is necessary to align organizational strategy with organizational structures, project deployment and information technology strategies.

Regarding the necessity to achieve competitiveness, Hanson *et al*. (2012) explores the alignment between processes outcomes and strategic goals, stating that

> *"The implicit proposition is that alignment is a state that can be created and that has a causal linkage to competitive advantage. While the construct of alignment is conceptually clear and intuitively appealing, it is not at all clear how one might actually measure it. …"*

This assumption motivates decision-makers to understand and adapt the alignment concept to use it to measure performance in collaborative networks as is explained in the next section of this chapter.

Alignment can be referred separately or simultaneously according to the main levels: strategic alignment, organizational alignment, operational and team alignment (Henderson and Venkatraman, 1993, Shimizu, Carvalho and Laurindo, 2006; Kathuria, Josh and Porth, 2007; Pijpers, Gordijn and Akkermans, 2009; Miller, 1992). The alignment of the main activities of the organization around a generic strategy makes their implementation easier and improves communication with customers, employees and shareholders (Kaplan and Norton, 2006). Then, the challenge is to achieve effective alignment of interactions with both the business environment, including strategies and resources, as the internal environment, considering the support structures and vision shared by CN participants. However, this research seeks to specifically focus on intra- and inter-organizational alignment, but considering closely the strategic alignment.

Strategic Alignment – It means the interests of stakeholders are aligned with the strategy objectives of the business itself concerning the inherently dynamic fit between external and internal domains (Henderson and Venkatraman, 1993).

Inter-organizational Alignment – It refers the interaction between organizations in a value chain within a context which requires alignment of process outputs and targets. By aligning the inter-organizational processes a sustainable network can be reached (Pijpers, Gordijn and Akkermans, 2009).

Complementing this, Kathuria, Joshi and Porth (2007) states the alignment is very important in formulating strategies and defining processes, mainly for adjusting the key processes, as well as for supporting the decision-making system. They argue that there are two types of organizational alignment (Figure 24):

Vertical Alignment - This type of organizational alignment deals with the configuration of strategies, objectives, action plans and decisions throughout the various levels of the organization. It is achieved when the implementation of the strategy is effectively accomplished in a bottom-up approach, in order to make the decisions made at the lowest level consistent with the decisions at higher levels.

Horizontal Alignment - This type of organizational alignment refers to the coordination of efforts applied in the processes of the entire organization which is important to the lower levels of the strategy hierarchy. The consistency of decisions to mutually complement and support different activities such as marketing, manufacturing, logistics and HR management provides cross-functional interaction. Moreover, horizontal alignment is achieved if this interaction can fit the intra-functional integration (internal fit). Thus, it must be coherent across decision areas (level 4, in Figure 32) to achieve synergy within each function and it implies exchange and cooperation among various functional activities. According to Kathuria, Porth and Joshi (2007), quoting Skinner (1974), the "internal fit" in a manufacturing context means consistency between tasks, policies and practices.

Therefore, horizontal alignment means integration across various functional areas. For example, the interaction of manufacturing processes with manufacturing structures in order to provide better performance.

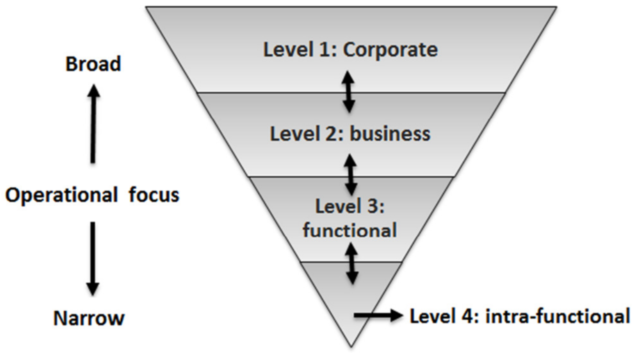

Figure 32. Hierarchy of alignment (Kathuria, Joshi and Porth, 2007)

According to Kerzner (2000), some aspects should be considered in order to design the most appropriate organizational structure to bring organizational alignment, such as: project size, duration, the organization's experience in managing projects, the philosophy of the company's upper management regarding project management, the physical location of the project, available resources, and other specific project aspects (Shimizu, Carvalho and Laurindo, 2006).

Kaplan and Norton (2001) argue that the integration of scorecards makes it possible to manage the collaborative service units and the decentralized business units as a unique entity. Also, these authors (Kaplan and Norton, 2006) contend that the alignment provides a better use of some important practices, such as:

- improvement of the financial synergy using an adequate process to monitor allocated resources in a diverse corporative portfolio;
- creation of integrated solutions for shared customers by using methods to motivate crossed sale among different units;
- use of techniques to share common processes among the units;
- reaching scale economy;
- promotion of knowledge and specialized abilities in specific management fields.

These challenges are difficult to manage and mainly to put into action. Therefore, without effective coordination among participants in a CN, it may not be possible to achieve these practices. The term alignment, although it has other connotations, it is usually defined as an arrangement of groups or forces in relation to one another (Merrian-Webster Dictionary, 2011). Deductively, in the context of collaborative networks, **alignment** could be interpreted as an arrangement of the CN structure (e.g., resources, knowledge, interoperability) and the intra- and inter-organizational processes performance related to strategies and targets established by the CN. In summary, a CN cannot be effective if there is no inter-organizational alignment. In other words, achieving inter-organizational alignment can provide consistency and efficiency in the relationships among CN participants, but each one of them must achieve operational efficiency to support their contributions to the CN.

Saiz, Rodríguez and Bas (2005) believe that enterprises acting in a CN maximize the participants' capacities that are combined to achieve the strategic objectives and goals in a context where customer needs are taken into consideration by integrated and efficient solutions on the collaborative processes. This perspective implies that the decision-makers of CNs must promote more and more the alignment of inter-organizational processes between the involved organizations.

Furthermore, if a CN obtains inter-organizational alignment, it can reach sustainable gains through the state of synergy[5] between collaborative processes. In this context, this state can occur if a performance management system, acting as a tool, can transform the strategies into actions for achieving alignment of the relevant and critical activities (Chituc and Azevedo, 2005). This special concern with the achievement of alignment in a CN appears to be key and must be accompanied with adequate attention to prevent disorientation in the inter-organizational processes, as well as when formulating strategies.

Therefore, the alignment between performance results of inter-organizational processes and performance targets established by the CN are extremely important to improve performance and bring sustainable gains. This means that the creation of an interactive performance management system can be a tool that makes it possible to formulate strategies to apply better solutions, or at least plan them based on accurate data.

Instantiating intra- and inter-organizational processes performance makes it possible to detect gaps but cannot show whether the efforts of each participant effectively contribute to the improvement of the CN's overall performance. Therefore, if it is possible to measure the alignment of the inter-organizational processes, then it could keep participants aware of the effort necessary to reach the expected overall performance so as to achieve the goals that led to this partnership.

However, the collaborative efforts for alignment can be measured and the respective alignment indicators must be defined (Kaplan and Norton, 2006). For instance, in an abstract form it can be proposed that alignment is strongest when the real performance line converges closer to the optimal performance line. For example, Figure 33 depicts in point A the better degree of alignment that occurs along the CN life-cycle.

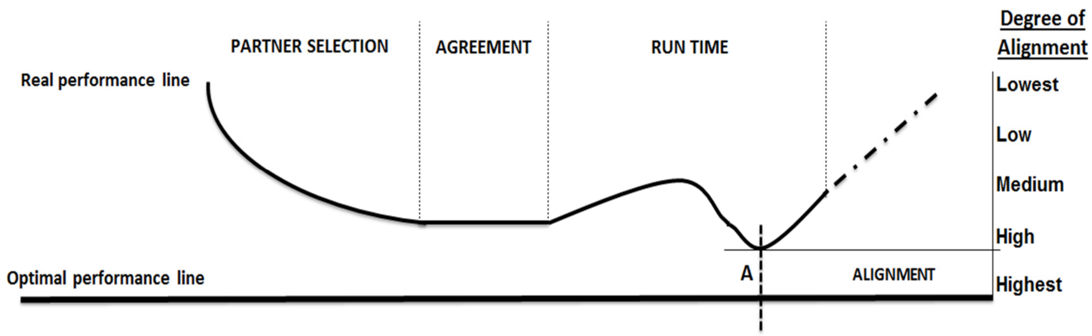

Figure 33. Alignment measurement throughout the CN life-cycle

[5] *"Synergy is the interaction of two or more agents or forces so that their combined effect is greater than the sum of their individual effects, or also a cooperative interaction among groups, especially among the acquired subsidiaries or merged parts of a corporation, that creates an enhanced combined effect".* (www.thefreedictionary.com, Farlex, 2011)

According to Francisco, Azevedo and Bastos (2010), there are three main moments in the CN's life-cycle when alignment should be measured: partner selection, agreement and run time. Therefore, it is stated that during the collaborative network implementation process, such concerns must be kept in mind to effectively fit with the expected goals, and then alignment can be achieved. Moreover, the degree of alignment may have different levels, according to each moment of the CN's life-cycle.

This measure, even if it is subjective, should instantiate the degree of alignment that occurs in these three moments. If the alignment is instantiated, decision-makers can improve inter-organizational processes and deliver better customer solutions. Therefore, the measurement system and performance management could contribute decisively to help CN decision-makers. Nevertheless, the inter-organizational alignment should be pursued, even though there could be setbacks and new situations that may cause difficulties. But, if the degree of alignment is considered an important factor by participants in these three decision moments this makes it possible to manage the inter-organizational processes more effectively.

In the development of this research five degrees to instantiate the alignment that is perceived in the CN are proposed: highest, high, medium, low and lowest (Francisco, Azevedo and Bastos, 2010). The intention is to support the decision-making process for selecting partners, signing the agreement, and monitoring the operational performance. Therefore, with each participant's indicators set then specific methods can be used to determine the degree of alignment according to the classifications suggested above.

In this context, certain alignment factors and indicators should be considered, in order to establish metrics to evaluate the performance of each participant and the inter-organizational processes.

3.1.2 Fit Concept

The discussion around the "Fit" concept had its most important questions dictated by Venkatraman, Camillus and Prescott (1984, 1989, 1990), among others, in the scope of strategic management, emphasizing the need to relate context and strategy. The relationship or alignment between the requirements of business environment and strategy applied by the organization is usually referred as "Strategic Fit" (Anand and Ward, 2004; Chorn, 1991). Furthermore, the links between business environments, organizational structures and internal processes is called "Fit" (Miller, 1992).

According to Venkatraman and Camillus (1984), the fit concept comes from studies on the contingency theory, specifically from works that relates to links between technology-structure (see Woodward, 1965), leadership style (see Friedler, 1967), organization-environment alignment (see Katz and Khan, 1966; Thompson, 1967), the formulation of business strategy (see Hofer, 1975) and strategic management (see Miles and Snow, 1978; Snow and Miles, 1983).

In addition, Fit was also perceived as a normative concept to highlight the importance of synchronizing complex organizational elements to effectively implement the strategy set (Venkatraman and Camilus, 1984; see Stonich, 1982) through the alignment of the organizational resources with environmental opportunities and threats (Camilus and Venkatraman, 1984; see Andrews, 1971, Chandler, 1962).

According to Miller (1992), it is "often claimed that firms must fit their settings in order to perform well". Figure 34 shows that Fit is a process geared to deduce not only whether the business environment and organizational structure are aligned (e.g., external fit), but also if there is an alignment between the structure and processes of the organization (e.g., internal fit).

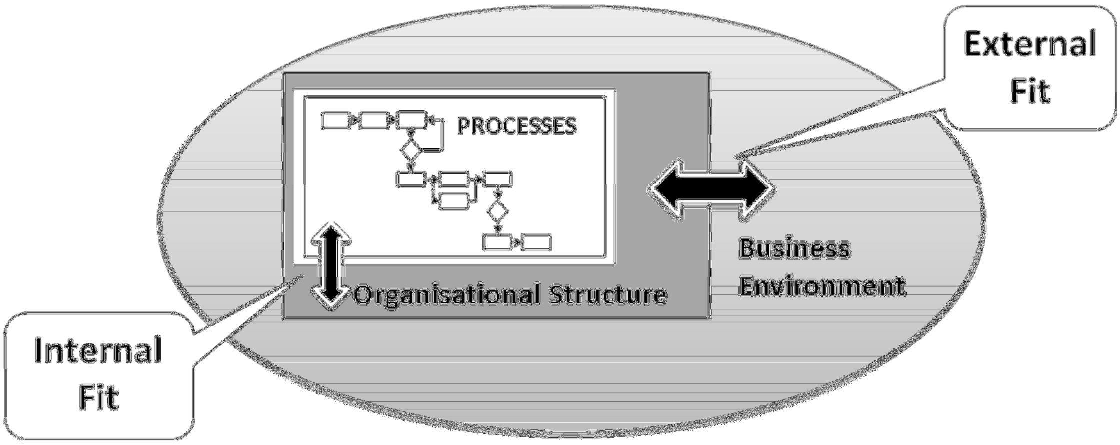

Figure 34. Fit concept

However, some authors argue that in most cases compatible internal and external fit does not occur simultaneously. According to Miller (1992),

> *"…managers may have to perform their adaptive tasks sequentially striving for a harmonious alignment among their internal variables in order to achieve smooth functioning, but periodically disrupting this harmony to adjust to a changing environment."*

This previous statement, which originated from an empirical research by Miller (1992), means that if the market imposes uncertainty or diversity distinctively then a trade-off must be established regarding efforts and provision of resources. The author asserts that companies which demonstrate a lower level of consistency (external fit) related to market uncertainty have greater consistency between the structures and processes (internal fit). To the contrary, groups of firms that present greater external fit in relation to uncertainty, have an insignificant relationship between structure and processes. Therefore, a more flexible structure is required in order to respond to market uncertainties. Furthermore, achieving a higher degree of external fit in markets with high uncertainty may mean that links between structural variables and processes are weak.

The approaches and definitions found in the literature to explain the use of the term "Fit" in strategic management generally seek to understand the relationship between the organizational structure and performance (Silveira and Sousa, 2010). The "Fit" concept, as mentioned in the literature, represents the alignment or configuration of an organizational strategy, taking into account the contingencies faced by the organizations within their business environment. Furthermore, in the management context, this term can be used to conceptualize a situation where strategies, organizational structures, stakeholders, stockholders or any existent participant or process in a business environment, are combined in strategic decisions to attain specific objectives and goals. Meanwhile, the internal fit is usually related to performance improvements (Silveira and Souza, 2010) ensured by a higher degree of alignment between structure and processes, focusing the decision making process.

One aim of this research is to find measures of the alignment between CN's structures and intra- and inter-organizational processes to assess the CN's overall performance (Figure 35). To support this, the hypothesis proposed by Silveira and Sousa (2010) regarding internal fit being related to performance improvements and also the empirical research by Miller (1992) on the occurrence of greater internal fit in companies with smaller external fit in markets with more uncertainty is utilized.

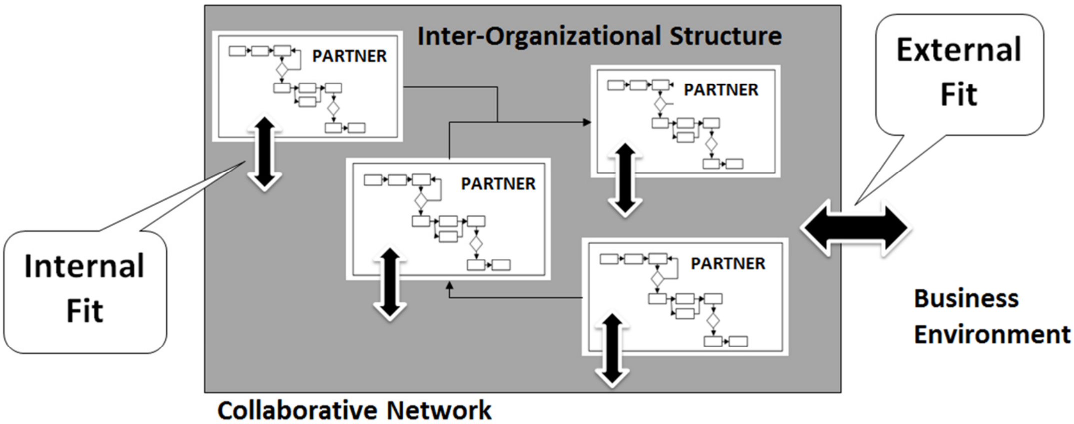

Figure 35. Fit Concept for Collaborative Networks

3.1.3 Gap analysis

With regard to alignment, relevant gaps in research, technology and practical applications were detected in the survey carried out in this research. Indeed, the requirements encountered during this research motivated it to propose different approaches to measuring inter-organizational alignment of various types of collaborative networks with distinct objectives. Therefore, this gap analysis instigated the use of state-of-the-art of performance measurement and management techniques for alignment assessments in collaborative networks in the deductive-inductive approach used in this research.

The scarcities and lack of methods, tools and approaches to address the alignment issue in collaborative networks motivated the development of such methods in order to support the main objectives of this thesis. Therefore, different approaches for various types of CNs are suggested, developed and tested in order to make an important contribution to the management of collaborative networks.

The following Table 15 shows the research gaps and subsequent analysis which helped to establish requirements necessary to construct such approaches.

Table 15. Gap analysis on alignment measurement

Context	Gap analysis
Research	Scarce conceptual frameworks for helping decision-makers for designing and managing performance in CNs.
	Lack of research in the strategic and inter-organizational alignment in CNs.
	Lack of modeling for monitoring the alignment of inter-organizational processes.
	Scarce research on alignment measurement.
	Lack of predictive approaches on performance measurement and alignment.
Technology	No specific tool designed for supporting the CN's decision-makers are currently available, specifically monitoring inter-organizational performance and alignment.
	Scarce configurable interfaces to support inter-organizational communication
Practical Application	Scarce alignment measurement methods
	Lack of measurement tools for application in different CN typologies
	Lack of ICT technologies for helping performance or alignment measurement in CNs

Furthermore, requirements for assessing alignment are addressed in the following section.

3.2 Alignment as a Performance Measure

3.2.1 Alignment factors

Kaplan and Norton (2001) argue that the alignment of organizational processes provides the use of best practices by adequately monitoring the allocated resources in a diverse corporative portfolio. This perspective can be extended to the collaboration strategy for encouraging decision-makers to lead to the alignment between the organizations involved.

Furthermore, some alignment factors can significantly influence the desired level of alignment, including: trust, reliability, competency (skill level), experience and know-how. The CN's participants should pay attention to these factors in order to support the alignment efforts mainly in selecting partners and setting targets for the commitment between them.

Trust - It is certainly the main issue in reaching alignment in CNs. In this context, it is necessary to understand concepts on inter-personal trust in order to perceive some interrelations with inter-organizational trust. According to Straker (2008), trust is

> *"both an emotional and logical act. Emotionally, it is where you expose your vulnerabilities to people, but believing they will not take advantage of your openness. Logically, it is where you have assessed the probabilities of gain and loss, calculating expected utility based on hard performance data, and concluded that the person in question will behave in a predictable manner. In practice, trust is a bit of both. I trust you because I have experienced".*

This definition is concentrated on human relationships, but the organizations are driven by human beans. So, it is expected that during the interactions among partners the perceptions stated above can be used in a collaborative networks environment. According to Msanjila and Afsarmanesh (2009),

> *"Differently from inter-personal trust, inter-organizational trust is not subjective and so some antecedents are known, such as shared values, previous interactions and practiced in order to prepare organizations towards trusting each other's behaviors".*

Trust between partners in a collaborative network is important because the participants must share available reliable information related to strategy, business processes and competencies that are usually the source of competitive advantage (Faria and Azevedo, 2006,). Different organizations consider different aspects when assessing the trust level of other organizations. Msanjila and Afsarmanesh (2009) state that the elements of trust must be identified and implemented, and should also be based on performance so that it is easier for the CN participants to recognize trust.

This need for trust in relations between partners can become a competitive differentiator but, in the absence of trust, organizations are left out of the competition. This may also be the difference between the organization that adapts quickly to new challenges and those that become slow due to mistrust.

Reliability - Alignment in a collaboration strategy can also be motivated by the process reliability verified by the participants of the CN. In a relationship of cooperation or collaboration where there is uncertainty with regard to the reliability of products and processes, this will certainly cause distrust in terms of the partner's reliability in providing products or services.

Some specific requirements need high levels of reliability, including:

- Quality of product and/or service
- Supply of raw material or product
- Storage and handling
- Communication and information data
- Delivery time
- Logistic service level
- Post-delivery service

The maturity level of operations of each CN participant dictates the degree of reliability desired in the inter-operations between them. Low levels of process reliability may cause the exclusion of participants, or even dissolve the CN before the expected time. In turn, the level of reliability is maintained and improved in accordance with the level of skills that each organization has, or intends to have when working in collaboration.

Competences (skill level) - Competence is the combination of knowledge, skills, technologies, physical systems, management and values that generate competitive advantage for the organization to create distinctive value perceived by customers and that are difficult to be imitated. Organizations which are able to identify and develop the required skills necessary to reach competitiveness and those that can accomplish this task gaining a significant competitive advantage and becoming stronger and capable of surviving in the market (Hamel and Prahalad, 1994).

In the new economy many competences must be accomplished by the organizations, including: agility, sense of urgency, flexibility, high performance teamwork, sharing ideas and knowledge, innovation, continuous learning and improvement, influence, leadership, strategic vision, and others.

Basically, competence may be interpreted as the management of available resources (financial, material, human, technological and property) referring to the personal skills and organizational capabilities. Therefore, it is important for the CN's participants to develop these aspects in order to highlight their potential, mainly the necessary skills regarding their contribution to the collaborative network's success.

Experience and know-how - Participants in a new relationship of collaboration which has experience in that business environment can offer two main advantages: specific skills and knowledge on how to start the activities on the network, and on how to manage them during the CN life-cycle.

Organizations cooperating or collaborating must individually hold a set of technical and/or business skills, allowing for higher efficiency and better results in operations for the production and distribution of product and/or services. This know-how should be effectively available to the CN since it certainly was agreed during its formation.

By maintaining at least these alignment factors, a CN would have more chances of reaching adequate performance to achieve their goals and objectives. Furthermore, these factors may be important to measure the alignment at the formation and during the operation of the CN, in order to see if the strategies are effective or if there is a large gap in the alignment between inter-organizational performance and the established targets.

3.2.2 Alignment measurement factors

The conceptualization of alignment within a performance measurement approach for CNs is the main conceptual proposal of this thesis. In fact, how to measure alignment is a difficult task because it is not easy to explain. What is more, no matter the definition of alignment there will be a reasoning approach that must be properly aligned with the preconditions related to the different business environments and distinct CN typologies (Hanson *et al.*, 2011).

In summary, it was concluded that there is a causal relationship between alignment and performance management in the collaborative network context. With this understanding, decision-makers can pre-detect some potential performance gaps in intra- and inter-organizational processes to help avoid instability in a CN. Specifically, alignment can be exploited as a means to measure performance so long as it can provide metrics that reflect the efforts of the CN participants to achieve their objectives and goals. Furthermore, it is stated that internal fit is reached by an alignment between the inter-organizational structure and the intra- and inter-organizational processes. Both are the foundations used to guide the development of the alignment measurement methods that are presented in this research. Therefore, this modeling means that alignment indicators, motivational factors for alignment and inter-organizational performance indicators are the sources for this development.

For this reason, a multi-dimensional model was designed in order to explore the main factors that contribute in the design of an alignment measurement construct. Thus, alignment factors and performance measurement factors are used in developing alignment measurement methods. In fact, the metrics derived from motivational factors (subjective approach) or process performance indicators (descriptive approach) are based on the relationship between the partners and by the outcomes of inter-organizational processes (Table 16).

This means alignment is the coherence between two or more related variables, in order to demonstrate if a fit state exists between these variables (factors), according to the adopted approach.

Depending on the characteristics of the collaborative network and the characterization of the business environment, the partner's relationship and inter-organizational factors may be used together or not, subject to the adopted approach.

Table 16. Alignment measurement factors

ALIGNMENT FACTORS	PERFORMANCE MEASUREMENT FACTORS	
Indicators	Partner's Relationships	Inter-organizational processes
Alignment Motivational Factors	Trust, knowledge transfer, market share, others	Performance (efficiency; effectiveness), reliability, others
Key Alignment Indicators (KAIs)	The LSSM (local shared strategic measures)	The LSOM (local shared inter-organizational measures)

3.2.3 Requirements for assessing alignment in collaborative networks

This research found that there are few studies about measuring alignment in collaborative networks. There are some subtle references in articles that deal with aspects related to the implementation of VEs (Roberts, Svirkas and Matthews, 2005), regarding business prospects in collaborative networks (Chituc and Azevedo, 2005), the need for performance measures to achieve higher levels of alignment (Pereira-Klen and Klen, 2005), business-IT alignment (Zarvić, Wiering and Eck, 2008) and alignment measurement (Francisco, Azevedo and Bastos, 2010). However, a reference model for analysis of alignment around the CN's core-values was presented by Macedo, Abreu and Camarinha-Matos (2010) which contained methods, graphs and maps that establish the core-values for the comparison between the evaluation results of each participant in the CN. Although it is an important milestone in the introduction of "alignment" in the context of collaborative networks, this approach deals exclusively with how to surpass the significant differences between the partners with regards to the values of CNs, i.e. the importance of collaborative planning and synergies.

Another inclusion of alignment in this context was proposed by Bremer, Azevedo and Klen (2009) regarding the comparison between proposed value to the customers and the subsequent value delivered, which establishes a concept based on value creation.

However, it is possible that none of these methods for measuring alignment are effectively concerned with the constant monitoring that deals with performance as if it were a quantitative variable that instantiates the degree of alignment. Therefore, designing methods and tools to evaluate the degree of alignment in specific moments of the CN's life-cycle can offer an interesting and powerful contribution to support the decision-making process in collaborative networks.

Alignment measurement methods should be primarily concerned with providing reliable data through scientific approaches which take into account: motivational factors for collaboration strategy, intra- and inter-organizational performance, monitored life-cycle moments, performance measurement and management requirements, degree of compliance within a process, key alignment indicators and the overall degree of alignment.

In summary, this research focused on how to assess performance in collaborative networks using alignment metrics relating to the KPIs of the intra- and inter-organizational processes, as well as the alignment motivational factors. In order to determine propositions it was necessary to define the appropriate general requirements for assessing alignment. Next, these requirements were defined in order to establish the objectives of the performance functionalities. In fact, it was necessary to define the functional and non-functional requirements when the PMMS is designed for real-life situations.

The establishment of functional requirements is relevant because the performance and alignment requirements act decisively in the design process of the PMMS, such as: parameters and guidelines used to design the PMMS, the ICT interoperability systems used to promote the participants' interactions, the measurement specifications and patterns, the technological support to develop the PMMS, the methods of data manipulation and processing, the methods and tools for measuring process performance and the approaches that would be used to construct the alignment measurement methods. The main benefit of determining functional requirements is to capture the behavior that can occur related to certain system functionalities.

In addition, there are non-functional requirements that determine quality, planning, reliability, cost attributes and limitations in the design and implementation of the system. They also highlight the constraints under which the system should operate. In this research, non-functional requirements are not considered in depth. However the practical applications carried out in this research show their relevance by describing the conditions under which operations must be performed.

Furthermore, the challenge is to design a PMMS which considers such alignment requirements in order to be effective in assessing the performance of CNs. Therefore, it is relevant to identify and propose specific requirements to support the CN's performance management.

For these reasons, the alignment requirements can be grouped into different categories which consider: establishing matching relationships for the management of a collaboration strategy, supporting the development of the PMMS, defining performance management functionalities, determining specifications of inter-organizational processes, supporting the development of systems of interaction between partners. Therefore, the categories are:

- Design parameters and guidelines;
- Development support to the performance management system;
- Performance management functionalities;
- Data manipulation and processing;
- Measurement specifications;
- Measurement concepts;
- Alignment measurement approaches.

These categories contain several specific requirements which are presented in Table 19. This table provides a description of each specified requirement in order to contribute decisively to design measurement methods taking into account the context and structure of the CN, as well as the tools and methods needed, the management of information data and finally performance measurement and management concepts.

Moreover, with respect to non-functional requirements, the alignment measurement approaches shown in Figure 36 consider abilities and actions for preventing the constraints that may affect the PMMS implementation. Therefore, it is important to consider the competence of the CN in establishing quality and reliability attributes used in the PMMS, planning measurement and evaluation processes, and border delimitation concerning inter-organizational processes, as can be seen below (Table 17).

Table 17. Non-functional requirements

Requirements category	Non-functional requirements
Quality Attributes	Capability to develop an effective PMMS in terms of accuracy and performance.
Planning	Use of effective planning methodologies for measuring and assessing performance.
Reliability	Capability to obtain and provide reliable data.
Limitations	Demarcate the boundaries regarding problem situations researched.

Therefore, assuming that alignment can be measured using both descriptive measurements of the intra- and inter-organizational processes and subjective measurements of motivational factors for alignment, then designing reliable methods for measuring alignment, which take into account the moments of the life cycle where the measurement occurs, becomes relevant.

Because of this, specific methods and tools were developed and tested in order to validate the alignment measurement approaches, including an innovative predictive measurement.

Table 18. General requirements for measuring alignment in collaborative networks

Requirements category	Specific requirements	Description
Design parameters and guidelines	Typology	The type of CN should be described and understood by the participants using the appropriate taxonomy in order to provide a conceptual view suitable for modeling the CN.
	Topology	The network topology must be seen in a perspective of a physical network used to represent both the physical flow of inter-organizational processes and the direction of data flow information.
	Partner selection criteria	The criteria for selection of partners should be established considering, at least, the focuses of activity related to the typology of the CN and also the steps of the establishment of the selection process.
	Agreement conditions	The achievement of agreement for the formation of the CN and jointly agreeing goals and targets by the participants should be consubstantiated by a plan focused on sharing resources, knowledge and operational structures.
	CN life-cycle phases definition	It is very useful defining the life-cycle phases for determining the specific activities that happen at each stage, which tasks must be undertaken, what are the requirements to be met, which indicators should be used to monitor performance, which data and information are important, among other tasks.
	Performance and alignment measurement	The PMMS should be developed to collect, integrate and analyze performance measures in order to enhance decision-making processes, while evaluating strategy effectiveness and promoting alignment at the same time.
Development support to the PMMS	Performance conceptual framework	It is important to build a conceptual framework to make it possible establishes functionalities of performance management and to support the development of the collaborative PMMS.
	PMMS implementation process	Establish a structured methodology to support the designing and implementation of the collaborative PMMS as well as referring to the technology and infrastructure support, management tools and performance measurement solutions.
	Technological support	ICT is undoubtedly needed in terms of support for the operations and management of intra- and inter-organizational processes. This requires common IT solutions or middle-ware solutions addressing the requirements of technological support systems.

Requirements category	Specific requirements	Description
Performance management functionalities	CN Performance management	There should be a planning process to guide and support activities during the Partner Search, Design & Set-up and Operating phases. It is necessary to capture data from the performance repository in order to determine benchmark performance for the selection of partners when these data are available. Moreover, this functionality concerns with the performance targets.
	CN real time performance management	It should be measured the outputs that can contribute to solving emerging problems and formulate improvements during the Evolution phase. The efficiency and effectiveness of processes should be measured in order to understand the performance issues, especially the performance obtained during the different phases of the life cycle, and the outcomes data should be stored in the performance data repository. Gaps that may exist relating to improvements on the processes monitored are dealt with during the Evolution phase.
	Performance evaluation	The performance evaluation functionality deals with the compilation of performance data in order to understand whether the CN has achieved its objectives and goals at the Dissolution phase and then transfer this memory of performance to the Performance Repository. It should also provide knowledge from the analysis and creates a repository of information about the performance generated by participants at each stage of the life-cycle. This is mandatory in the Dissolution phase.
Data manipulation and processing	Performance data repository	The data repository is related to data acquisition and data management. All data regarding performance and general information is coming from new data collection actions and past experiences relating to each partner's performance as well as the CN's overall performance.
	ICT interoperability	The challenge in collaboration strategy development is to keep the different parties updated through a common data management system. It should also to address the distinct requirements of technological support systems that can support a dynamic PMMS tailored for a networked business environment in order to provide integration of the ICT systems of the CN participants.
	Communication systems	Communication systems should make it possible the interaction between partners and provide consistency and reliability on the data interchange.

Requirements category	Specific requirements	Description
Measurement specifications	KPIs definition	The selection of indicators should consider whether the results of the processes meet the needs of stakeholders and if it is essential to set up an evaluation system to test this situation. It is relevant apply an appropriate methodology to define KPI levels, classes and applicability.
	KAIs definition	The selection of alignment indicators should be performed taking into consideration whether the CN participants are contributing to the consecution of the objectives and goals. It is relevant apply appropriate approaches to devise the KAIs for a collaboration strategy.
Measurement Concepts	Performance measurement and management	Several concepts, systems and methods on performance measurement and management should be studied, selected and applied in the design and application of the PMMS.
	Performance prediction	A predictive model consists of a number of predictor variables which are likely to influence future behavior. Predictive measures should be applied in measurement systems and should be designed to create a balanced set of performance measures to monitor processes.
	Alignment prediction	Predictive KPIs are set to calculate the degree of alignment of CN, i.e. predicting the future alignment. Should be established KAIs that can instantiate the degree of alignment. Predictive performance indicators should be transformed in alignment indicators.
Alignment measurement approaches	Motivational factors for collaboration	Alignment factors can significantly influence the degree of alignment. The aim is support the alignment efforts mainly in selecting partners or setting targets for the commitment between CN participants in order to obtain a higher degree of alignment.
	Performance comparison between participants (benchmarking)	The objective of benchmarking is to know the performance of other companies and compare them in order to use this information to improve performance. Using methods such as DEA to determine the performance of a group of networked organizations makes it possible to classify each partner.
	Alignment prediction	Mathematical tools should be developed to overpass the gaps found in order to enhance performance management. They should gather the essential process information relating to functional and non-functional requirements that can positively or negatively affect the system.

3.3 Alignment Measurement Approaches

After analyzing research gaps and requirements for alignment measurement in collaborative networks, three different approaches are proposed for assessing alignment. They are:

- Measuring the alignment considering motivational factors;
- Measuring the alignment considering a benchmarking analysis;
- Measuring the alignment considering predictive performance indicators.

These approaches were designed during the application of exploratory case studies in collaborative networks in Brazil. For each approach, alignment measurement methods were developed and applied including their specific methodologies and tools. Specifically, the motivational factors and KAIs were used as metrics for the Pet Shop Retailers case (Section 5.3) while only KAIs were used as metrics for the G3 Supply Chain case (Section 5.4).

Moreover, the subjective, descriptive and predictive aspects imposed the use of different mathematical treatments. Another relevant aspect is the focus on the specific moments of the CN life-cycle most amenable to alignment assessment, such as: the partner selection, the moment of agreement for the constitution of the CN and during the operation of inter-organizational processes.

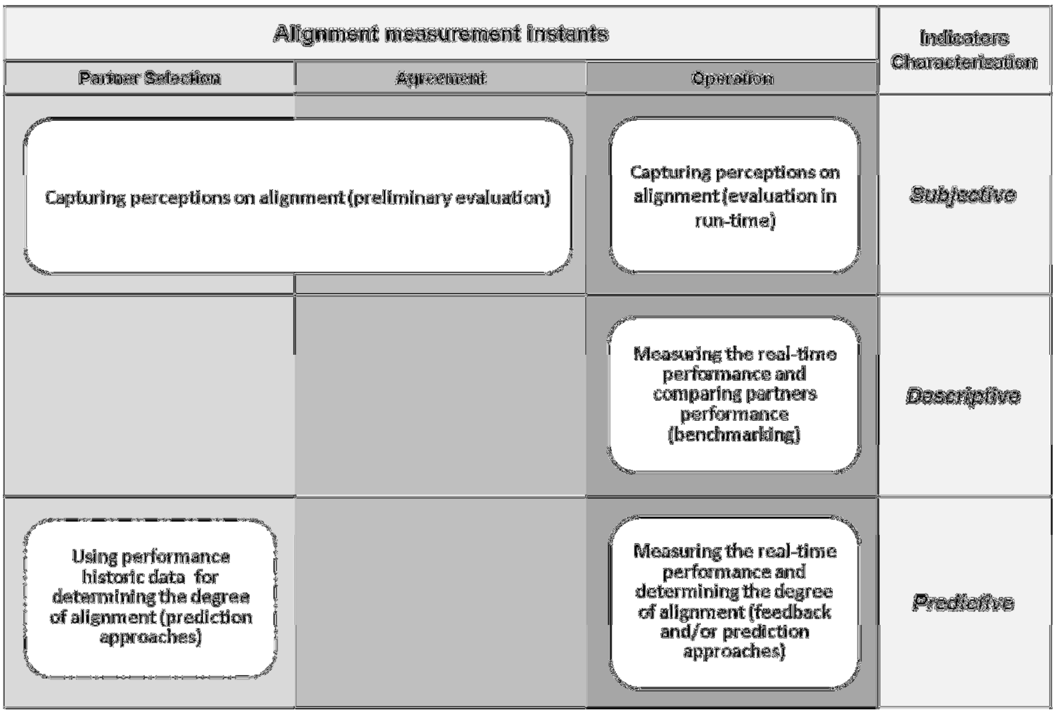

Figure 36. Alignment measurement approaches

However, difficulties occurred throughout the research. Because of the wide range of CN types covered which resulted in an extremely time consuming and complex task. Therefore, it became necessary to develop various methods and tools to test, apply and validate the different approaches.

Furthermore, for a practical application, these approaches should follow certain requirements in order to be conceptually substantiated, such as:

- What relationships are established for determining the type of alignment and what focuses are related to the assessment of the internal and/or external fit;
- CN life-cycle moments for alignment measurement;
- Methods and tools for measuring alignment;
- Variables for measuring the degree of alignment;
- KPIs for measuring performance of the intra- and inter-organizational processes;
- KAIs for measuring the degree of alignment;
- Mathematical techniques that could be adopted;
- Types of technological support that could contribute to efficiently measuring the alignment.

These requirements to develop alignment measurement methods are relevant for establishing what must be done in relation to the different approaches. In fact, the development of the methods for assessing alignment intends to create paths to support CN decision-makers to manage performance.

Such approaches used in this research demonstrate the author's intention to measure and manage performance in collaborative networks. In fact, it is proposed that these approaches can combine certain factors known by CN participants making it possible to develop a metric that instantiates the degree of alignment between the results of inter-organizational processes and performance targets established by the collaborative network. As shown in the Figure 37, the proposition is to measure the alignment using key alignment indicators set by motivational or performance indicator factors. These KAIs should be used in the comparison of the targets with the processes' results by a criteria-based formulation in which the degree of alignment is obtained through performance outcomes (Hanson et al., 2011, see Venkatraman, 1989).

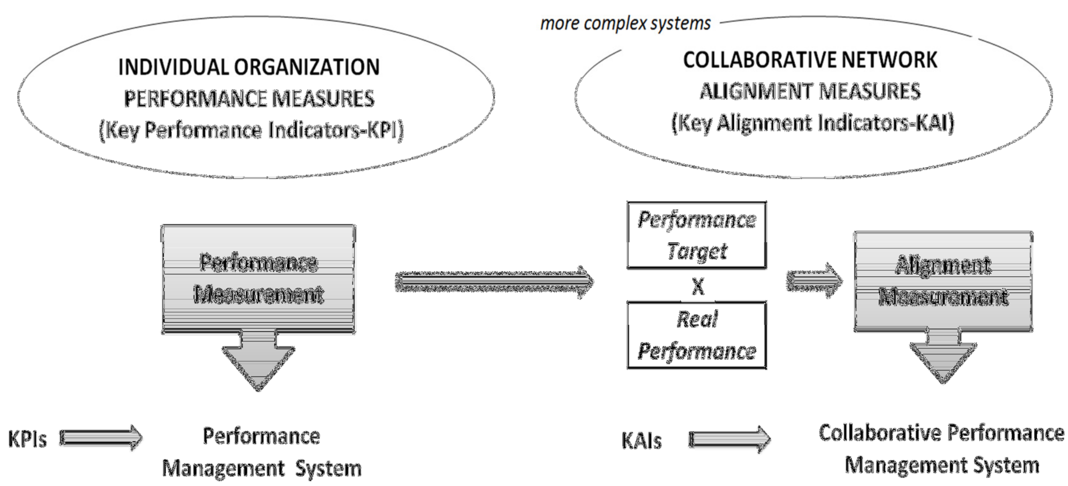

Figure 37. Determination of the degree of alignment through a criteria-based formulation

3.3.1 Measuring alignment considering the motivational factors

This approach takes into account motivational factors for informing if there are, or not, a satisfactory perception of the decision-makers on strategic and inter-organizational alignment. The aim is that managers of participating organizations should express their opinions about these factors and thus obtain a qualitative value that instantiates the degree of alignment of the inter-organizational processes of the CN. In fact, this information it makes possible to establish priorities relating to carrying out actions to the improvement of intra- and inter-organizational processes, as well as the subjective aspects that interfere on accomplishment of strategic objectives and goals.

This subjective approach can be used in all moments of the CN life-cycle and may be an interesting alternative for monitoring the progress of the degree of alignment that is measured from the preliminary evaluation until the evaluation in run time (Figure 36).

Firstly, questionnaire methods for evaluating the perception of the CEOs on the motivational factors of alignment were applied. It is based on the respondent's assumptions and the aim is to translate its assessment over time whether the performance achieved coincides with the previously established. Subsequently, with the application of these questionnaires at the critical moments of the CN life-cycle it aimed not only to explore the participant's perception on the degree of alignment, but also to assess gaps related with the motivational factors and its relevance.

Therefore, the proposal is to apply these questionnaires in small and medium-sized networks of enterprises, and it should focus on the motivational factors that have a huge impact on the alignment, such as trust, operational performance, process reliability and know-how. Just a few questions may be developed to be answered by the CEOs of the CN participants in a simple manner, however must ensure that the questions are neutral; they should not influence the respondent's decision (Hill and Hill, 2005).

In fact, this approach leads to the determination of a degree of alignment which is instantiated using the results of the questionnaire then helping decision-makers to plan the necessary support for the alignment efforts.

For the moment of selecting partners (it is assumed a CN whose participants have never had previous relationships), the so-called questionnaire Q-0 was developed to be used when the CN is in formation in order to assessing the subjective degree of alignment (SDA) at that moment. Therefore, the expectations of potential participants were captured in relation to a single motivational factor, trust. Thus, the proposed question in the questionnaire Q-0 is the following:

1. What is your expectation of a high level of <u>trust</u> among participants, considering the invited participants for this CN?

The use of only one factor is due to the fact that in this research was observed small businesses that had never participated in a formal manifestation of cooperation or collaboration. Certainly, if the maturity level of the companies participating in the CN is high then other motivational factors can be applied, taking care to verify whether it is possible to the respondents of the questionnaire to establish relationships with their strategic objective and goals. It is necessary to verify whether there are reliable data that can help them in this exercise of perception.

Subsequently, to measure the SDA at the moment of agreement, standard questions that take into account more factors were developed, as seen in the questionnaire Q-1:

1. Is your organization confident that the level of trust between the partners of the collaborative network at this moment is satisfactory?
2. Is your organization confident that it will improve its performance after operating within the collaborative network?
3. Is your organization confident that it will improve its reliability in delivering products and services after operating within the collaborative network?
4. Is your organization confident that it will improve its knowledge and competence level after operating within the collaborative network?

Unlike the agreement moment, in which there are only expectations, in the run time period the focus should be on the performance measurements already done in the CN. For this moment, the same motivational factors are proposed to guide the questions. However, these issues are described in present and past tense, as seen in the questionnaire Q-2:

1. Is your organization confident that the level of trust among the partners of collaborative network is currently satisfactory?
2. Is your organization confident that its intra- and inter-operational performance has improved since acting in the collaborative network?
3. Is your organization confident that its reliability in delivering products and services has improved since acting in the collaborative network?
4. Is your organization confident that its knowledge level and competence has improved since acting in the collaborative network?

Therefore, it is proposed a simple method for assessing the SDA as follows:

- Applying the survey questionnaire and then compiling the results;
- Calculating the coefficient of misalignment of each participant by using the Euclidian distance method considering every factors according to the CEOs considerations;
- Designing a decision table to support the determination of a classification for the degree of alignment;
- Observing the results using a polar graph in order to visualize the behavior of the motivational factors.

In fact, when it is necessary to define criteria to measure the SDA, undoubtedly, the role of the manager (or expert) arises for establishing these criteria. This should take into account the manager's perceptions as well as the expectations of the CN and the targets that each participant had determined for evaluating their own performance. These observations on the motivational factors are used to determine a classification for each motivational factor that is pointed by the CN managers. Only three classifications are proposed: highly confident (hc), confident (cf) and not confident (nc).

Complementing this, the coefficient of misalignment (CM) is applied to measure the misalignment of target values vs real values. The smaller the distance between the optimal value line and the real performance value line, the higher the alignment, i.e. the perfect alignment is zero misalignment. In fact, the value set for each motivational factor or KPI is compared with reported real performance then the distance between these two lines is measured. In fact, this approach conduct to a model of alignment measurement according to the statements of Venkatraman (1989) which states that fit (when alignment occurs effectively) is a pattern of covariance or internal coherence among a set of underlying variables that are theoretically related.

Consequently, it is used the Venkatraman and Camillus (1984) idea on measuring misalignment, which has been used for alignment measurements. Therefore, it is used the Euclidian distance method that means the misalignment occurs when is greater the distance between two constructs. On contrary, when the distance is very small closer to zero there is less misalignment, i.e. the higher alignment. By using the values of this distance, the coefficient of misalignment (as Euclidean distance) is calculated as

$$CM = \sum_{j=1} \left(\left(X_{sj} - \dot{X}_{cj} \right) \right)^2 \qquad [7]$$

where X_{sj} = the score for the business unit in the study sample for the "j^{th}" variable;

$\dot{X}_{cj}$ = the mean score for the calibration sample (or, the 'ideal' type) along the "j^{th}" variable;

$j = 1,n$ where n is the number of variables that are applied.

The method is performed by selecting metrics (motivational factors) then the pattern value set for each metric is compared with its value obtained by measurement. Then, the Euclidean distance between these values is measured in order to find the coefficient of misalignment (CM). The smaller the distance between pattern and measured performance values the higher the alignment. Therefore, by adapting the Soni and Codali (2011) approach, the main tasks to be done are:

- Calculation of the coefficient of misalignment for each participant using the data reported from the questionnaires;
- Determination of the total range of misalignment values;
- Averaging the coefficients of misalignment of all CN participants;
- Calculation of the range of values which constitute a CM class, i.e. the interval which is related to the Fit Degree rating;
- Determination of the degree of alignment by comparing the average CM value, within a CM class, using the Fit Degree classifications.

Furthermore, in this approach on alignment measurement are used the motivational factors which are scored from one to two points, in ascending order from "not confident" to "highly confident", represented by the following values: highly confident (two points), confident (one point) and not confident (zero). The highly confident punctuation is valued with 2 points then becoming this the pattern value for the metric evaluated. Then, the distance between the optimum values of the motivational factors (targets) and their respective values (outcomes), which are extracted from the questionnaires applied to each CN participant, is measured in order to obtain the CM. Following, the average value of the CM of overall participants is calculated.

In sequence, the maximum value (the minimum value is zero) is obtained by summing the squares of the difference when this assumes the highest value to the coefficient of misalignment and, finally, the average of the CM is then converted into an alignment score. In fact, a decision table is proposed to be the standard criterion for classifying the degree of alignment in five degrees: highest, high, medium, low and lowest. This means the value of the difference between the maximum and minimum values should be divided by 5 to determine each classification for the SDA.

Certainly, the effectiveness of this criterion could be questioned and more accurate mathematical methods could be used. However, in a micro and small sized enterprise environment it may not be productive to create complex rules where participants have difficulty understanding them. Therefore, in this case, the criteria used were adequate to demonstrate that it is more important to have discipline in the application of simple methods than having a sophisticated method. In fact, the debate on the performance will allow the participants to implement actions to achieve better performance.

Moreover, the sample extracted from the "CN" universe is considered a useful sample because a qualitative analysis will be performed on the use cases of collaborative networks. This means the sample should consider the answers from all participants.

After this, the results are evaluated using a polar graph which clearly shows which motivational factors need special attention in order to help the CN decision-makers to improve strategies and processes. This can be seen in sections 5.3.

However, more complex mathematical approaches can provide more accurate values and less subjectivity and also these questionnaires should be adapted and improved in future works and they should be applied to practical applications in more complex CNs. Another important aspect is choosing the most appropriate motivational factors to the alignment measurement at distinct life-cycle moments. This observation especially refers to the development of different motivational factors for assessment of the SDA in each moment of the CN life-cycle.

3.3.2 Measuring the alignment considering a benchmarking analysis

Aiming to assess the performance of a CN constituted by participants of the same branch business environment, another approach on alignment measurement was developed. Rather than subjectively evaluate the degree of alignment, when the aim is to verify whether the use of performance measurements could help CEOs form opinions on the alignment between collaboration strategic objectives and inter-organizational processes performance, has become important to measure the efficiency of intra-organizational processes of each participant in order to compare them and observe those with better performance and others who had worse performance. This would be a way to assess the alignment of CNs that consists of small and medium-sized businesses, without the need for complex systems of performance management.

The Data Envelopment Analysis (DEA) is a tool that offers an estimate of comparative efficiency in situations in which multiple inputs and multiple outputs are under consideration (Cooper, 1999) and can handle large numbers of variables and relations, or constraints (Çelebi and Bayraktar, 2008).

DEA finds the most favorable set of weights, i.e. the set of weights that maximizes the DMUs (CN participants) efficiency rating without making its own or any other DMUs rating greater than one. As a result, it aids the decision maker in classifying the DMUs into two categories: the efficient ones and the inefficient ones (Çelebi and Bayraktar, 2008, cf. Boer et al., 2001). Consequently, DEA is a valid evaluation method only when decision making units are comparable meaning they use the same set of inputs to produce the same set of outputs (Cooper, 1999).

The participation in the CN should motivate their participants in evaluating their performance and therefore to implement new programs and strategies to improve efficiency and effectiveness in order to gain a competitive advantage over their competitors. This approach to performance management can be described as a continuous process of measurement and comparison of key performance indicators of products, services and practices with reference to organizations recognized as market leaders.

In fact, in order to automate the process of "benchmarking" it is possible to use an approach based on the DEA method that make it possible process and analyze large amounts of variables and constraints, as well as relations between them, in a simple and transparent manner to the user. This technique is developed especially for the comparison of efficiency levels for a homogeneous set of organizational units of decision making (DMUs).

Thus, is proposed a technique focused in the specification of targets equal to the maximum value observed in the performance of another similar DMU. Although it is simpler to apply in cases of a single input and single output (Figure 38), it becomes increasingly more frequent the evaluation of organizational units taking into account multiple variables of input (resources) and output (results).

In these circumstances, in order to be able to calculate a measure of efficiency is necessary to aggregate multiple input and output variables into a single efficiency ratio, corresponding to some heavy variable output divided by the weighted sum of input variables. In this approach, the main difficulty involves the selection of appropriate weights to optimize the calculation described.

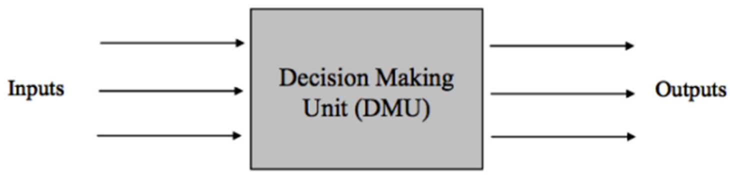

Figure 38. Decision making unit (DMU)

This model is thus able to determine the weights that give the highest possible performance score related to each DMU on a scale between 0 and 100 percent. Thus, if an organizational unit does not get a score of maximum performance, then it means that their partners are more productive even when the weights are specified to maximize the productivity of the DMU under analysis.

However, regardless of whether we are limited with this approach to compare homogeneous systems, each of the DMUs under consideration may have strategies, approaches and different business models, which give rise to different qualitative objectives and therefore different targets, represented by KPIs. Moreover, in order to carry out a correct evaluation and comparison of performance, it becomes necessary to map each of the individual indicators for each DMU, a set of global indicators for the benchmarking process and study its influence in the calculation.

Therefore, it aimed in this work to use a DEA approach for performance benchmarking analysis to determine the CN participants' efficiency scores in the first phase for after this to determine the descriptive degree of alignment (DDA)

3.3.3 Measuring the alignment considering predictive performance indicators

Both methods above appeared in the initial phase of this research, but they are not innovative proposals for performance assessment. In fact, their contribution is to demonstrate that we could use motivational factors of alignment and benchmarking methods for companies in the same industry, which may be useful in networks of small businesses. In sequence, this study aimed to find other approaches to measuring alignment in networks of midsize companies in order to develop measurement methods with predictive and descriptive indicators.

This approach appeared to be more interesting and therefore innovative methods and tools to measure the alignment relating to the inter-organizational processes were researched, developed and tested. This led to an approach in which some performance indicators derived from the set of KPIs of the collaborative PMMS are used to instantiate the degree of alignment. Consequently, a metric called the "Fit Degree" was designed to quantify the alignment causing the development of specific methods to assess the alignment in different CNs.

The calculation of this metric is performed by using the KPIs of the intra- and inter-organizational processes collected from the collaborative PMMS, turning them into key alignment indicators (KAIs). The alignment indicators should then be compared with the targets set in order to assess the degree of compliance of each participant in the CN relating to the inter-organizational processes performance. Subsequently, a value for the metric of the degree of alignment is then determined as can be understood from Figure 37 (page 94), but using predictive measures.

Furthermore, if the reaction time to implement improvements need information generated after a feedback time, a predictive approach can surpass this gap of time by applying the emerging paradigm of performance prediction. Thus, the reaction time can be reduced by applying a performance prediction approach using estimation tools to calculate future performance.

In fact, it is assumed that the outcome values of performance measurements can contribute to instantiating the alignment by introducing alignment measures which are used to assess the overall performance in collaborative network environments. Moreover, a transition of performance prediction to alignment prediction aims to introduce the paradigm of prediction for the alignment measurements that can determine the CN's future goals and targets, as well as assist in selecting partners and predicting their contribution to the alignment when a new CN is created.

Finally, it is possible to say that the research evolved from the assumption that the alignment can be measured using key alignment indicators and then estimation tools and performance classifiers were developed to determine the CN alignment. In fact, the Fit Degree, a metric for determining the predictive degree of alignment (PDA), is proposed for contributing to solve these propositions by using the prediction paradigm as presented in the Chapter 4.

3.4 Concluding Remarks

In this chapter were discussed the importance and relevance of alignment measurement when the objective is to measure the performance of CNs. In this context, a definition of alignment was explored and related with the concept of 'fit' in order to explain alignment measurement approaches. This definition was addressed to the performance of inter-organizational processes that occur in collaborative networks in order to be adopted as a performance measure.

Subsequently, a gap analysis in this research field was done in order to justify and motivate the approaches presented in this thesis. Furthermore, performance management and alignment requirements were addressed deeply in order to propose specific requirements for developing alignment measurement approaches. In addition, methods and tools for measuring performance were described in order to guide the development of performance management systems (PMMS). Furthermore, the relevance of alignment factors was characterized, which suggests using it as a criterion to measure the alignment in collaborative networks.

Moreover, different approaches to measuring alignment are described taking in account different collaborative network typologies and business environment. In fact, after the proposition of using alignment measurement for assess performance in CNs, it is stated that specific alignment measurement methods should be designed in order to meet the specific needs of the CNs, such as structure (typology and topology), ICT infrastructure, cultural and legal aspects, the size of participant companies and others.

Thereafter, both SDA and DDA measures of alignment may be used when the CN typology and a specific business environment are proper to use this approaches.

Complementing this, a performance prediction approach is then presented in the next chapter to serve as the foundation to apply a performance value estimator tool using a data fusion approach which drives the prediction of future performance values or behaviors, i.e. for determining the predictive degree of alignment (PDA).

On a strategic level the alignment is understood as the fit between the organizational structural conditions and the conjuncture conditions of the business environment. However, at tactical level the alignment can be understood as the fit between the operational performance standards and the real operational performance. Therefore, if the alignment is considered as a performance measure then it means to compare performance standards with real performance.

Chapter 4

Alignment Prediction

This chapter aimed to introduce the alignment prediction paradigm as an innovative approach to measuring performance in collaborative networks. The proposal is to use performance indicators that can be transformed into key indicators of alignment which are then estimated and used as alignment predictive indicators to assess the future behavior of the degree of alignment.

4.1 Introduction

Collaborative networks are being formed more and more in order to establish consensual strategies to attain specific goals normally in a short-term collaboration. Furthermore, the response time to design a product and processes and also to select partners and manage CNs requires specific approaches to deal with performance management in order to align the CN's participants as quickly as possible. However, traditional approaches to performance management are considered unsuccessful because they use performance data that are extracted after a feedback period, and only after this period it makes possible to analyze them to develop actions to the next period of improvements. This means that the reaction time is conditioned by periods of feedback and improvement thus causing a very long reaction time. Therefore, it is important to find innovative approaches that can reduce this reaction time using performance prediction data to eliminate the feedback period. This is possible using methods and tools that can provide accurate estimates for replacing the traditional methods of forecasting.

Thus, it is presented a metric to measure the alignment that uses key alignment indicators and a predictive approach. Furthermore, because the performance of inter-organizational processes can be predicted, it is possible to say that an alignment metric obtained by predictive measures can provide instances of the future performance and also establish goals for the next periods. Therefore, it is assumed that the alignment prediction is a way of understanding and measuring performance, particularly in collaborative networks.

4.2 Proposed Approach

The processes effectiveness usually depends on the time spent by organizations to react and make improvements. Therefore, it is essential not only to reduce the reaction time, but, more importantly, anticipate it. Modeling complex manufacturing systems, using a predictive tool through a data fusion approach, can present tangible benefits for performance management in today's industries. This approach is concerned not only with statistical data, but also with factors that may influence the future of the CN

According to Seifert (2009), the reaction time has two main stages: the feedback time and the improvement time (Figure 39). The first stage is represented by the "time span between the evaluated period and the calculation of the KPIs" during the performance measurement process. The second stage is represented by the "time span between detection and elimination of the performance deficit" closing the performance management cycle. This challenge intends that the time taken to measure and make improvements can be decreased.

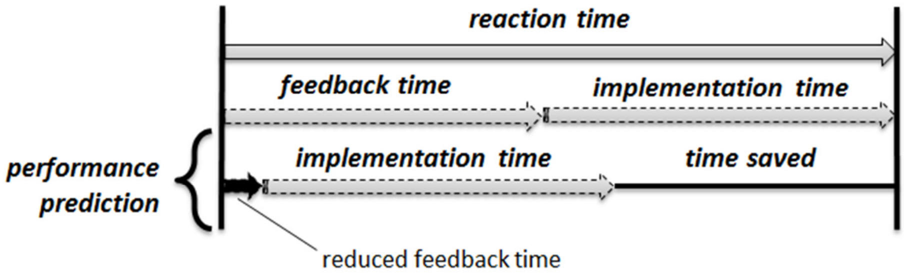

Figure 39. Performance prediction benefits (Seifert, 2009)

Having established that performance can be measured using predictive key performance indicators then estimation tools were developed and tested in order to materialize this concept.

The current view on the performance measurement indicates that there is a change from passive traditional performance management into a proactive vision. The passive vision dealt with historical lagging measures and the proactive vision focuses on leading measures of real-time performance under feedforward control. This proactive approach is supported by a balanced set of leading and lagging performance measures that make it possible to anticipate values for the performance indicators instead of just correcting a poor performance.

With this in mind, it is important to extract knowledge on statistical analysis and data mining tools that collect information and knowledge from these data in order to use it to predict future patterns of behavior. A predictive model consists of a series of predictive indicators and variables that are likely to influence future behavior.

An important aspect that is related to the performance prediction concept involves a definition of appropriate and relevant performance indicators. This is critical for the organization's performance, both acting individually and in a network environment. Measurement and performance management systems should be designed to support proactive management, based on both feedback and feedforward operation controls (see Figure 27, page 67).

This anticipation of the implementation time for improvements can be provided by forecasting and estimation tools. In fact, estimation deals with past, present and future actions. The estimation is the process that consists of using the sample data to estimate values of unknown population parameters such as mean, standard deviation and proportions. By the other hand, forecasting tools are used to predict the future. Furthermore, in order to understand these concepts fully, an example can be used of a robot which has to follow a specific trajectory. In this case, if the robot is equipped with a forecasting tool, then it will only be able to predict its location at a later date. Then, using an estimator as a tool for its location, it can calculate, with a degree of uncertainty, its position across the temporal scale.

Historically, forecasting techniques have been of great scientific and industrial interest. They have mainly been used to predict outcomes and thus undertake the effort necessary for the allocation of resources and the adaptation and improvement of processes.

Thus, a PMS which defines an appropriate set of categories of performance measures is normally thought to quantify the efficiency and effectiveness of past actions. In summary, an estimator tool can apply these principles and develop methods in order to extract performance values, and also to define targets, in order to guarantee data reliability and accuracy.

In conclusion, it is interesting to apply this approach in order to support decision-making processes in collaborative networks. For example, it could be applied to partner selection or performance management during operation by assessing the future performance behavior.

In addition, due to constant changes in organizational processes and their requirements, this research aims to recommend a conceptual performance framework and a practical tool for predicting the future performance in order to support this proactive approach. Indeed, within a proactive approach for performance prediction it is possible to foresee that the performance model will be based on the current status. Furthermore, contrary to the reactive approach that is not able to predict what the module will become unless a trigger is detected, the proposed approach will proactively react once a system concept/model change is identified (Yang and Wu, 2006). Therefore, it is proposed a tool for learning the system behavior in order to predict the reaction time for improvements due to changes instead of using only the analysis of past data.

4.2.1 Performance estimation

The use of data to monitor operational systems requires an effective combination of data sources in order to accomplish greater accuracy to predict the system's outcomes. Thus, the data fusion approach is being used more and more in diverse research areas, including (Shahandashti *et al.*, 2010):

- signal processing
- information theory
- artificial intelligence
- statistics (estimation and inference).

Therefore, the use of the data fusion approach is increasingly used in various applications in emerging areas including robotics and automation, medical diagnostics and intelligent buildings. Furthermore, this approach is effectively used in applications for business processes, especially in manufacturing. It presents excellent results for analysis, data manipulation and representation of the production performance (Hall and Llinas, 1997), using information regarding processes and supporting performance predictions to aid both the measurement system and performance management. In fact, a methodology for data fusion can be used not only to integrate the different information available but also to increase its reliability. Moreover, when a great number of input factors affect the performance of the organizational system, this approach can be very useful.

According to Hall and Llinas (1997), the initial JDL Data Fusion Lexicon defined data fusion as:

> *"A process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete and timely assessments of situations and threats, and their significance. The process is characterized by continuous refinements of its estimates and assessments, and the evaluation of the need for additional sources, or modification of the process itself, to achieve improved results."*

Thus, the data fusion concept makes it possible to gather data, manipulate the information and finally provides a reliable snapshot of the system that will support decision making. It has advantages (Shahandashti *et al.*, 2010), such as:

- Enhancing confidence and hence reliability of measurements
- Improving detection by extending spatial and temporal coverage
- Reducing data ambiguity
- Improving accuracy

Manufacturing data are often vast and disperse in organizations. Subsequently, it becomes increasingly complicated to combine, manage and integrate a large amount and variety of data. Therefore, it is crucial to develop tools for data fusion approaches and integrate them into company working methods.

In order to support the challenges presented previously, the JDL functional model (Das, 2008; Llinas, Bowman, Waltz, Steinberg 2004) is currently widely used. This process model (Figure 40) is a functionally oriented data fusion model that aims to be more general and more appropriate for diverse areas and applications.

Thus, the JDL is divided into five main levels, according to Almeida's (2010) adaptations:

1. "*Source Pre-processing (level 0) involves the processing of data from individual sensors to extract information and to prepare data for subsequent fusion processing;*
2. *Object Refinement level (level one) combines all of the raw data to obtain the most reliable and accurate estimates of an entity's attributes and identity;*
3. *Situation Refinement (level two) outlines the current relationships between entities and events within their environment;*
4. *Impact Assessment (level three) projects the current situation into the future in order to increase processes and find opportunities;*

5. *Process Refinement (level four) monitors the overall data fusion process to assess and improve the real-time system performance."*

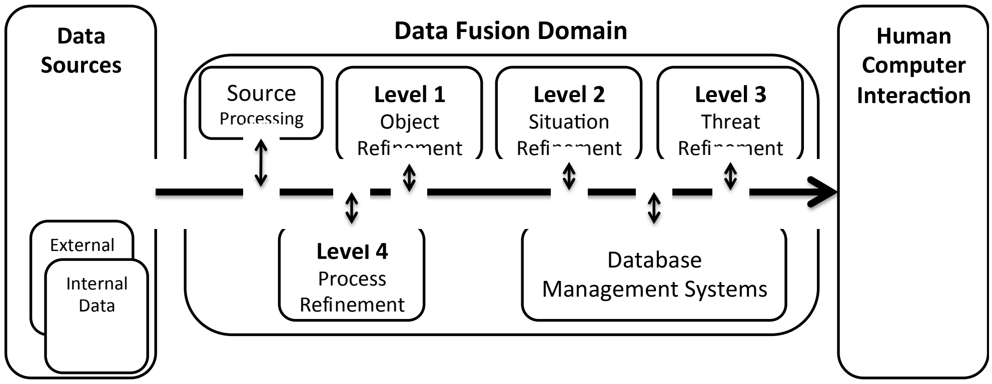

Figure 40. JDL data fusion model adaptation (Azevedo and Almeida, 2011)

Furthermore, the JDL model can operate with other sources such as human interference, databases and external sensors that are available for the developed data fusion system and it is widely used to support the estimation tool within the data fusion approach.

4.2.2 Supporting tool

This thesis has continuously argued that the new model of collaboration can support organizations to follow strategies that enable them to become more flexible and agile. The interval between analysis and evaluation, which precedes the development of solutions in reaction to process failures or new market demands, must be reduced in order to improve organizations' responsiveness. Consequently, a tool that learns the behavior of the system is proposed in order to anticipate the performance reaction to the changes, and not only through historical data analysis.

In the current business environment it is common for companies to perform forecasting exercises that target different issues such as the price of raw materials, production demand, weather forecasting and predicting the production system's performance. However, from the different tools that are normally applied to data forecasting, the majority are strictly connected with historical data and not with the factors that can positively or negatively influence the performance of the manufacturing system. In order to approach this issue, this section presents a framework composed of a non-linear system emulator (Neural Networks), a filter that targets modeling error estimation systems (Kalman Filter) and finally, a methodology for data fusion used not only to integrate the different information available but also to increase its reliability. With this approach, the tool presented becomes more proactive as it depends on present factors and not on historic data.

The Performance Value Estimator (PVE) tool is composed of two main components: Neural Networks and Kalman Filter. Although it depends on the type and the path through which the information is made available, these components need to have purposes and goals adequately defined (Bolland and Connor, 1997). The Neural Network's main goal is to emulate and model complex, dynamic and non-linear systems, in a simple, efficient, fast and computationally undemanding way. The purpose of the Kalman Filter, however, is to optimize and minimize errors that occur during the modeling of the system. In the context of the Data Fusion approach, this filter is essential when working with complex environments, such as in factories, hospitals and other systems where the number of input factors affects the performance of the organizational system. Indeed, when the quantity of factors is vast, how these variables interact with the system becomes complex and non-linear and then controlling and managing the system is a difficult task. Consequently, a decision support system is important in order to facilitate data integration within the organization.

The PVE is a mathematical tool which was developed for performance management in order to bridge the gaps previously outlined. This tool's main goal is to provide estimation values for the current KPIs or define new targets, bringing together all of the essential process information regarding activities, tasks, internal and external disturbances and functional requirements that can positively or negatively affect the system.

The PVE tool is a performance hybrid model that has a core system that uses leading measures in performance estimation (Figure 41) of KPIs.

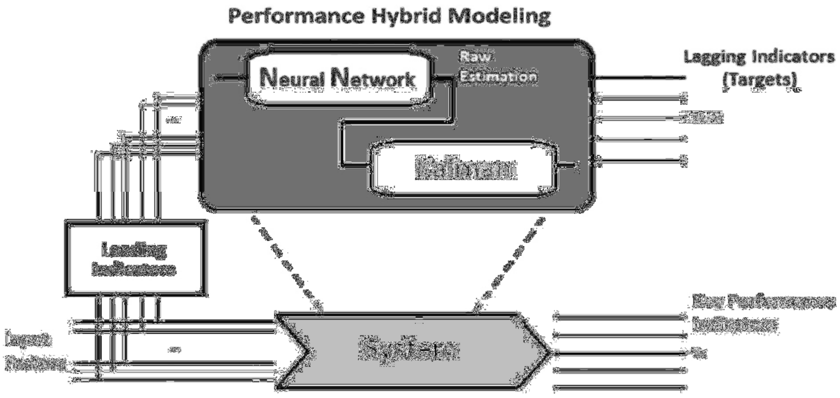

Figure 41. PVE estimator architecture (Azevedo and Almeida (2011)

The PVE core operates in parallel with the system that is being emulated. In real-time this receives the measures (leading measures) in a proactive performance management approach and the predictable information about the factors that can influence or positively/negatively disturb the system. With this information, target estimates are produced for the selected KPIs. According to Azevedo and Almeida (2011), KPI estimations can be monitored in real-time, making it possible to estimate and predict the system's reaction to improvement processes in a long term. These authors state that:

> *"Using leading measures of real-time performance, it is possible to do a feedforward control on development and deployment of plans and objectives. Otherwise, through a feedback control, the comparison of actual performance with proposed targets is based on historical lagging measures. Therefore, proactive performance management, using feedforward and feedback controls, tries to predict the future performance instead of treating processes with poor performance. In line with this, it is necessary to provide a proper combination of leading and lagging measures, thus enabling the use of forecasting methods and tools to obtain good quality predictions."*

A component called “System Emulator Core” was developed in order to make it possible to apply this concept not only to one system, but also to a network with different sub-systems, which interact with each other, as depicted in Figure 42. This component deals with four types of data: disturbances, control, performance and decision data. The first type represents the information that disturbs and influences the performance and behavior of the system. This information can also be divided into two main categories, such as internal and external disturbances. Internal disturbances are the factors caused by the entity, where the nucleus is embedded, affecting this component due to the entity’s behavior and internal interactions. Furthermore, external disturbances can be seen as the other factors that are not derived from the entity, and yet influence the system that is being analyzed.

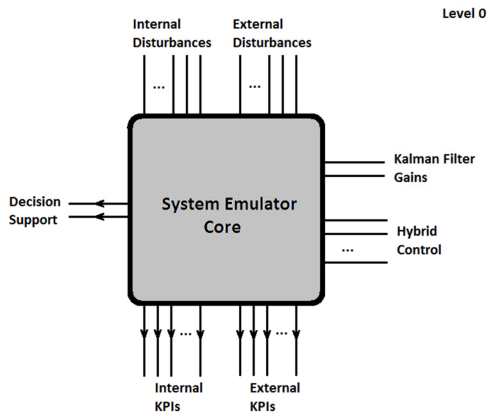

Figure 42. System core emulator

Control data allows users not only to define the best filter gains, in order to tune and improve the estimation quality, but also to choose the desired behavior for each moment. Thus, the disturbance data and control data are the input data.

Furthermore, the decision and performance data represent the response and the output of the PVE. In fact, the decision support data provide a relevant support for decision-makers, guiding them in re-designing the company's strategies. In conclusion, performance data is the values of targets of the KPIs, and it mean the best performance value that can be achieved by the system in a certain context.

In real-life scenarios, there are often factors and variables that cannot be controlled or predicted, this makes it difficult to achieve the state model definition. Estimation and forecasting problems may become easier to solve by using existing deterministic observers, such as the Luenberger observer (Luenberger, 1971). Therefore, it is important to distinguish between factors that are deterministic and those that are stochastic. According to Origlio (2011), the stochastic concept is used to indicate that a particular subject is seen from the point of view of randomness, whereas deterministic means that random phenomena are not involved. Therefore, it is possible to conclude that stochastic models introduce critical uncertainties, while deterministic models always produce the same output for a given starting condition. When the type of factors is known, it is useful to represent this assumptions with a mathematical tool so-called the Deterministic-Stochastic System that is presented in Appendix E.

Therefore, the JDL steps, previously described in the data fusion approach, were carefully taken into account during the PVE algorithm in order to deal with both dynamic and complex environments and the stochastic factors. First, the estimation tool collects the specified data from data repository systems (JDL level 0). At this point it is important to specifically select the factors that affect the system's performance. It is important to underline that the information required, which comes from sources inside and outside of the system, is subject to disturbances (both internal and external disturbances) that should be anticipated and considered during the estimation process. Therefore, an algorithm capable of combining all of the raw data in order to extract the more reliable data must be used (JDL level 1). In the next step, the PVE tool, through the ANN tool, specifies a network in order to describe and emulate the relationships that occur within the system between the different entities, factors and the performance indicators involved (JDL level 2). Finally, a performance projection is achieved, as well as a dashboard and it is possible to monitor the future performance in the defined time period (JDL levels 3 and 4).

Figure 43 shows a more detailed description of the Artificial Neural Networks and the Kalman Filter's integration within the PVE tool. First, a rough estimation of the state variables is achieved by treating the input factors. In this module, the leading indicators are instantiated into an untreated estimation. Following this, the estimated state variables are translated into performance indicator estimations through the multiplication of these data with system description variable *C*. This result is then compared with the output measures of the real system in order to bring the value of the gain of the filter closer to an optimal value. The behavior of this gain can also be tuned. This can increase or decrease sensibility to errors, thus avoiding oscillations and overshoots. Finally, this correction variable is added to the rough estimate in order to bring the value of the estimate closer to the real value, bridging the gap between the modeling, process and measurement errors.

In conclusion, the combination of Neural Networks with the Kalman Filter presents an important advance for the performance prediction within non-linear system with complex behavior (e.g., those with large quantities of measurements and process errors, factors with complex iterations or missing data). The result of this combination can be described as a "stable neural network".

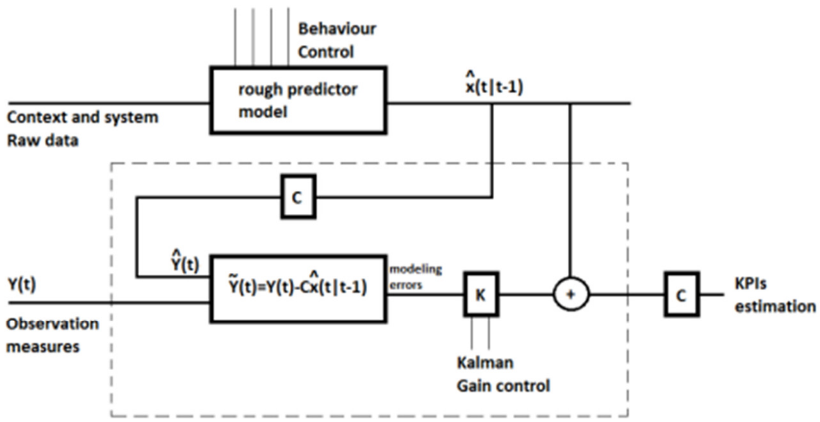

Figure 43. PVE Concept (Azevedo and Almeida, 2011)

4.2.3 Alignment Prediction: a new paradigm

In fact, employing the performance prediction paradigm made it possible to suggest a similar approach to the alignment for CNs with respect to setting performance goals. Therefore, the predictive KAIs (PKAIs) will be used to calculate the degree of alignment of the CN, predicting the future alignment. It is important to understand that the aim is to use the indicators of performance for certain critical operations in order to ascertain whether the values of the KAIs selected by CN decision-makers are within predefined patterns. The PKAIs chosen for assessing the performance of the inter-organizational processes are then obtained using a method based on a fuzzy expert system to determine the future degree of alignment of the CN.

The criteria for selecting the PKAIs are derived from the expectations of the CN decision-makers with regard to the strategies and inter-organizational characteristics. Moreover, it is initially important to conduct a survey on the main KPIs used by each participant and choose the KAIs relating them to time, cost or quality. Depending on the complexity of the selected KAIs, the CN manager must not only select the predictive KPI used for this transformation, but they must also choose each PKAI which can be composed of one predictive KPI or a combination of KPI's. Therefore, it is possible to define measurable alignment indicators that are capable of instantiating the state of the overall future performance of the CN according to the strategy defined by the network management board.

The alignment prediction concept aims to be useful in measuring performance in CNs. It has been stated that performance management based on data collection and assessment of KPIs may not be effective due to the different indicators and measurement systems in place for the various participants in a collaborative network. Therefore, measuring the inter-organizational alignment based on key alignment indicators (KAIs) can be an excellent alternative that improves collaborative performance management systems.

This approach motivates the development of a theory on alignment prediction and, consequently, proposes an alignment metric for this purpose since this research has evolved from the assumption that the alignment can be measured using PKAIs. Thus, an estimation tool, the PVE, and performance classifiers based on fuzzy logic, were developed and tested to create a metric to instantiate the future alignment, ensuring the future internal fit of the CN.

Indeed, one of the main advantages of applying the alignment prediction concept is its ability to assess the future alignment of a CN. Consequently, fuzzy logic can be relevant in the development of a toolkit which includes the PVE tool, making it possible to assess the performance of each potential partner during the partner selection process, and evaluate the overall network performance during the operation time. Fuzzy Logic was introduced in 1960, by Lotfi Zadeh, in order to respond to problems with non-probabilistic uncertainties (Driankov, Hellendorn and Reinfrank, 1993). From that moment, this technology has been widely applied to support decision-makers in the classification of problems, computer vision and many other subjects. Indeed, this technology is normally used when there is not enough knowledge and certainty about the system that needs to be controlled. Moreover, this represents an interesting tool for modeling non-linear systems, which are the most common in the real world.

According to Oliveira Jr. and Aguiar (1999), Fuzzy Logic can be described as "*a set of methods based on the concept of fuzzy set and fuzzy operations, which enables realistic and flexible modeling systems. The most notable aspect of this methodology is the ability to capture in a mathematical model, intuitive concepts such as degree of satisfaction, comfort, fitness, others*". It refers to the modeling of degrees of uncertainty existing in natural language and it is widely used to develop expert systems.

In the collaborative network context, Camarinha-Matos and Afsarmanesh (2008a) state that there are some examples of the potential applicability of fuzzy logic in CNs, including: "*supervision and assessment of performance in CNs, modeling and assessment of enterprise agility, negotiation and decision making in consortia formation, partners' selection, modeling agents' interactions, simulation for analysis of emergent behavior, implementation of auctions, negotiation in resource sharing / access, others*".

In Appendix D, a Fuzzy Logic explanation is provided in order to explain the approaches and methods that are applied in this research.

Predicting the future alignment makes it possible to support business planning in order to establish the individual actions necessary for each partner in order to improve alignment within the entire network.

4.3 The "Fit Degree" Concept and Method

In this research it is stated that there are many advantages to using the alignment prediction approach for collaborative networks, in particular with regard to the assessment and evaluation of the overall performance of the CN. By instantiating the performance of intra- and inter-organizational processes, it is possible to detect gaps in order to plan improvement solutions and provide the necessary resources. However, it may not be easy to measure the participants' individual efforts. Consequently, measuring the alignment around the CN targets can be a successful way of making participants aware of their individual efforts towards achieving the overall expected performance.

Complementing this, it is necessary to support the alignment prediction approach using a toolkit that consists of estimates (e.g., the Performance Value Estimator) and qualitative classification (e.g., the Fuzzy Expert System). In fact, the previously mentioned "Fit Degree" is an alignment metric that is obtained using the values of predictive states through PKAIs that are defined by the CN decision-makers from the existing set of KPIs (Figure 37, page 94).

With predicted values, the performance of participants in the CN can be classified using a Fuzzy Expert System that looks at the performance targets, making the degree of compliance previously obtained by each participant explicit.

Basically, this proposed metric means selecting KAIs derived from predictive KPIs in order to compare them with the target process values (compliance degree), to instantiate this using a decision table developed by the CN experts and then revealing how they were fulfilled or, how the performance targets will be fulfilled by the participants in the CN. This classification of the degree of alignment is then performed using the fuzzy logic to obtain the predictive degree of alignment - the Fit Degree.

Following, the comparison results are determined using a decision table developed by the experts that reveal if these targets have been achieved or why the participants in the CN were not able to achieve these performance targets. The classification of the alignment is then performed using the fuzzy logic to determine the qualitative rate for the future degree of alignment. Therefore, the Fit Degree process has the following tasks:

T1: Definition of CN Strategy and Goals – First, the CN stakeholders must define the main strategic goals for the entire network in order to define the strategy that will be followed by each participant.

T2,T3 and T4: Collection of Key Alignment Indicators – From the list of KPIs already calculated in each of the CN partners, the main KPIs should be selected that are capable of providing the appropriate alignment information as well as translating the performance in terms of the strategic purpose and expected outcomes for the inter-organizational processes of the CN.

T5: Definition of Target Values – Once the KAIs have been selected, it is necessary to transform the CN objectives into KAI target values.

T6: Application of the PVE Tool (performance prediction) – Once the KAIs have been selected, the PVE tool should be applied in order to obtain the predictive values (PKAI).

T7: Application of a Compliance Decision Table – Having obtained the estimated values for the KAIs, the CN experts must compare these values with the expected targets by using a decision table in order to evaluate the individual performance of each partner in the network.

T8: Classification of Compliance Degree – During this stage, the matrix that supports the classification of the compliance degree (CD) should be defined and performed in accordance with the network assumptions.

T9: Partner Classification using CD value – During this stage, the values of the CD should be transposed to a decision table that makes it possible to classify each participant in the network and thus calculate the participant compliance degree. Depending on the number of KAIs chosen, the decision table must be designed following a multi-variable approach.

T10: Calculation of the Fit Degree (alignment prediction) – Finally, taking the values of the classification of individual alignment, the value for the Fit Degree that represents the predictive degree of alignment (PDA) should be calculated.

This process is composed of different methods and tools in order to enhance the tasks and provide criteria, outcomes and procedures to determine the Fit Degree. A pilot case was applied in a supply network in order to validate this approach, as presented in Section 5.4., by performing the next steps.

Figure 44 show the Fit Degree process establishing the main interveners, such as: CN stakeholders, CN expert, Performance Management System.

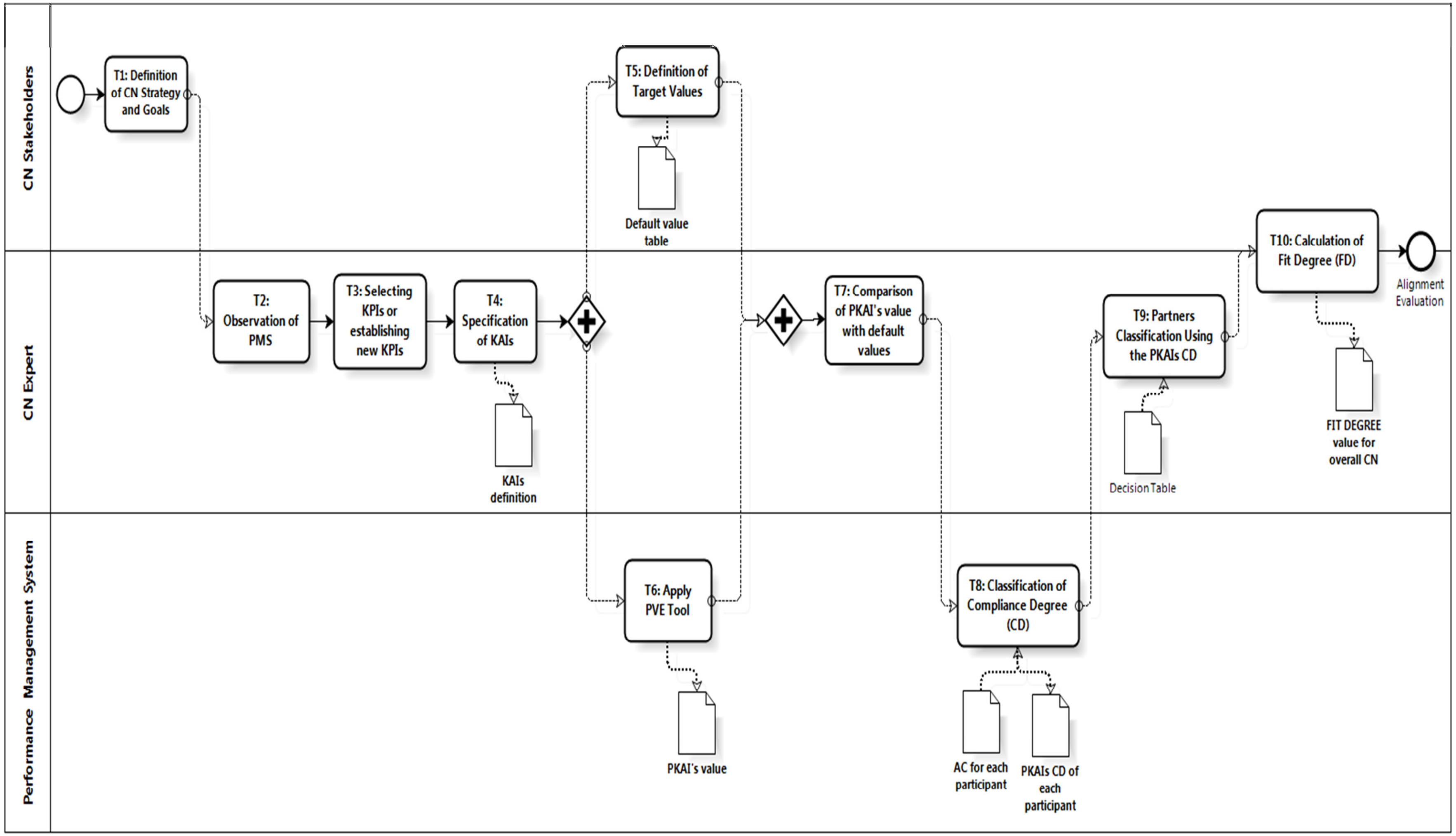

Figure 44. Fit Degree process

4.3.1 From KPIs to KAIs

First, decision-makers extract from the PMMS the KPIs that can be transformed into KAIs. At this point, the KPIs are analyzed to select appropriate indicators that best translate the inter-organizational processes which show whether the overall performance of the CN is being fulfilled.

The selection of the KPIs must be performed within an appropriate PMMS that effectively translates the performance objectives and goals of the CN. If not, other KPIs must be established. These chosen KPIs will then be used as the KAIs that can effectively translate the performance objectives and goals of the CN relating to the accomplishment of operation targets.

4.3.2 Transforming the KAIs into predictive KAIs

Following, using the PVE tool, each of the defined KAIs must be used to estimate the system's behavior for the following period or periods. In order to accomplish this, the system under analysis should be modeled according to the historical data, using a learning machine such as Artificial Neural Network (Farahat, 2004).

These historical data, which include system input and output information, must be carefully selected since this decision will strongly influence the estimation reliability, as following described. The input information, also defined as the leading factors or performance drivers, expresses the factors that can influence/disturb the overall system performance. These factors can be divided into system factors (U) and process factors (Q). In other words, from the leading factors selected, there are variables that are known beforehand (system factors), as is the case of the number of requested orders, as well as the overbooking possibility and the scheduled actions for preventive maintenance. However, although restrained within a known or proposed range, variables such as the production performance and the supply and transportation reliabilities affect the system in an unpredictable way. Therefore, this last group of data is defined as process factors. Finally, the output data (lagging factors or outcome measures) express the KAI's values in the conditions imposed by the input data.

4.3.3 Specification pattern definition

After the predicted performance values are obtained, they may or may not be in compliance with the values previously defined as targets by the CN's decision-makers. Therefore, it is important to compare these values with the predefined values (targets).

Furthermore, when PKAI's values are assessed there are goals that are established in order to be accomplished and it is important defining the specification pattern values or intervals in order to classify the compliance degree with these pattern values (see Table 64).

For example, in a manufacturing operation the number of losses for manufactured products is a common concern (how many of the total products produced were produced with irreparable non-conformities). Thus, this methodology proposes five degrees to assess compliance with defined targets: very good, good, medium, bad, very bad. Following this specification pattern value table makes it possible to compare and classify the PKAIs to determine the degree of compliance with targets.

4.3.4 Compliance degree classification process

After having developed the patterns table, for a certain PKAI, the collected values from each CN participant are compared with the pattern values. Thus, the set of PKAIs of each participant is then classified according to a degree of compliance with the respective pattern, such as: “fits very well”, “fits relatively well”, “fits moderately”, “fits badly” and “fits very badly”.

By using a decision table to determine the classification of the degree of compliance, it makes possible to describe the key concerns when assessing whether the set of PKAIs of each participant is appropriate to the goals established.

NON \ DDT	very good	good	medium	bad	very bad
very good	fvw	fvw	fw	fm	fb
good	fvw	fw	fm	fb	fb
medium	fw	fm	fb	fb	fvb
bad	fm	fb	fb	fvb	fvb
very bad	fb	fb	fvb	fvb	fvb

fvw fits very well
fw fits relatively well
fm fits moderately
fb fits badly
fvb fits very badly

Figure 45. Compliance degree classification (CD table)

In the use case explored in this research, just two variables are taken in account: DDT – Delay of Delivery Time (of orders) and NON – Orders (delivered) with Nonconformities detected. Thus, the CD table (Figure 45) instantiates the degree of compliance of one participant and clarifies whether its performance meets the expectations of the CN. However, more than two PKAIs could be used making it necessary to follow a multi-variable approach to determine this classification.

It can also be noted that the decision table may consider some PKAIs as more important than others and not linearly as in Figure 46. Therefore, a PKAI may surpass the other when it is more important, like the NON in this example (Figure 53).

NON \ DDT	very good	good	medium	bad	very bad
very good	fvw	fvw	fw	fm	fb
good	fw	fw	fm	fb	fvb
medium	fm	fb	fb	fvb	fvb
bad	fb	fb	fvb	fvb	fvb
very bad	fvb	fvb	fvb	fvb	fvb

fvw fits very well
fw fits relatively well
fm fits moderately
fb fits badly
fvb fits very badly

Figure 46. Compliance degree classification table without linearity

This decision table calculates the CD for each participant using both PKAIs, making it possible to visualize the participants that will perform better or worse in the future. It is therefore imperative that these values are able to contribute to determining the future level of overall alignment. Following this step, the Fit Degree can be calculated to obtain degree of alignment.

4.3.5 Fit degree calculation process

Although the Fit Degree metric was initially used in the first case study, during this research it has been totally changed to the predictive approach. Furthermore, methods can be used to classify each participant in relation to the degree of compliance with targets as an input to determine the Fit Degree according to the following classifications: highest, high, medium, low and lowest.

The objective is to use Fuzzy Logic in order to calculate the Fit Degree. Indeed, one of the main advantages of this decision support tool is its ability to determine a qualitative value for the future alignment of the CN, or even just to analyze the potential performance of each potential partner.

The triangular and trapezoidal membership functions are used in the fuzzification process. The inputs and outputs are the PKAIs from the estimator tool and the participant's evaluation, respectively. During this process, the membership functions were specified taking different requirements of the CN under study into account.

Moreover, during this demonstration, only two PKAI vectors were used, the NON and DDT, in order to keep the demo representation simple and clear. However, this proposed technology has the ability to support an indeterminate number of independent variables, maintaining the logical reasoning as previously described. In fact, it is important to clarify that, as more variables are defined, the evaluation of the potential network partners becomes more specific and rigorous. Thus, this new control surface would be similar to a polynomial of degree n, attempting to model all of the requirements defined by the CN controller and aiming to model the existing knowledge about the behavior of the CN structures and the inter-organizational processes (internal fit).

During the partner selection process, the different values of PKAI of a set of potential partners makes it possible to predict the level of reliability for each partner, in terms of the requirements and expectations initially set by the CN decision-making board.

More details on this process of determining the Fit Degree will be presented in section 5.4 in which this use case is outlined and the PVE tool is run.

4.4 Concluding Remarks

This chapter presented the alignment prediction approach and outlined its ability to support the evaluation of the future performance of a collaborative network.

Furthermore, using the performance prediction paradigm, a performance estimator tool using a data fusion approach to predict future performance behaviors was presented. Moreover, the motivation for using this approach was discussed along with the mathematical approaches that make it possible to design estimation tools. Complementing this, it is necessary to pay attention to possible restrictions which can affect the results. Thus, the reliability of performance data, the conceptual knowledge on performance measurement and the technological support are crucial issues.

This innovative approach was structured to use predictive alignment indicators derived of estimation of performance indicators in order to measure performance in networked business environment. In addition, appropriate methods and tools were justified and explained only in part because they will be used in the case study "G3 Supply Network", presented in section 5.4.

The Fit Degree alignment prediction method was introduced in detail and depicted a flowchart. The steps of this method are based on a practical application leading to a reading of the supply chain case in the next chapter.

Chapter 5

Application Cases

This chapter presents application cases developed and used to analyze and validate the alignment measurement approaches and methods. Thus, two cases were studied in collaborative networks of small and medium-sized Brazilian companies. The outcomes should contribute to improve these approaches and methods for other specific applications in real life situations. In order to support the CN decision-makers, a performance management framework is also proposed to make it possible to develop and implement a collaborative PMMS which is guided by a specific methodology for its implementation. Complementing this, the relevance of ICT technologies is highlighted and a web service application to improve the interaction between CN participants is referred.

5.1 Introduction

The cases presented in this chapter were carried out at different times and each one evolved differently. First, the business case Pet Shop Retailers began with the use of the PMMS Implementation Methodology in order to highlight the tasks relating to performance management in collaborative networks. In fact, the goal is to instantiate the performance of intra- and inter-organizational processes to motivate CN decision-makers in developing and implementing a PMMS. Furthermore, this case also aimed to highlight the use of SSM in the effective planning, implementation and monitoring of a performance management system supported by a conceptual framework that can provide instances of CN performance. Finally, this approach aims to make it possible to consistently measure the alignment in small-sized CNs.

The business case Pet Shop Retailers was performed essentially to be a pilot case, but thereafter allowed the determination of the degree of alignment as a subjective-descriptive measurement. However, in this case, this approach evolved to make it possible to establish a performance benchmark for the CN participants because they use exactly the same KPIs. Furthermore, a questionnaire method to get perceptions of the CEOs on performance and also

KPIs of intra-organizational processes were used then Euclidian Distance method and DEA approach were used respectively for obtaining the SDA and DDA measures, as presented in Section 5.3.

Another business case, the G3-Supply Chain Case, was also carried out, but different approaches and tools were used. Moreover, the performance prediction paradigm introduced the concept of alignment prediction. Subsequently, the PVE tool was introduced in the CN performance management functionality of the CNPMS framework (Francisco *et al.*, 2011). In practice, this estimator tool provides predictions in relation to the participant's performance in order to feedforward this behavior and then establishing the performance targets and forecasting performance in the CN operation, as well as forecasting another objectives that require predictive values. The alignment prediction then is the concept used to create a method for determining the PDA in order to forecast the alignment in collaborative networks.

Application software was also introduced at a later stage. This web service, the CNPMS Manager, was designed to facilitate CN participants to exchange information and performance data. This ICT tool was developed and tested in the G3-Supply Chain Case.

5.2 Performance Management Framework

5.2.1 A performance management framework for collaborative networks

In this research, a framework proposal to support performance management was developed in order to facilitate the accomplishment of requirements of the collaborative PMMS. This approach includes the life-cycle paradigm to enable the assessment of the CN's performance from the moment of conception, including the partner selection and operation stages, until its dissolution or metamorphosis.

This framework was used in application cases of collaborative networks of Brazilian SMEs supported by the PMMS implementation process that uses an approach based on the Soft System Methodology. These applications based on the proposed performance management framework, the CNPMS, were useful for implementing the PMMS in these CNs.

Therefore, this conceptual framework aims to make it possible to instantiate the performance of inter-organizational processes in order to meet the strategic assumptions that lead to the creation of a CN. In order to meet this need, a hierarchical approach was adopted in the development of this conceptual framework. This approach proposes various functionalities of performance management within a timeframe of phases of the CN life-cycle. Therefore, this framework is composed of specific layers, such as: performance data repository, performance functionalities and CN's life-cycle.

Employing a hierarchical performance management framework offers several important benefits. This approach provides a unified framework for aggregation performance measures across the network. In fact, for certain network nodes this framework intends to facilitate the development of measures for the nodes and it also supports the whole performance system. This hierarchical approach can also contribute to aligning the collective activities to conform to a desired vision, mission and the network's targets. Moreover, it is necessary to design this framework adequately and it should guarantee three main effects:

- It should be used as the basis of the as-is situation, helping to describe the past and the present of each business process considered;
- It should be used during the search, design, agreement and operational phases for managing the CN;
- It should be used to set global and local performance goals, focusing on the future.

In this way, the CNPMS framework (Figure 47) proposed by Azevedo and Francisco (2007) is based on two main layers: data & information and functionality.

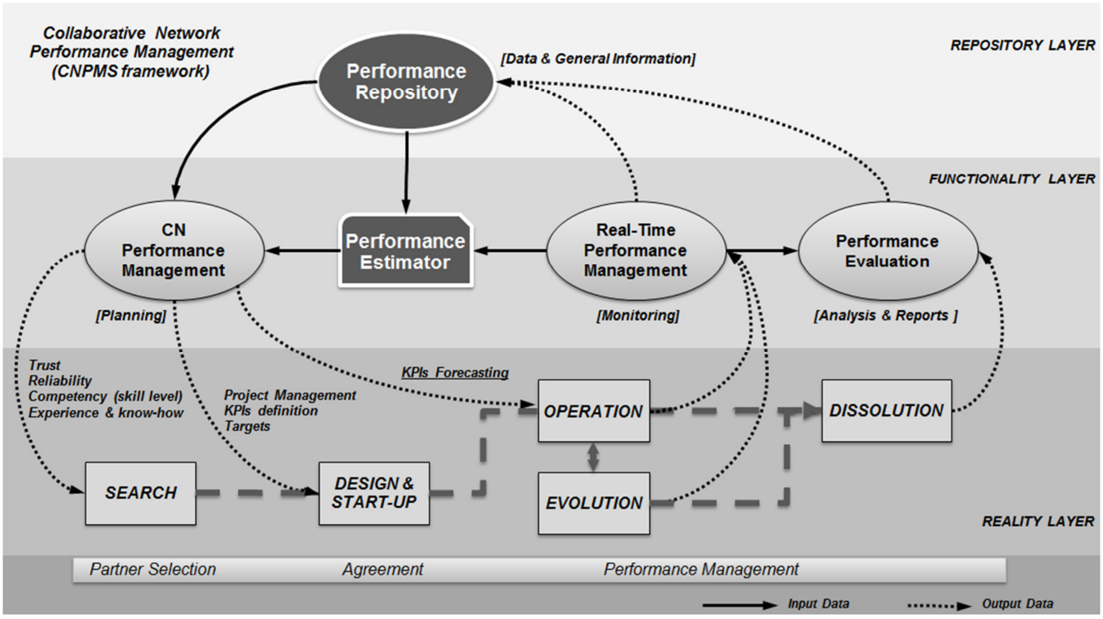

Figure 47. CNPMS framework

The first layer is composed exclusively by the data repository that deals with data acquisition and data management. All data regarding performance and general information is coming from new data collection actions and past experiences relating to each partner's performance as well as the CN's overall performance. In the Search phase, the relevant information on trust, experience and know-how, reliability, competencies (skill level), among others, would came from the Performance Repository when past performance of CN participants are known. This makes it possible to save time during the Search phase as well as during the Design phase by using this information. The Performance Repository module continuously receives data of performance in real-time. It also receives data on the analysis of results and in particular on the effectiveness of the intra- and inter-organizational processes. Consequently, it can keep the data updated to manage future network collaboration or support the improvement of the overall performance.

The CN's performance memory should be used during the Search phase of the life-cycle, during the selection and recovering of performance measures and during the Dissolution phase. This is relevant in order to understand the competencies, experiences and specific performance indicators to increase organizational learning. The intention is to learn from the analysis of past experiences. This means creating a repository of performance information, where the leading and lagging data are extracted during the CN life-cycle for implementing decision-making support repositories. With this information, actions such as performance benchmarking, partner selection, KPI definition and also definition of performance targets can be performed. These activities must be adapted and enhanced with continuous improvements.

The second layer is the functionality layer that leads to planning, monitoring, analyzing and reporting performance; it manages the collaborative performance during the CN life-cycle phases using the following functionalities:

1) network performance management functionality supports process planning and drives the activities during Search, Design & Set-up and Operation phases and also when capturing data from the performance repository to provide performance benchmarking for partner selection. Furthermore, it helps describe the performance targets that will be upgraded and improved using proper KPIs that will predict the performance and, consequently, contribute to the deployment of the CN's project;

2) real-time performance management functionality can contribute to solving emerging problems rapidly and formulate improvements during the Evolution phase by measuring the performance outcomes. It can also monitor the efficiency and effectiveness of intra- and inter-organizational processes in order to understand the performance and the knowledge on the performance results collected during the life-cycle phases. During the Operation phase, proper static and dynamic KPIs are applied that enable improvements on the time factor (agility) and operation performance (flexibility) to providing sustainability for the continuous improvement and change management in order to increase the alignment between participants. An indicator that shows the operational results is considered static and those that are defined to facilitate reactions and resolve emerging problems are considered dynamic. Gaps that may exist relating to processes' improvements are dealt with during the Evolution phase;

3) the performance evaluation functionality deals with the compilation of performance data in order to understand whether the CN has achieved its objectives during the Dissolution phase and then transfer this memory of performance to the Performance Repository. This functionality also extracts knowledge from the analysis and creates a repository of information about the performance generated by participants at each stage of the life-cycle. This is mandatory in the Dissolution phase, especially for a VBE collaboration.

Furthermore, the activity layer includes the CN life-cycle phases, the three milestones (partner selection, agreement and performance management) to measure the alignment and also the management requirements and tools suggested to be developed. These milestones can be adapted by academics and practitioners, in terms of the methods and tools for planning and operating CNs.

An important module was introduced to the CN Performance Management functionality, the Performance Estimator. In practice, the estimator tool provides predictions for a partner's potential performance in order to feedforward the behavior of the CN performance. It defines the possible performance targets and forecasts performance for the CN and it also defines other objectives that need predictive values. By applying an estimator tool the aim is to provide estimates that enable the CN Performance Management functionality to support planning of the performance management systems. The KPIs that monitor the collaborative performance are set in order to be estimate. This research has led to the development of an estimator tool called the Performance Value Estimator (PVE) that provides predictions on a partner's potential performance to feedforward its behavior, define the possible performance targets and forecast performance in the CN operation.

Different subjects may be considered to establish the set of measures and indicators supported by concepts and methods to deal with the PMMS implementation process, including: change management, continuous improvement and Kaizen philosophy, quality management systems and excellence models, Business Process Modeling (BPMN), Total Productive Management (TPM) and Lean Six Sigma.

Certain aspects of a performance framework for collaborative networks in particular, should be considered, as depicted in the next figure (Figure 48).

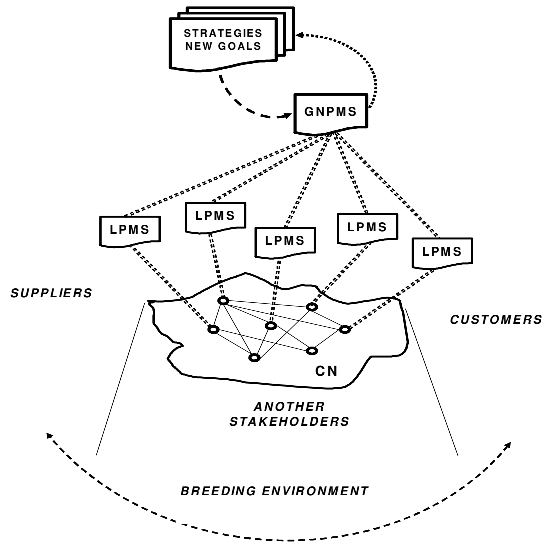

Figure 48. Global and local measures system

The main concern is the interaction between the CN participants considering their own local performance management system, i.e. LPMS, and the global network performance management system, i.e. CNPMS. First, a LPMS must be developed for every significant CN participant and they should consider the alignment of that local system with the CN infrastructure and common global objectives and goals (i.e. internal fit). It may support the CN decision-makers in terms of managing and improving intra- and inter-organizational processes. Consequently, an analysis of performance must be carried out in order to understand if the CN has reached its goals and to build a memory about their performance. It is mandatory during the Dissolution phase.

It was already mentioned that the VBE collaboration strategy has to be propitious to implement such performance management systems and to be capable of showing the benefits provided by the performance assessment. This insight considers that the inter-organizational alignment becomes more feasible. Moreover, the ICT interoperability must be integrated for performing better in order to obtain consistent data and to design a platform to integrate the CN participants.

Therefore, an implementation process to implement a PMMS should be designed considering the requirements necessary to meet the objectives and goals of the CN.

5.2.2 ICT support technologies

The cooperation and collaboration strategies are still growing because they are supported by the improvements in information and communication technology (ICT). This technology area is unquestionably necessary in terms of supporting operations and internal process management and their interrelationship with the market. According to Wiehler (2004), "*Information and communication technologies have been developing at a breathtaking speed, their evolution accelerating despite the recent slow-down in the economy*".

Although there are a large number of infrastructure and ICT solutions to support integration between departments and companies, new solutions must be developed or acquired because those available are generally heavy and are not able to respond to the latest technological advances. Architectures that can provide a natural operational environment are also important (Chituc and Azevedo, 2005). Camarinha-Matos, Afsarmanesh and Ollus (2005) state that

> *"Implantation of any form of collaborative network depends on the existence of an ICT infrastructure. In order to leverage the potential benefits of the collaborative networked organization paradigm, more flexible and generic infrastructures need to be designed and implemented. The lack of common reference architectures and generic interoperable infrastructures, together with the rapid evolution of the underlying technologies, represents a major obstacle to the practical evolution of the area."*

According to Holmström *et al*. (2002), forecasting, distribution and inventory management across a network of various companies linked together is possible using Enterprise Resource Planning systems and/or Supply Chain and Control systems. This requires common IT solutions or middle-ware solutions. Similarly, the challenge in collaborative product development is to keep the different parties updated through a common product data management system.

Furthermore, for collaborative networks, the aim is to address the distinct requirements of technological support systems that can support a dynamic PMMS tailored for a networked business environment. Even so, the ICT issues demand an accurate response by decision-makers. The aspects related to information processing in CNs require conscious attention in managing the shared systems, probably using a web service application.

Web services are structured within a Service Oriented Architecture (SOA) that consists of an environment in which applications are linked to other applications in their own system or they are remotely controlled through a web network (Wiehler, 2004). Although the web services are autonomous in relation to the systems, they can offer modular solutions for different applications, but the most attractive advantage of web services is the possibility of them being available on the Internet.

With regard to using information systems to support interaction between organizations by collecting data for further analysis, the main objective should be to obtain reliable values to assess performance and alignment. Thus, the operations necessary for computing data compiled from certain sources (e.g., CN participants) require a software application that can run between all CN participants in a clear and systematic manner.

According to Chapell (2009), "*A Web service contract is essentially a collection of metadata that describes various aspects of an underlying software program, including:*

- *the purpose and function of its operations*
- *the messages that need to be exchanged in order to engage the operations*
- *data models used to define the structure of the messages (and associated validation rules used to ensure the integrity of data passed to and from the messages)*
- *a set of conditions under which the operations are provided*
- *information about how and where the service can be accessed*"

Therefore, for supporting this research was developed a software application, called CNPMS Manager, which is an web-based software. It can provide the necessary interactivity to manage the performance data and also deliver the performance and alignment results to the CNs participants. Furthermore, the web service model adopted is classified as a task service which is based on the nature of the logic it encapsulates, the reuse potential of this logic, and how the service may relate to domains within its enterprise (Chapell, 2009).

The CNPMS Manager is a software application designed to help the users perform singular or multiple related specific tasks to provide information on performance in CNs. Basically, this consists of requesting data from the participant organizations in order to compile these data for a performance dashboard. Thus, the CN has the performance data in a repository (database) of performance that can be used for the analysis of past and present and also to supply data for the PVE tool to analyze the future of the overall performance.

This application offers advantages with regard to communicating the values of KPIs and/or KAIs to the CN participants. Each participant enters the data on their performance, as well as the broker (or manager) that can also enter data related to the inter-organizational processes then these results can be assessed by several tasks, including: analysis and interpretation of the data available, application of the PVE tool for the prediction of KPIs and/or KAIs. Therefore, this application software consists of the following stages: functional requirements, systems engineering requirements, configuration, implementation and validation tests. Therefore, the CNPMS Manager has the following core functions:

User administration - Each participant organization must determine which of their employees has the login and password to access the CNPMS Manager. Therefore, this web application must support multiuser access and then authorization procedures have to be developed.

Enrollment process for participants and KPIs – The participants are registered with the associate information and the KPIs are also registered with code/name, dimension unit, utilization profile and category of measures.

KPI data collection – The KPI values are collected by users and managers to enter these data. The information requirements are: KPIs, KPI category, local and inter-organizational measures (e.g., LSSM, LSOM, CNSM and CNIM), unit dimension, the value and the collection period.

Report and performance analysis – After entering the data it is possible to request a report with the performance measured values, but only after all of the data have been entered. The performance analysis process can then be performed.

Using this web service solution to integrate the CN participants seems to be a useful approach that can be applied in collaborative networks that consist of small and medium-sized organizations. However, this solution just performs the data exchange in order to replace the recorded performance values in a database, or performance repository. This solution makes it possible decision-makers analyze and identify gaps occurring in each partner's processes as well as in the inter-organizational processes of the CN. A more precise explanation about this software application is presented in Appendix C.

In fact, another solution can be developed to publicize this performance information on the CN participants and respective stakeholders. A Web Dashboard released on the Internet environment can be appropriate for anyone that is able to access corporate data in the form of graphics, reports and blogs.

In addition, user "manager" and "participant" have different responsibilities in providing data. The user "manager" conducts the following tasks:

- managing the CNPMS Manager
- validating the network participants
- providing login and password details for the user "participants"
- cataloging the categories of KPIs (e.g., collaborative measures and participant measures)
- collecting data of the collaborative measures and introducing them in CNPMS Manager

The user "participant" conducts the following tasks:

- managing the performance measurement system of its own organization
- collecting data of individual measures and introducing them in CNPMS Manager

In summary, the performance data are compiled in the database of this application and stored, not only for your viewing and analysis, but also for use in other applications such as the PVE tool and the alignment classification tool, the Fit Degree.

5.3 Pet Shop Retailers Case

The “Pet Shop Retailers” network is a Brazilian collaborative network of small-sized enterprises that joint participants interested in achieving benefits through the joint formulation of strategies and operations in a regional market. This CN was created in 2007 as part of the Empreender Project, sponsored by the Brazilian Support Service to Micro and Small Enterprises (SEBRAE). It is an initiative to increase entrepreneurship for micro and small companies so that they can benefit from the synergies between competitors within the same business branch. This project aims to address common problems with regard to common suppliers, logistics services, marketing campaigns, asset security and employee training which can be contracted through aligned strategies. It mainly aims to reduce costs and increase bargaining power with suppliers. In conclusion, they work together to increase competitiveness.

This CN includes about sixteen participants and acts as a dynamic project-based partnership without a dominant participant (Camarinha-Matos and Afsarmanesh (2004). This entrepreneurship program is supported by SEBRAE which offers its expertise in business management and provides resources to support planning activities and consulting on business planning in order to point the way forward.

In fact, this CN aims to share knowledge and resources management, including: the ability to manage inventory and purchasing, sharing resources for marketing actions and merchandise and hiring instructors and locations for training.

The PMMS implementation process was performed in order to guide the CN participants to assess both the enterprise’s performance and the CN’s overall performance. For this purpose, both subjective and descriptive approaches were used. First, the participants sought to measure the performance of their operations and after starting the collaborative network they then sought to check if improvements in the performance were occurring in order to assess whether they should remain in the CN or not. After this, another approach was applied using the results of individual performance and comparing them to determine a benchmark in order to help participants with a poor performance. This aims to design and implement actions for their processes that make it possible to obtain results which coincide with those from participants with a better performance.

Complementing this, the SDA was calculated for the three decision-making moments in order to verify the participants' perception about the benefits offered by this collaboration strategy. Therefore, the alignment assessment process is composed of the following phases:

1. Advising how to implement the CN performance management using the PMMS Implementation Methodology.
2. Structuring a questionnaire to assess the perception of the degree of alignment answered by the CEOs of the CNs.
3. Performing performance benchmarking using the DEA tool.
4. Choosing or developing a tool to calculate the overall degree of alignment for the CN.

5.3.1 CN strategy and typology

This network topology considers the proposition of Afsarmanesh, Marik and Camarinha-Matos (2004), i.e. a dynamic project-based partnership without a dominant participant. The problem-situation is how to increase the business performance and then improve competitiveness.

Moreover, its structure can be defined as a fully connected mesh topology in which the network components are connected to each other, making it possible for physical flow and information to occur simultaneously from any single node to all other nodes (Figure 49). The participants are all directly connected to all other participants, for example in local clusters and social networks, although some links may be interrupted if necessary.

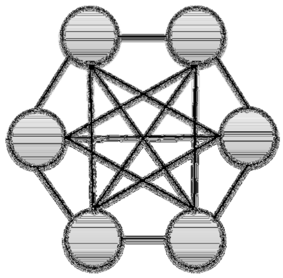

Figure 49. Pet Shop CN (fully connected mesh)

5.3.2 PMMS implementation process

In this business case, the tasks pertaining to the implementation of the PMMS were performed using the PMMS Implementation Methodology. Subsequently, a questionnaire method to assess the degree of alignment and the DEA tool to establish a benchmark value relating to the participants with better performance was used. This method is shown ahead (see Section 5.3.4, page 137).

The PMMS implementation process then begins with the aspects related to strategy and the skills which are essential during the search for partners and the design of the PMMS. The following Table 19 displays conclusions.

Table 19. Strategies and skills on performance management

CN Partners	Task 1: strategy/skills for using the PMMS
All participants	They joined in order to reduce costs and increase the visibility of their stores. Individually they had no PMMS. Most managers do not have superior management skills.

Subsequently, the benefits that can be achieved when strategic goals are attained should be highlighted (Table 20) in order to propel the CN participants to increase their efforts in cooperation and collaboration and to integrate their operations more effectively.

Table 20. Benefits analysis

CN Partners	Task 2: expected benefits from each participant
All participants	Everyone wanted to increase sales and profits and generate greater visibility for their stores.

The participants understood the benefits that motivated their decision to participate in the collaborative network then this motivated them even more to stay in the CN and participate more actively in the improvement actions. The shared marketing actions were then implemented and other actions for the joint purchasing of materials and contracting services for single suppliers were also successfully implemented. Next, each participant developed a PMS to define KPIs and to monitor their own performance.

Consequently, the design of the PMMS was drafted and the performance measurement was started (Table 21). The performance measures were also defined in order to monitor the local and overall performance of the CN (Table 22).

Table 21. PMMS creation and validation

CN Partners	Task 3: development of the collaborative PMMS
All participants	Although all participants did not have a formalized PMS, they understood the need to create their own systems to provide performance data for the PMMS and perform benchmarking to guide them in improving their competitiveness.

Table 22. Checking performance

CN Partners	Task 4: performance monitoring
All participants	LSM: Annual cost sales, average billing, average ticket value, average ticket quantity, average inventory, marketing cost, number of client's sales and number of clients entering in shop. LSSM: Marketing cost ratio, administration costs, customer satisfaction, inventory turnover and sales lost. CNSM: Efficiency (benchmarking).

In networks that exploit business opportunities that have a short time limit, a greater inter-organizational alignment in environments with short time projections is essential to justify the use of tools to assess the performance in order to know the degree of compliance/non-compliance with the defined objectives and goals. It must also ensure a platform to facilitate the operationalization of the CN strategy.

Therefore, CN managers improved the PMMS in order to reconfigure inter-organizational processes that presented poor performance. Managers then assessed the SDA using the questionnaire Q-0 at the partner selection moment and the questionnaire Q-1 at the agreement moment. The Euclidian Distance method was used to accomplish these tasks. Thereafter, the DDA was assessed at the run time moment by using KPIs of intra-organizational processes and the DEA approach.

Therefore, to check whether the alignment is maintained, the feedback on performance is observed following the assessment of decision-makers (Table 23) using the results of the questionnaires Q-0 and Q-1. At this time, the "CNPMS Manager", presented previously in the Section 5.2.1, page 120, had not yet been developed, thus the management bureau collected the performance indicators manipulating them to perform a benchmarking measurement tool.

Table 23. Checking performance for alignment evaluation

CN Partners	Task 5: assess the degree of alignment
Management bureau	Using the questionnaires Q-0 and Q-1 and the Euclidian Distance method to assess the degree of alignment. Analysis and review of the results.

In task 6, the processes that showed a poor performance should then be improved or reconfigured. However, in 2009 this CN started the process of dissolution and there was no time to adequately perform this task. Therefore, only a few occasional adjustments in the inter-operational processes were performed.

In this research was not part of the objectives the understanding about the dissolution of a CN although it was observed in this case that the expected benefits were achieved then the partners agreed to continue to manage their own business alone. Furthermore, at this time the last task in this methodology was performed briefly, but it was possible to observe that the intentions and opportunities that promoted the creation of the CN were accomplished. Table 24 shows why the performance outcomes were mismatched with those originally proposed.

Table 24. Checking the necessity for the continuation of the CN

CN Partners	Task 6: checking the necessity to keep the CN
All participants	Even though the CN terminated prematurely after two years, the knowledge gained by participants was very important for the maturation of these small-sized enterprises. Several participants with less experience in business management techniques were able to improve the way they plan their marketing and inventory management. In this case, the more efficient companies preferred to work alone with regard to planning and management, but took advantage of the opportunities for joint purchasing to reduce costs.

5.3.3 Alignment measurement

The aim is to measure the degree of alignment using a set of alignment factors and performance measures for the sixteen organizations. The number of participants may be considered a small sample for the calculations imposing a limitation for reliable conclusions. However, the approaches and methods used are appropriated to determining the SDA and make a comparison between participants performance.

Alignment measurement for the partner selection moment - In this case, the specific questionnaire Q-0 was developed for the time when the CN is being formed in order to observe the SDA. The expectations of the CEOs of the potential participants were then questioned. Just one question was developed based only on the trust expectation as the main alignment factor at this time:

1. What is your expectation of a high level of trust among participants, considering the invited participants for this CN?

For the responses to this questionnaire are assigned the following values: confident (two points), slightly confident (one point) and not confident (zero). Complementing this, the metric SDA used for measuring the alignment degree is composed by the following classification with regard to the comparison of decision table values: highest, high, medium, low, lowest.

The sample has just sixteen cases corresponding to all CN participants that composed the Pet Shop Retailers Case. Table 25 presents the output of questionnaire Q-0 applied at the partner selection moment.

Table 25. Outcomes of the questionnaire for the partner selection moment (questionnaire Q-0)

Cases (CN participants)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Output value	0	0	2	0	0	1	0	0	1	1	0	0	2	1	0	0

Thereafter, using the Euclidean Distance method, the coefficient of misalignment for just one variable (trust) is:

$CM = (M_{sj}-M_{cj})^2$ [8]

where

M_{sj} is the score for the questionnaire output of each variable j, and

M_{cj} is the misalignment calibration value along the “i^{th}” variable.

For example, the calculation for the sample 1 is (Figure 50):

$CM = (0-2)^2 = 4$

CASE	VARIABLE (TRUST)	FULL MISALIGNMENT	CM	
1	0.00	2.00	4.00	
2	0.00	2.00	4.00	
3	2.00	2.00	0.00	
4	0.00	2.00	4.00	
5	0.00	2.00	4.00	
6	1.00	2.00	1.00	
7	0.00	2.00	4.00	
8	0.00	2.00	4.00	
9	1.00	2.00	1.00	
10	1.00	2.00	1.00	
11	0.00	2.00	4.00	
12	0.00	2.00	4.00	
13	2.00	2.00	0.00	
14	1.00	2.00	1.00	
15	0.00	2.00	4.00	
16	0.00	2.00	4.00	
			2.75	AVERAGE MISALIGNMENT VALUE
			4.00	TOTAL RANGE OF MISALIGNMENT VALUES

FIT DEGREE CLASSIFICATION			
Coefficient of Misalignment (CM)		0.80	Range of classes
Interval		Classification	
3.20	4.00	LOWEST	
2.40	3.20	LOW	2.75 AVERAGE MISALIGNMENT VALUE
1.60	2.40	MEDIUM	
0.80	1.60	HIGH	
0.00	0.80	HIGHEST	

Figure 50. Fit Degree at the partner selection moment

Subsequently, is obtained the average of coefficients of misalignment of all CN participants then is calculated the range of misalignment values which allows to determining the CM classes by subdividing the overall interval to five classes representing the SDA ratings.

Finally, the SDA is obtained comparing the average CM value, within a CM class. Therefore, in this case, the SDA presented a **LOW** classification. The trust level was not as satisfactory and the CN decision-makers should deal with this concern more actively in order to improve the alignment related to the expectations of trust.

Alignment measurement for the agreement moment - The specific questionnaire Q-1, developed for the time when the CN is being agreed (agreement moment), was applied. Questions were developed based on four motivational factors for alignment (e.g., trust, performance, reliability and knowledge), as proposed in the Section 3.3.1 (page 95):

1. Are you confident there is trust between network participants at this moment?
2. Are you confident about the possibility of your organization improving its performance after operating within the collaborative network?
3. Are you confident about the possibility of your organization improving its reliability in delivering products and services after operating within the collaborative network?
4. Are you confident about the possibility of your organization improving its knowledge and competence level after operating within the collaborative network?

Equally to the criterion used in the previous item, the values for the responses (e.g., confident, slightly confident and not confident) and the values for classifying the SDA (e.g., highest, high, medium, low and lowest) are the same. Thus, the outcomes of questionnaire Q-1 applied to the sixteen cases are depicted in Table 26.

Table 26. Outcomes of the questionnaire for the agreement moment (questionnaire Q-1)

CN Partners	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Trust	1	1	2	1	0	2	1	2	1	1	2	1	0	1	1	0
Performance	2	2	2	1	2	2	2	2	1	2	2	2	1	2	2	2
Reliability	2	2	2	1	2	1	2	2	2	2	2	1	2	1	2	2
Knowledge	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2

Thereafter, using the Euclidean Distance method, the coefficient of misalignment for these variables (trust, performance, reliability and knowledge) is:

$$CM = \sum_{j=1}\left(\left(MT_{sj} - \dot{M}T_{cj}\right) + \left(MP_{sj} - \dot{M}P_{cj}\right) + \left(MR_{sj} - \dot{M}R_{cj}\right) + \left(MK_{sj} - \dot{M}K_{cj}\right)\right)^2 \quad [9]$$

where

$\boldsymbol{Mf_{sj}}$ is the score for the questionnaire output of each variable j, and

$\boldsymbol{Mf_{cj}}$ is the misalignment calibration value along the "j^{th}" variable.

For example, the calculation for the sample 13 is (Figure 51):

CM = $((2-0)^2 + (2-1)^2 + (2-2)^2 + (2-2)^2) = (4+1+0+0) = 5$

Case	VARIABLE	VARIABLE	VARIABLE	VARIABLE	CALIBRATION	CM	
1	1.00	2.00	2.00	2.00	2.00	1.00	
2	1.00	2.00	2.00	2.00	2.00	1.00	
3	2.00	2.00	2.00	2.00	2.00	0.00	
4	1.00	1.00	1.00	2.00	2.00	3.00	
5	0.00	2.00	2.00	2.00	2.00	4.00	
6	2.00	2.00	1.00	2.00	2.00	1.00	
7	1.00	2.00	2.00	2.00	2.00	1.00	
8	2.00	2.00	2.00	1.00	2.00	1.00	
9	1.00	1.00	2.00	2.00	2.00	2.00	
10	1.00	2.00	2.00	2.00	2.00	1.00	
11	2.00	2.00	2.00	2.00	2.00	0.00	
12	1.00	2.00	1.00	2.00	2.00	2.00	
13	0.00	1.00	2.00	2.00	2.00	5.00	
14	1.00	2.00	1.00	2.00	2.00	2.00	
15	1.00	2.00	2.00	2.00	2.00	1.00	
16	0.00	2.00	2.00	2.00	2.00	4.00	
						1.81	AVERAGE MISALIGNMENT VALUE
			By adapting the X" Method			8.00	TOTAL RANGE OF MISALIGNMENT VALUES

FIT DEGREE CLASSIFICATION				
Coeficient of Misalignment (CM)			1.60	Range of classes
Interval			Classification	
6.40	8.00		LOWEST	
4.80	6.40		LOW	
3.20	4.80		MEDIUM	
1.60	3.20		HIGH	1.81 AVERAGE MISALIGNMENT VALUE
0.00	1.60		HIGHEST	

Figure 51. Fit Degree at the agreement moment

Finally, at this moment, the SDA is obtained comparing the average CM value, within a CM class

Therefore, at this measurement moment, the SDA presented a **HIGH** classification. Differently to the previous assessment moment, at the time when the CN agreed on their goals, the partners concluded that they were highly aligned with regard to the motivational factors.

Evaluation of the motivational alignment factors - When more than one factor is used it is relevant to note which ones are the most worrisome. Thus, in the agreement moment, it was observed that trust (red line) is the one with the worst result (Figure 52) and transferred knowledge (lilac line) is the most efficient factor to take into account.

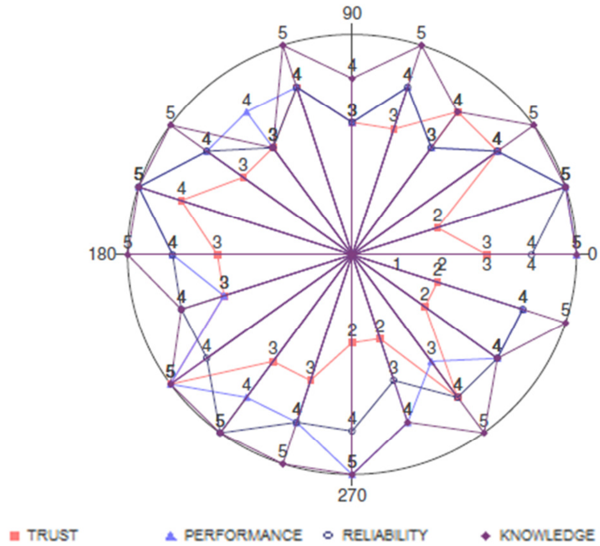

Figure 52. Analysis of the CN's participants on alignment factors (polar graphic)

Although the SDA can be considered satisfactory, it is still possible to see that trust level had worst classification and the CN decision-makers should deal more actively with this concern in order to improve the alignment.

5.3.4 A DEA method for performance benchmarking analysis

Certain indicators with cost attribute to determine the efficiency of the CN participants were selected. The data related to such indicators were collected during a period of one year and then they were used to provide input and output data that could be applied in the DEA tool for a performance benchmarking analysis.

Therefore, the efficiency calculation on a benchmarking approach was performed considering the following data per participant (monthly average):

- Total value of billing (in U$ Dollar)
- Value of spending on marketing (in U$ Dollar)
- Value of spending on shop administration (in U$ Dollar)

These indicators were used to form the set of data reported by each participant in order to establish KAIS which are used in the collaborative PMMS. The partner's performance data is used to help decision-makers develop actions to improve their processes and also to use them in the DEA tool. These indicators were collected monthly, but the data used in this case is the monthly average which is obtained from the total value of the year.

CN experts consider cost attributes to define the KPIs and translate the strategies that led to the creation of the CN and keep it effective. Table 27 depicts the performance data and the efficiency indicators to establish the benchmark including their respective formulas.

Table 27. Key alignment indicators

Data	KAI	KAI description	Formula
Output	**BMA**	Billing Monthly Average	Annual value of billing / Twelve months
Inputs	**MKC**	Marketing Cost	Value of spending on marketing / Billing monthly average
	ADC	Administration Cost	Value of spending on shop administration / Billing monthly average

These KAIs are then applied to get the data that will be used in the DEA tool. Thereafter, an expert-based approach should be developed to determine criteria to calculate the descriptive degree of alignment (DDA) of the CN. Therefore, for a benchmarking analysis as a degree of alignment determination method has the following steps:

1. Collecting the performance data;
2. Applying the DEA tool and analyzing results;
3. Calculating the DDA.

If applied with discipline this method can provide reliable data for each participant in order to determine the KAIs to implement a benchmarking approach to compare their performance and determine the DDA. These benefits aim to help decision-makers from each participating company improve their processes and make their strategies more effective. They should also contribute to increasing the degree of alignment.

According to Macedo *et. al*. (2004), experts choose the variables and they limit themselves to assert that the variables chosen are those that best describe the performance of DMUs under analysis. It is not priority to define weights because, in its classic form, DEA allows complete flexibility in selecting the weights. Furthermore, these authors state that it is not necessary to worry about any technique used for selection of variables when there is a small availability of variables and a great amount of comments, or even in cases where the number of DMU is small compared to number of possible inputs and outputs. In fact, DEA has important characteristics, such as: does not require a priori an explicit production function; examines the possibility of different, but equally efficient, combinations of inputs and outputs; finds the efficient frontier within a group analyzed and units included; determines, for each unit less efficient, subgroups of efficient units, which form a benchmark.

Data Collection - Once each participant agrees to use the KAIs outlined above, they will performing the measurement in order to obtain a monthly average value for each indicator. The CN management bureau then collects the data from each participant to calculate the values of efficiency using the DEA tool. This action may be more effective if they use an ICT system such as the CNPMS Manager described in Section 5.5.2 and shown in Appendix C.

In this case, the experts propose only three indicators with the financial attribute in order to assess whether efforts in terms of administrative and marketing costs, reformulated by the participants due to the collaborative approach, allow for a higher sales turnover. Therefore, administration cost (includes material, human resources and administrative tasks) and marketing cost are inputs, and the billing monthly average is the output.

The following table (Table 28) depicts the values used for the application of DEA tool by measuring the performance of the sixteen participants of this application case.

Table 28. Participant's performance data

Participants	Billings	MKC (input)	ADC (input)	Total Input
P1	13,862.32	446.37	3,812.14	4,258.51
P2	14,353.88	699.03	2,521.98	3,221.01
P3	16,101.06	837.23	3,919.00	4,756.23
P4	17,342.76	1,078.72	3,893.45	4,972.17
P5	12,726.54	337.25	3,968.14	4,305.39
P6	15,322.66	700.25	3,049.21	3,749.46
P7	14,421.13	550.89	3,802.85	4,353.74
P8	17,153.87	1,240.22	4,212.99	5,453.21
P9	14,910.23	499.49	4,490.96	4,990.45
P10	18,086.75	1,003.81	4,120.16	5,123.97
P11	13,890.45	461.16	4,604.68	5,065.84
P12	16,739.78	831.97	4,215.08	5,047.05
P13	11,976.96	412.01	3,411.04	3,823.05
P14	12,813.27	563.78	2,697.19	3,260.97
P15	13,261.11	413.75	3,874.90	4,288.65
P16	17,337.33	1,087.05	3,021.90	4,108.95

Expert-based DEA application - The DEA method measures the efficiency using multiple inputs and output variables into a single aggregate efficiency index that corresponds to the output variable divided by the weighted sum of the input variables. As stated by Fitzsimmons and Fitzsimmons (2000), an intuitive way to apply the DEA can be calculating the ratio. Thus, for each DMU, it is obtained a measure of ratio of all outputs over all inputs, i.e. the optimal weights uj and vi are obtained by solving the mathematical programming problem.

DEA models derive input and output weights by means of an optimizing calculation. Based on that, units can be classified into efficient and less efficient. In less efficient units, they tell us target values of inputs and outputs which would lead to efficiency.

For n productive units DMU1, DMU2,…, DMUn, each one produces s outputs and consumes m inputs. The input matrix is X = *[xij, i = 1, 2, …, m, j= 1, 2, …, n]* and the output matrix is Y = *[yij, i = 1, 2, …, s, j= 1, 2, …, n]*. The weights of all inputs and outputs must be greater than zero. In a case where the input value is set supposing that it is possible reducing the input for obtaining the maximum efficiency, the efficiency rate of each DMU is generally expressed as:

$$\frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}} = \frac{\sum_{i=1}^{s} u_i y_{iq}}{\sum_{j=1}^{m} v_j x_{jq}} \qquad [10]$$

where: v_i, $i = 1, 2, \cdots, m$, are weights assigned to i^{th} input,

u_j, $j = 1, 2, \cdots, s$, are weights assigned to j^{th} output.

y_{jk}, is the output from the k^{th} DMUs.

x_{ik}, is the input from the k^{th} DMUs.

In this case, the DEA was used as an output approach to accomplish the benchmarking analysis, particularly the variation model BCC (Banker, Charnes and Cooper) as a variable returns to scale method. This approach could be more appropriate because the goal is to maximize the outputs obtained for the DMUs without changing the current level of inputs (Macedo *et. al.*, 2004).

$$Min \frac{\sum v_i x_{ic}}{\sum u_j y_{jc}}$$

$$S.a.: \frac{\sum v_i x_{ik}}{\sum u_j y_{jk}} \geq 1,\ k = 1,2,\ldots,c,\ldots,n$$

$$u_j,\ v_i \geq 0, \forall\ x,\ y \qquad [11]$$

Thus, the efficiency in the output approach is calculated as the inverse of the objective function, i.e. Efficiency = 1/E. This problem defines the relationship of inputs to outputs, where c is the index of the DMU being evaluated. Therefore, the weighted sum of inputs divided by the weighted sum of outputs is minimized, subject to the constraint that this quotient is greater than or equal to 1 for all DMUs.

However, the scale used for determine the Efficiency is between 0 and 100 per cent. Therefore, if a DMU does not receive a peak performance score, it means that their partners are more productive. In fact, these indicators lead to assess the participant's efficiency in order to determining the positioning of DMUs relative to each other. Figure 53 depicts the result of the DEA approach applied in this case and exhibits the efficiency of participants relatively to the Efficient Border Line (EBL) which allows observing those participants that are closest to the better performance.

Table 29.DEA use case results

DMU	Input (x)	Output (y)	Efficiency	f(x)=4.46x+0	Result	Target
1	4,258.51	13,862.32	3.26	18,977.32	73.1%	5,115.00
2	3,221.01	14,353.88	**4.46**	14,353.88	100.0%	-
3	4,756.23	16,101.06	3.39	21,195.33	**76.0%**	5,094.27
4	4,972.17	17,342.76	3.49	22,157.62	**78.3%**	4,814.86
5	4,305.39	12,726.54	2.96	19,186.23	66.4%	6,459.69
6	3,749.46	15,322.66	4.09	16,708.83	91.7%	1,386.17
7	4,353.74	14,421.13	3.31	19,401.70	74.2%	4,980.57
8	5,453.21	17,153.87	3.15	24,301.30	70.6%	7,147.43
9	4,990.45	14,910.23	2.99	22,239.09	67.0%	7,328.86
10	5,123.97	18,086.75	3.53	22,834.10	**79.1%**	4,474.35
11	5,065.84	13,890.45	2.74	22,575.05	61.4%	8,684.60
12	5,047.05	16,739.78	3.32	22,491.31	74.4%	5,751.53
13	3,823.05	11,976.96	3.13	17,036.55	70.2%	5,059.81
14	3,260.97	12,813.27	3.93	14,531.95	88.1%	1,718.68
15	4,288.65	13,261.11	3.09	19,911.64	69.3%	5,850.53
16	4,108.95	17,337.33	4.22	18,310.83	94.6%	973.50

Table 29 shows the calculations to classify the efficiency of participants in relation to maximum efficiency (EBL), including targets derived from the output approach. Therefore, the colored dots shown in the graph (Figure 53) represent each participant and their respective efficiency. By using the efficiency representation criteria (Table 30) makes it possible to see that three participants (blue dots) had the most efficient performance. The other thirteen participants have a worse performance, especially nine of them (red dots) which have less than 75% of best efficiency.

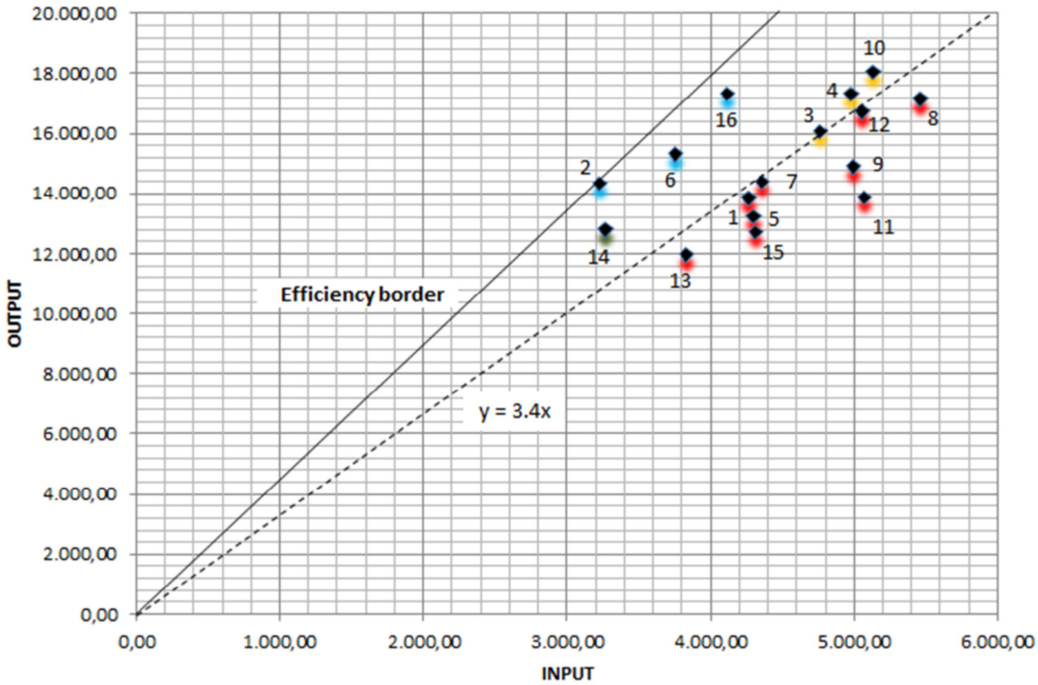

Figure 53. DEA outcomes graph

Table 30. Efficiency representation criteria

Efficiency representation	Efficiency
Blue dots (EBL)	90% - 100%
Green dots	80% - 89,99%
Black dots	75% - 79,99%
Red dots	< 75.00%

Table 31 shows the score for the ranking of efficiency in relation to the EBL obtained by the set of participants.

Table 31. Efficiency ranking

Efficiency representation	Count	Score
Blue dots (EBL)	3	18.75%
Green points	1	06.25%
Black points	3	18.75%
Red points	9	56.25%

Classification of the DDA - Using the results of the DEA tool, it is possible to propose a method to determine the DDA for this CN. It is seen in Table 31 that the efficiency ranking is derived from the counting of dots depicted in graph (Figure 53) in order to obtain the efficiency score which is used in an expert-based approach for determining the DDA.

At this moment the role of the manager (or expert) appears to define the criteria to determine the degree of alignment that could be obtained from the performance of participants. This takes into account the expectations of the CN and the goals that all of the participants had determined to evaluate their own performance. Thus, Table 32 presents the criteria proposed for determining the DDA that considers the amount of participants which scored above the efficiency average line.

Table 32. DDA Classification for the operation time (expert-based approach)

Score	DDA classification	Criteria	Result
43.75%	HIGHEST	>80% - 100% above the average line	No
	HIGH	>60% - ≤80% above the average line	No
	MEDIUM	>40% - ≤60% above the average line	**Yes**
	LOW	>20% - ≤40% above the average line	No
	LOWEST	≤ 20% above the average line	No

Therefore, the DDA has **MEDIUM** classification.

Certainly, the effectiveness of these criteria could be questioned and more accurate mathematical methods could be used. However, in a micro and small sized enterprise environment it may not be productive to create complex rules where participants have difficulty understanding them. Therefore, in this case, the criteria used were adequate to demonstrate that it is more important to have discipline in the application of simple methods than having a sophisticated method. In fact, the debate on the performance will promote the implementation of actions to achieve a better performance seeking new revenue goals (billing targets).

5.3.5 Case summary

In this case, it was noted that the perception of alignment has changed over time. In fact, at the agreement moment (#2) the alignment was higher than at the partner selection moment (#1) however the perception on the alignment decreased at the operation moment (#3). After the initial period, when the partners believed in the benefits of collaboration strategy, the participants had difficulties in aligning the joint tactical and operational actions. It could be said that CEOs could not get rid of their paradigms of small business management. They needed more time to improve the alignment because there are different perceptions about their business. Consequently, at this time when the CN participants concluded that they were slightly aligned with the objectives and goals, they enhanced their efforts to increase the performance of the intra- and inter-organizational processes. For this purpose, the PMMS was designed and implemented.

Regarding the subjective approach that was used (SDA), it was noted that issues of trust have been resolved. When it was questioned again at the agreement moment, the partners concluded that they were satisfactorily aligned at this time. Thereafter, a strategic planning proposal was discussed in several meetings with consultants support in order to promote the balance of various proposals to reach a greater alignment between performance outcomes and performance targets. Consequently, during the CN runtime many activities were then carried out jointly by the participants, such as marketing campaigns, purchasing, training sessions and outsourced services. Finally, after 12 months, the DEA tool was applied in a descriptive approach (DDA) and it was concluded that there were some participants with lower performance and that some of them needed more time to improve their performance.

In conclusion, Table 33 shows the outcomes of the alignment measurement:

Table 33. Pet Shop Retailers Case: Degree of alignment

Decision-making moments	Method	Degree of alignment
#1 - Partner Selection	Questionnaire Q-0	LOW (SDA)
#2 - Agreement	Questionnaire Q-1	HIGH (SDA)
#3 - Operation	DEA Expert-based approach	MEDIUM (DDA)

Moment #1 – It was noted that there were significant differences between the set of potential participants involved.

Moment #2 – Strategic planning and performance goals were defined and most of the impediments have been overcome.

Moment #3 – After the performance assessment meeting that dealt with the outcomes of the DEA tool, it was noted that some partners still needed more time to contribute for alignment because they had worse performances due to their management expertise level and due to low investment in process improvement.

The network has not existed since 2010, but managed to keep the companies participating in the market and several improvements were implemented. However, many partners still had a deficit in business management and they needed to maintain relationships with expert partners. In addition, the performance of all participants has improved as well as the management knowledge and expertise.

5.4 "G3 Supply Chain" Case

Companies with codename "*GFilms*", "*GPackage*" and "*GAlimentary*" integrate a Brazilian industrial group that is called G3 Group. These companies formed a CN and manifested interest in monitoring the inter-organizational processes that have huge impact on the collaborative network performance. They also were interested in using a specific system of performance management to instantiate their own performance as well as the CN overall performance. In 2009, these companies addressed the need to enhance their business relationship in a more conceptual and scientific way and they assume that their interactions meant operating in networked environment.

The G3 Group is controlled by the same stakeholders, but each company has distinct products and operates in specific markets, consequently they have different customers. The companies "*GFilms*" and "*GPackage*" are autonomous business strategic units (BSUs) of a medium sized company. This company was founded in 1975 to produce plastic packaging for food. Initially, it began producing plastic package in low density polyethylene just to pack cookies of a very famous Brazilian brand.

While these companies have their strategies and policies defined by the same stakeholders, each one defines its own market segment and their own customers. Currently, "*GFilms*" produces co-extruded plastic in coils supplied in various sizes and compositions that are sold in a B2B strategy for companies that produce plastic packaging for food and pharmaceuticals products. "*GFilms*" provides about 50% of its own production to "*GPackage*". The aim of this relationship is to supply the partner offering low prices, better delivery time and product quality. However, there is a permanent possibility of that partner purchasing the co-extruded films from other suppliers in Brazilian and global markets. Hence, "GFilms" must refine their processes and products to remain a priority partner. They must also continuously develop new products and customers in order to not be too dependent of the other participants of the CN.

Furthermore, "*GPackage*" produces printed plastic films for food packaging. This company supplies about 30% of their own internal production to the "*GAlimentary*". They also sell products for Brazilian and Latin American markets. Similar to "*GFilms*", it needs to improve its processes and products to remain a partner in this CN.

Although the proximity of these companies facilitates strategic alignment due to the decision-making power be concentrated in the same stockholders, the strategy of the network aims to reduce the dependence between partners and makes it possible to look beyond the borders of each company. This strategy seeks to increase market share in their specifics markets. In this context, each one has autonomy (budget, infrastructure, purchasing), but they do not have a collaborative plan for production and therefore they are not taking advantage with this opportunity for gaining synergies.

With regard to the main concerns for the effectiveness of inter-organizational processes, continuous monitoring is necessary using specific indicators to support decision-making. Therefore, this collaboration strategy should improve competitiveness in order to face the emerging challenges caused by their business environments.

5.4.1 CN typology

This network typology considers the proposition of Afsarmanesh, Marik and Camarinha-Matos (2004) that is a dynamic project-based partnership without a dominant participant. With regard to network characterization it is possible to consider that this CN is a supplier network whose involves subcontracting and agreements between a client and its suppliers of intermediate inputs for production. Moreover, the observed problem-situation is how to improve the manufacturing and logistics performance and also improve the quality of products, processes and human resources.

Furthermore, the network topology can be classified as a Linear Bus (Figure 54). It is a common topology that appears in existent process-oriented companies (e.g., manufacturing industries). Indeed, in the G3 Group all of the nodes of the network are connected to a common transmission medium which has exactly two endpoints. Disregarding propagation delays, all data transmitted to or from nodes takes place over a common transmission medium. The product flow moves in the opposite direction to the information flow despite the information accompanying the product (identification, technical reports).

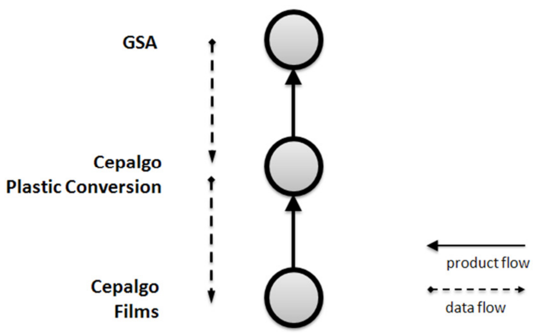

Figure 54. G3 topology (a linear bus network)

Other stakeholders such as common suppliers and service providers of these companies are not considered in this research. Although the performance of the internal processes of each participant is considered to assess the overall performance, the inter-organizational processes are used considering product orders which are restricted to operations between participants. Moreover, the KPIs used were focused on cost, time and quality. In conclusion, expert managers proposed that the delay of the delivery time per order delivered and the number of orders with nonconformities may represents the CN's performance.

5.4.2 PMMS implementation process

The PMMS Implementation Methodology was also used in this application case. However, physical and decision-making proximity between participants led to the creation of the PMMS more quickly. In task 3 and 4 of this methodology, the PVE tool was included for guiding this research towards dealing with the prediction paradigm.

As can be seen in Table 34, the aspects relating to strategy and skills are essential during the setting up phase of the CN.

Table 34. Strategies and skills on performance management of G3 participants

CN Partners	Task 1: Strategy / Skills for using the PMMS
GFilms	This organization acts as a supplier of co-extruded plastic films and also provides laboratory tests service for the CN partners. This organization developed a PMS with a set of KPIs to cover its internal operational processes. The managers have superior skills in management. This organization has recent experience in its business area.
GPackage	This organization acts as a supplier of printed films for plastic packages. A PMS was developed with a set of KPIs to cover its internal operational processes. The managers have superior skills in management. This organization has vast experience in its business area.
GAlimentary	This organization acts as an alimentary branch company that produces candy, wafers, biscuits and snacks. A PMS was developed with a set of KPIs to cover its internal operational processes. The managers have superior skills in management. This organization has recent experience in its business area.

What is more, this CN is primarily supported by "*GFilms*" and "*GPackage*" which supply printed plastic films to "*GAlimentary*". However, in this application case, the "*GAlimentary*" only has the role of "observer" or "main customer" of these BSUs requiring quality and reliability for the requested product orders. Therefore, it is relevant to distinguish the major benefits that each participant can obtain in working together and using a collaborative performance management system (Table 35). In addition, in the next task Profit Consulting was introduced.

Table 35. Benefits analysis relating to G3 participants

CN Partners	Task 2: Expected benefits from each participant
GFilms	Maintains the role of "main supplier" and reduces logistics costs due to the *"GPackage"*. Improves process management and expertise due to *Profit Consulting*.
GPackage	Maintains the role of "main supplier" of "GAlimentary" and reduces logistics costs due to the *"GFilms"*. Improves process management and expertise due to *Profit Consulting*.
Profit Consulting	Increases its scope of activities in the consultancy market and tests the collaborative PMMS due to *"GFilms"* and *"GPackage"*.

Participation of Profit Consulting in this research project aims to support the CN decision-makers to develop and manage a collaborative PMMS. This consulting firm participated in this research and thus offered its expertise in process management to support changes and improvements in the implementation of the concepts and methods proposed in this thesis.

These benefits encourage the participating companies to integrate their communications systems using applications (software), i.e. the CNPMS Manager, in order to effectively implement the PMMS (Table 36). However, no questionnaires were used and this research, but were used the estimation tools (PVE) and the Fit Degree metric in order to provide measurements for the predictive degree of alignment (PDA). It means a predictive approach was used in this case.

Table 36. PMMS creation and validation

CN Partners	Task 3: Development of the collaborative PMMS
GFilms	Promoting the improvement of its own PMS. Drafting procedures of inter-organizational processes. Defining internal performance indicators to be shared.
GPackage	Promoting the improvement of its own PMS. Improving the performance of inter-organizational processes. Improving the ICT processes.
Profit Consulting	Increasing the advice for designing the PMS of each participant. Analyzing and reviewing the PMMS implementation processes.

In this step, the companies "*GFilms*" and "*GPackage*" agreed on the KPIs which would be used to measure individual performance and the performance of the entire network (Table 37). Using the CNPMS Manager (web service) they can then supply the performance data for the PMMS more easily.

Table 37. Performance monitoring and target analysis

CN Partners	Task 4: Performance monitoring
GFilms	The KPIs used for performance monitoring is included in LSOM measures, such as: production performance, supply reliability, transportation reliability, personnel skills level, absenteeism, equipment reliability, storage and handling reliability and row material reliability.
GPackage	
Profit Consulting	The KAIs chosen to represent the CN performance monitoring is included in CNIM measures, such as: delay of delivery time (DDT) and orders with nonconformities (NON).

The next task is to check whether the alignment is maintained using performance estimation, extracting the KPI values of the PMS of each participant. Therefore, in the following section, the performance prediction is presented by applying the PVE tool to determine the predictive key alignment indicators (PKAIs) in order to use the alignment prediction method.

5.4.3 Alignment measurement

This pilot case was developed by a group of researchers of INESC Porto, including the author of this thesis, where preliminary results had already presented by Almeida (2010). After using the CNPMS framework for developing the collaborative PMMS with regard to the "performance measurement moments"[6] (e.g., partner selection, agreement and performance management during operation) then it aimed to prove the predictive performance approach which consists of the following tasks:

- Developing the Performance Value Estimator (PVE) tool for predicting the KAIs in order to obtain the predictive KAIs (PKAIs) considering the established time period and pattern values. Consequently, the PKAIs used to obtain the PDA are determined.
- Calculating the Compliance Degree of the processes' performance relating to the established performance targets and using a fuzzy expert system in order to classify the participant's performance regarding the attendance to the pattern values previously defined.
- Performing the process for calculating the PDA (i.e. calculating the Fit Degree metric by using the PKAIs).

Therefore, the following topics describe this alignment measurement approach.

Transforming KPIs into KAIs - In order to define the KAIs, two derived KPIs were strategically chosen and calculated in order to express the network performance according to the goals that motivated the creation of the CN. The application of the estimator tool allows estimates

[6] In the context of this work, the "performance measurement moment" occurs when performance is instanced allowing the CN decision-makers to evaluate the global performance of the CN, whether be ancient, current or future

the values of the KPIs chosen to instantiate the future organization's performance. Specifically, indicators were determined for time and quality aspects, suppressing, in this case, any cost indicator to display the vital signs (Hronec, 1993) of the CN. The chosen KPIs will then be used as the KAIs that can effectively translate the performance objectives and goals of the CN, such as: DDT – Delay of Delivery Time (of orders) and NON – Orders (delivered) with Nonconformities.

Measuring the delay of the delivery time per order delivered (DDT) gives a crucial indicator for improving the agility of the supplier and impels each participant in the chain to reduce delivery time in order to meet the delivery date of orders. However, in a CN with more than two participants, the propagation of delays can significantly compromise the level of agility to the end customer. It impacts on the service level expected by the end consumer which leads to reducing the competitiveness of participants, namely those of front-line.

Furthermore, the term "nonconformity" is commonly applied when the quality standards ISO 9000 (ISO, 2008) are adopted and essentially means that there is evidence that do not are being met the customer requirements, established standards, conventions, regulations or laws. In an internal perspective, quality can be defined as the skills and capabilities needed to improve product, process and employees. Otherwise, in an external perspective can be defined as an optimal performance in terms of intrinsic quality of the product, attendance and delivery time, and cost. Deliver products and services with a higher logistic service level is an imperious challenge in order to reach competitiveness. In this context, by monitoring the number of orders with nonconformity (NON) makes it possible to establish appropriate policies to manage quality of intra- and inter-organizational processes.

However, two indicators may appear insufficient for assessing the performance of inter-organizational processes mainly because complex systems can generate a large amount of data that can turn into KPIs. Furthermore, these systems generally are more efficiently if the KPIs are translated from the strategies of organizations (or networks), reducing the need for a large number of KPIs. Specifically in this use case, where the inter-organizational processes are limited to the products supply, the CN´s managers understood that the use of few indicators whose composition depended on several internal and external factors could enhance the effectiveness of the collaborative PMMS. This system intends be focused on the estimation of these indicators in order to predict results based on supply forecasting and variations of the factors involved.

Furthermore, the PVE tool was used considering different factors that influence the individual and overall performance. Moreover, the values obtained by a participant upstream probably interfere in the values obtained by the participant downstream. Many factors are introduced in this situation, such as preventive maintenance occurrence, overbooked orders, personnel and environmental attendance, production performance, supply and transportation reliability, equipment reliability, row material quality, storage and handling reliability.

These KAIs are addressed in relation to the following relationships: 1) "*GFilms*" to "*GPackage*" and 2) "*GPackage*" to "*GAlimentary*". Thus, the relationships among participants of the G3 Group collaborative network are depicted in the Figure 55.

In this pilot case was found a production system that operates on demand according to customer orders in which several specific situations may occur including: seasonality, changes in demand due to market fluctuations, competition. Such KAI's values enable decision-makers plan actions to control and measure the actual performance and verify if the intentions and opportunities that impelled the CN creation are still valid.

The KAIs DET and NON can be estimated to predict the system's behavior for the following period, or periods. In order to achieve this goal, the historical data that are dealt by an ANN machine are used and the noises from the measurement occurring in the system modeling processes are filtered by the Kalman filter. Thus, applying the PVE tool for the next month, the PKAI values are obtained. Indeed, following these values, it is possible to confront the expected values with the established patterns in order to assess if the desired performance is attended and to what degree.

At this stage, each neural network is capable of receiving the different predictable factors as its input, and estimate which should be the factory reaction and the respective PKAIs values. However, it is important to understand that a supply chain like this have a "snowball" behavior. In fact, all nonconformities and delays verified at the supplier factory will have a crucial impact at the end of supply chain. This is the reason why in the estimation process there is not only a constant feedback between the different factories (ffi2-1, ffi3-1, ffi3-2), but also the output of the supplier factories (DDT1-2, NON1-2; DDT2-3, NON2-3) should be used as input (factors) of the ensuing factory (NN2 and NN3 respectively). So, it becomes possible to easily compile (data fusion) all the information at the bus lined supply chain.

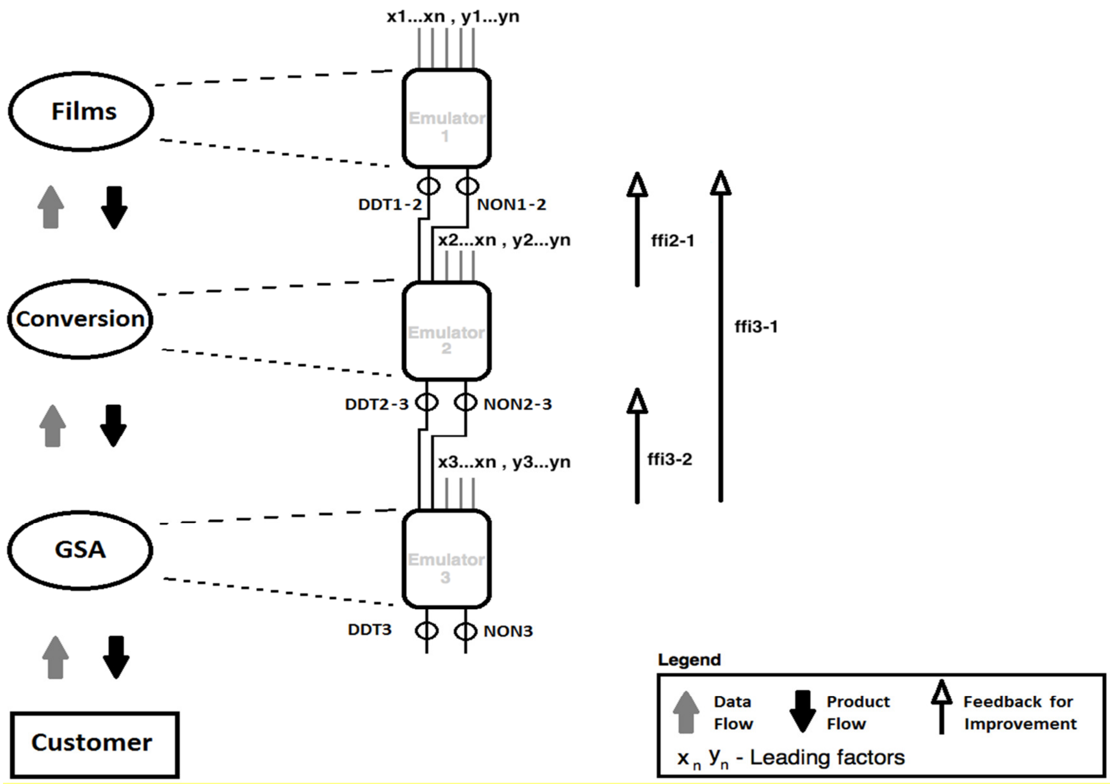

Figure 55. G-3 performance measures data flow

Table 38. System and process factors

KAIs	SOURCES	INPUT FACTORS		DISCRIPTION	DATA TYPE
		Factor	Factor type		
DDT	*Internal factors*	Preventive Maintenance	**U**	This factor affects the available time to schedule production because it reduces the number of production days hampering the recovery of delays which accumulate daily. When there is orders overbooking this effect may increase.	Binary
		Production Performance	**Q**	This factor takes into account speed loss and affects the overall equipment effectiveness (OEE). It is impacted by all factors that cause the process to operate at a speed less than the maximum speed possible during operation. For instance, these factors include machine wear, nonconforming materials, failure to supply row materials properly and operation inefficiency.	Decimal
	External factors	Overbooking	**U**	When there are more orders than planned production capacity is required that production cycle it be shorter. If this is not possible this factor will affect the delivery delay. However, other solutions may be implemented such as extending the production time schedule, or outsource the product (if possible), etc. Overbooking can arise due to inefficiency in the planning or due to seasonality.	Binary
		Supply Reliability	**Q**	This factor shows just how reliable are the deliveries on time by suppliers. It can affect the delivery time because obviously causes delays due to production's stoppage.	Decimal
		Transportation Reliability	**Q**	This factor affects the delivery time due to problems or inefficiencies of transporting the products to the customers.	Decimal
NON	*Internal factors*	Absenteeism	**Q**	Absent of employees that affect directly the product quality requirements.	Decimal
		Equipment Reliability	**Q**	The capability of the production and utility equipment to accomplish with the product quality requirements.	Decimal
		Storage & Handling Reliability	**Q**	The capability to store and handle the product packages with adequate protection rules and appropriate equipment and facilities.	Decimal
	External factors	Environmental	**U**	This factor affects the nonconformities appearance due facilities inefficiencies regarding climate protection.	Decimal
		Reliability of Raw Material Quality	**Q**	This factor affects the nonconformities appearance due more or less quality requirements compliance of the raw materials.	Decimal

Turning the KAIs into predictive KAIs (PKAIs) - Table 38 presents the factors to deal with the KAIs. In case of DDT indicator, such values are effectively dependent on system factors (U) and process factors (Q). In other words the number of the orders requested is known, as well as the overbooking possibility and the scheduled actions for preventive maintenance. In contrast, production performance and reliability of supply and transport are affected unpredictably although they are provided within a known range.

Relationship 1 - This occurs for the products delivered from "GFilms" to "GPackage", from January 2010 to December 2011. Table 39 presents the numbers of orders exploited during a period of two years.

Table 39. Numbers of orders from BSU "GPackage" to BSU "GFilms" (2010/2011)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	44	51	49	58	55	53	59	72	74	76	58	45
2011	59	63	64	76	69	67	73	77	79	85	76	59

These table places an irregular number of orders delivered. It happens because the demand is unpredictable and depends on marketing variations, customer satisfaction, trade efforts, and product portfolio. It visualized that the minimum were 44 orders delivered and the maximum were 85 orders. When demand exceeds 70 orders then a case of overbooking occurs that implies changes in production scheduling. Therefore, the next tables present the U factors that interfere on the DDT indicator. Then, the values for overbooking and preventive maintenance are represented by Y (yes) and N (no) if this factor respectively occurs or not.

Table 40. Overbooking (Y=yes; N=no)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	N	N	N	N	N	N	N	Y	Y	Y	N	N
2011	N	N	N	Y	N	N	Y	Y	Y	Y	Y	N

Table 41. Preventive maintenance occurrence factor (Y=yes; N=no)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	N	Y	N	Y	N	Y	N	Y	N	N	Y	N
2011	Y	N	Y	N	Y	N	Y	N	N	Y	N	N

Subsequently, next tables present the process factors (Q) values.

Table 42. Production performance factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.62	0.71	0.69	0.81	0.77	0.74	0.83	0.98	0.98	0.98	0.81	0.63
2011	0.83	0.88	0.90	0.98	0.97	0.94	0.98	0.98	0.98	0.98	0.98	0.83

Table 43. Supply reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.85	0.87	0.89	0.91	0.77	0.84	0.83	0.78	0.77	0.68	0.81	0.83
2011	0.84	0.86	0.90	0.90	0.92	0.87	0.83	0.81	0.79	0.70	0.85	0.86

Table 44. Transportation reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.95	0.97	0.96	0.95	0.96	0.97	0.93	0.98	0.97	0.98	0.91	0.93
2011	0.94	0.96	0.95	0.95	0.96	0.95	0.91	0.97	0.97	0.94	0.92	0.95

On the other hand, NON indicator places the known environmental factors (seasons) as input to the system and the uncertainties, such as: personnel skill and capability, absenteeism, equipment reliability, storage & handling reliability, and row material reliability.

Thereafter, the environmental factor values which interfere on the NON indicator are represented by Y (yes) and N (no) if this factor respectively occurs or not. This means the months when the temperature and humidity values exceed the appropriate pattern.

Table 45. Environmental factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	Y	Y	N	Y	N	N	N	N	N	N	Y	Y
2011	Y	Y	Y	N	N	N	N	N	Y	N	Y	Y

Subsequently, next tables present the process factors (Q) values.

Table 46. Absenteeism factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.02	0.03	0.01	0.03	0.04	0.03	0.04	0.02	0.01	0.02	0.03	0.02
2011	0.03	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.03

Table 47. Equipment reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.82	0.85	0.88	0.84	0.9	0.88	0.84	0.88	0.89	0.85	0.82	0.79
2011	0.85	0.88	0.89	0.88	0.89	0.9	0.89	0.88	0.87	0.88	0.85	0.85

Table 48. Storage & handling reliability

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.98	0.99	0.99	0.98	0.97	0.99	0.97	0.96	0.97	0.97	0.98	0.99
2011	0.98	0.98	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.99	0.99

Table 49. Reliability of Raw material supply

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.98	0.97	0.99	1	0.98	0.99	0.96	0.99	0.98	1	0.99	0.99
2011	1	0.98	0.97	0.99	1	1	0.97	0.98	0.99	0.99	0.98	0.99

Relationship 2 - This occurs for products delivered from “GPackage” to “GAlimentary”, from January 2010 to December 2011, when the numbers of orders are presented in the next table.

Table 50. Numbers of orders from “GAlimentary” to BSU “GPackage” (2010/2011)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	5	6	5	6	5	6	6	9	10	9	7	4
2011	7	8	6	9	9	10	13	15	19	14	9	6

As in the previous relationship there are an irregular number of orders delivered due the same causes. It visualized that the minimum were 4 orders delivered and the maximum were 19 orders. When demand exceeds 20 orders then a case of overbooking occurs.

Table 51. Overbooking (Y=yes; N=no)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	N	N	N	N	N	N	N	N	N	N	N	N
2011	N	N	N	N	N	N	N	N	N	N	N	N

Table 52. Preventive maintenance occurrence factor (Y=yes; N=no)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	Y	N	Y	N	Y	N	N	Y	Y	N	Y	N
2011	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N

Subsequently, next tables present the process factors (Q) values.

Table 53. Production performance factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.67	0.75	0.72	0.77	0.79	0.74	0.73	0.78	0.77	0.73	0.80	0.69
2011	0.69	0.76	0.76	0.79	0.75	0.76	0.72	0.77	0.76	0.75	0.81	0.79

Table 54. Supply reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.89	0.91	0.88	0.93	0.87	0.95	0.93	0.91	0.92	0.88	0.87	0.89
2011	0.87	0.93	0.90	0.94	0.92	0.94	0.94	0.91	0.93	0.89	0.90	0.88

Table 55. Transportation reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.96	0.98	0.98	0.97	0.95	0.98	0.99	0.97	0.98	0.98	0.99	0.98
2011	0.99	0.99	0.97	0.98	0.96	0.97	0.99	0.98	0.98	0.98	0.98	0.99

Thereafter, the environmental factor values which interfere on the NON indicator were collected using Y (yes) and N (no) if this factor respectively occurs or not.

Table 56. Environmental factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	Y	Y	N	Y	N	N	N	N	Y	Y	Y	Y
2011	Y	Y	Y	N	N	N	N	Y	Y	N	Y	Y

Subsequently, next tables present the process factors (Q) values.

Table 57. Absenteeism factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.02
2011	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02

Table 58. Equipment reliability factor

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.77	0.81	0.83	0.79	0.8	0.82	0.76	0.84	0.84	0.81	0.79	0.8
2011	0.8	0.82	0.86	0.79	0.82	0.87	0.85	0.84	0.85	0.84	0.85	0.84

Table 59. Storage & handling reliability

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.93	0.95	0.95	0.96	0.96	0.94	0.94	0.95	0.95	0.96	0.94	0.97
2011	0.94	0.95	0.06	0.97	0.95	0.96	0.96	0.96	0.95	0.96	0.95	0.96

Table 60. Reliability of raw material supply

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	0.97	0.99	0.98	0.98	0.97	0.97	0.96	0.97	0.95	0.99	0.97	0.96
2011	0.98	0.98	1.00	0.99	0.96	0.99	0.98	0.98	0.97	0.98	0.99	0.98

Thus, both the system factors and process factors are collected to compose the input data of the PVE tool. Subsequently, each defined KAIs is forecasted in order to estimate the system's behavior for the next period or subsequent periods. However, even if this approach is performed, it is necessary to be aware of the errors that can occur, not only from the generalization process of the ANN, but also from the noise brought about by the information sources and sensors. In line with this, the PVE tool applies, in a transparent way, a Kalman filter that will decrease modeling and measurement errors.

During the learning phase, the algorithm developed were capable of detect the best ANN architecture as well as the suitable corrective coefficient for the Kalman filter for each industrial partner. Once finished the system learning stage, the emulator network system was build, taking into account the behavior of the inter-organizational processes. Thereafter, it supplies to the PVE tool the expected values of factors that better characterize the system in analysis and directly influence the system in order to extract the KAI estimation values.

Consequently, it is necessary to explore the scenario that could be used to evaluate the prediction tool. In line with this, it was asked the CN's manager to gather variables that, in their point of view, could be interesting not only to support the test case, but also to increase their capability of reaction to internal and external disturbances. These questions are related with the supply chain performance prediction in a short- and medium-term, respectively:

1. Forecasting KAI values for the next month. It is possible that leading factors involved cannot happen as previously expected, or changes in patterns of each factor may occur. For example, the improvement or worsening of the production performance, supply reliability, overbooking, upgrade of processes, elimination of bottlenecks, and others, that may occur or not.
2. Forecasting the KAI values for the next six months in order to provide support in the definition of KAI targets for this period. The intention is to support the commitment of the production team in order to manage the factors that negatively affect the KPIs, and then improve performance, or at least keep them within these predicted values.

After customizing and performing the PVE application for this use case then it is important assess and discuss the outputs of the tool described as well as compare its performance with the usual forecasting tools used by CN.

Therefore, as can be observed in the following Figure 56, the neural network was able to monitor and learn the historical system behavior for the data regarding the initial months, applying the same approach as described before. However, it was expected to have as timespan only one month because there is a more acknowledgement about the leading factors in a short-term. Thus, it was possible to obtain a more reliable and tuned estimation as expected after simulations performed by the author's research team which disclosed previously these results (Almeida, 2010; Francisco *et. al.*, 2012).

Furthermore, in order to facilitate the understanding of the following graphs, we consider the following caption: blue corresponds to the values associated with reality; green corresponds to the values associated with neural network; red corresponds to the values associated with PVE tool.

Nevertheless, it is possible to observe that the modeling error obtained (green line) is considerably higher mainly in the NON case. In fact, this situation is more notorious once it was used a single neural network to emulate both KAI, simultaneously. Indeed, because both indicators presents specific behaviors with different non-linear characteristics, it would be more interesting to use the same number of neural networks, in parallel, equal to the number of KAIs available, in order to emulate each alignment indicator and thus decrease the respective modeling error.

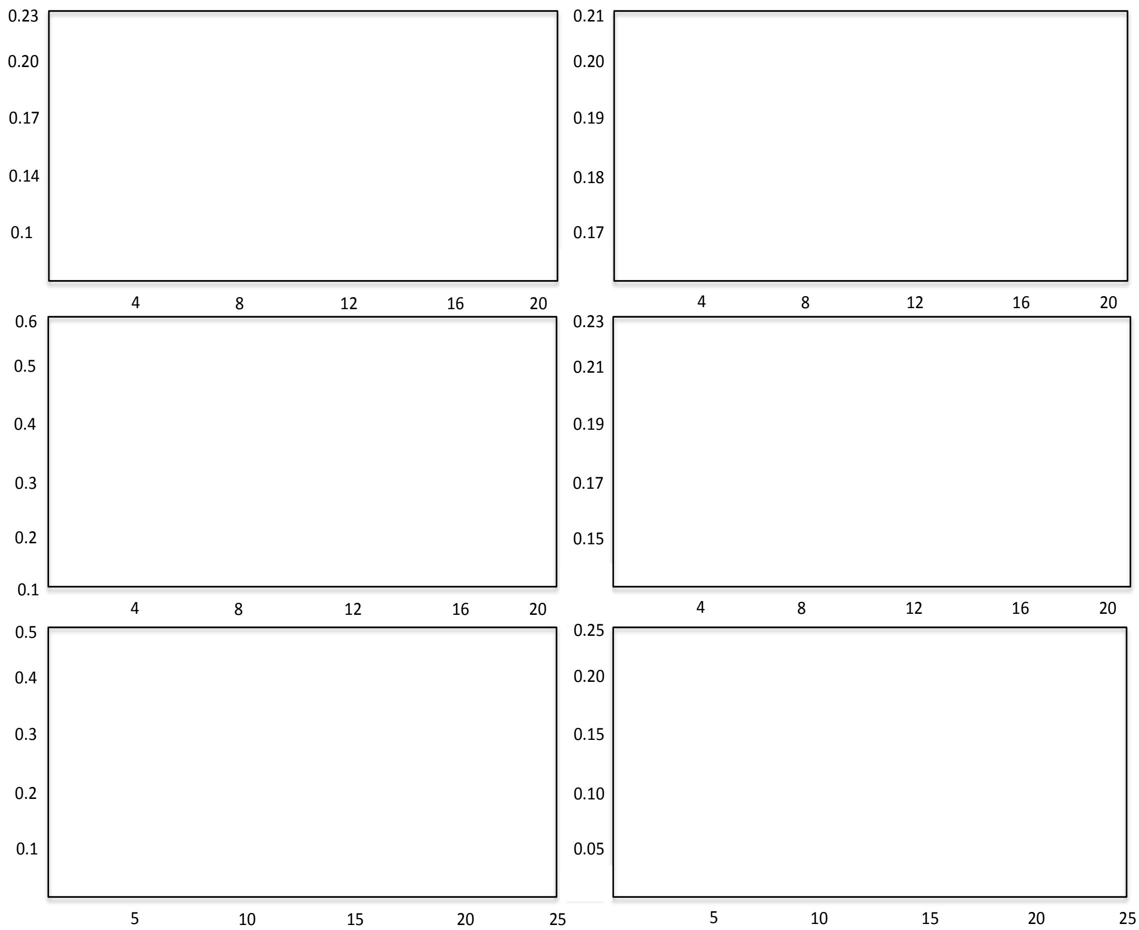

Figure 56. Estimation results

In conclusion, it is possible to understand that this use case which was defined by the CN's manager has the main purpose of focusing on the KAI estimation based on the supply estimation and oscillations of the involved factors. As an example, a deeply analysis had to be performed in order to understand the market demand oscillation during the time space defined, which normally is not a constant value. Indeed, in any company the factor market behavior require a detailed study, which is normally dependent of the characteristics of a specific month of the year by reasons underlying the type of product, such as seasonality, climate, fashion, trends and other factors that must be taken in account. In fact, the more reliable the estimates of these leading factors, the better the performance of estimation.

In the second approach, the experts proposed the estimation of values of each KAI defined for a timespan of six months. Thereafter, using the estimation values it was possible to draw a graph in order to reflect the system performance evolution during the timespan required. In the following Figure 57 it is possible to observe the results of this calculation and in Table 63 the error. Indeed, as it is possible to observe, after twenty four months of filter training (learning stage with regard to the historical data), the PVE tool was launched to estimate the inter-organizational processes performance for the next six months. In fact, there is a smooth offset error of modeling introduced by the neural network (difference between green and blue lines). However, the Kalman filter fulfills its function (red line), which is to nullify this error, as proposed in the architecture of the PVE tool.

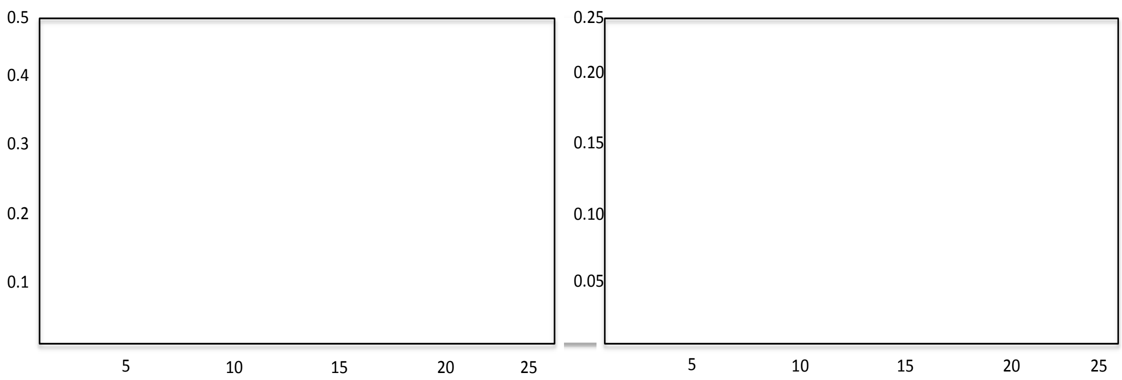

Figure 57. Next six month estimation

Furthermore, in the following tables (61 and 62), the input and output data retrieved from the PVE tool for the Relationship 2 were used to forecast the KAIs for the next month.

Table 61. Input data - leading and lagging factors

Factor	Values for the Next period
Number of Orders	**15**
Preventive Maintenance	**True**
Production Performance	**0.2**
Overbooking	**False**
Supply Reliability	**0.05**
Equipment	**0.2**
Storage and Handling	**0.2**
Row material Quality	**0.03**
Environment	**0.9**
Transportation	**0.1**
Personnel Skills	**0.35**
Absenteeism	**0.015**

Table 62. Output data - estimation KAI values

PKAI (Relationship 2)	Estimation Value
DDT	2.35%
NON	1.22%

Moreover, observing the performance graph, it is possible to emphasize the fact that this tool does not just follow the past trend, but takes a proactive behavior taking in account the factors oscillation that monthly directly influence the system performance. In fact, observing the results obtained of this situation, it is possible to conclude that the PVE is a consistent tool with a low admissible error and a high degree of confidence, approximately 97%.

Nevertheless, in order to validate the reliability of the PVE tool, a comparison with other estimation methods currently used is presented. In this case, the PVE tool obtained an error percentage of 2.2% for DDT and 0.9% for NON (Table 63), which is considerately inferior than what is registered with the other ones.

Table 63. Error comparison of different methods

Estimation Method	GFilms		GPackage		GAlimentary	
	DDT	NON	DDT	NON	DDT	NON
Moving average	0.1386	0.1351	0.2924	0.1790	0.3190	0.1512
Exponential moving average	0.1063	0.0197	0.1273	0.0266	0.1147	0.0145
PVE tool	0.0055	0.0035	0.0135	0.0073	0.022	0.0090

Definition of specification pattern - Thereafter, the PKAIs values must be compared with the predefined values (targets). It is necessary to compare these values with specification pattern values or intervals in order to classify the degree of compliance (DC) for each node of the network (Table 64). Generally, targets must be established when assessing performance. For example, in a manufacturing operation the number of losses for finished products is a common concern (e.g., how many of total products were produced with irreparable nonconformities?). Furthermore, this methodology proposes five degrees to assess compliance with predefined targets, such as: very good, good, medium, bad, very bad. Following this specification pattern value makes it possible to compare and classify the PKAIs to obtain the DC that provides data to predict the degree of alignment afterwards.

Table 64. Predefined values (specification patterns)

Classification of Compliance Degree	NON	DDT
Very Good	$NON^i < 1\%$	$DDT^i < 2\%$
Good	$1\% \le NON^i < 2\%$	$2\% \le DDT^i < 5\%$
Medium	$2\% \le NON^i < 5\%$	$5\% \le DDT^i < 10\%$
Bad	$5\% \le NON^i < 10\%$	$10\% \le DDT^i < 15\%$
Very Bad	$NON^i \ge 10\%$	$DDT^i \ge 15\%$

Compliance Degree classification process - The PKAI value of each participant is then classified according to the specification pattern value by using both PKAIs (DET and NON). Then, this task uses the following classifications: fits very well", "fits relatively well", "fits moderately", "fits badly" and "fits very badly".

Thereafter, is used a decision table (Figure 58) to instantiate the compliance degree (CD) of each participant and clarifies whether its performance meets the expectations of the CN. Furthermore, these predicted values may or may not comply with the values previously expected by the CN's decision-makers. It is therefore imperative that these values are used to obtain the PDA. As can be observed in the following decision table, if a CN participant has "good" classifications for DDT and NON, the CD will be "fw", i.e. fits relatively well.

		DDT				
		very good	good	medium	bad	very bad
NON	very good	fvw	fvw	fw	fm	bf
	good	fvw	fw	fm	bf	bf
	medium	fw	fm	fm	bf	vbf
	bad	fm	bf	bf	vbf	vbf
	very bad	bf	bf	vbf	vbf	vbf

fvw fits very well
fw fits relatively well
fm fits moderately fit
bf bad fit
vbf very bad fit

Figure 58. Compliance degree decision table (with linearity)

In this case, a linear decision table was used. This matrix calculates the CD for each participant using both PKAIs, making it possible to visualize the participants that will perform better or worse in the future. After this step, it is possible to obtain the PDA (Fit Degree).

Fit Degree calculation process - The objective of this last step is using Fuzzy Logic to calculate the Fit Degree for every CN nodes. The aim is to have ability to determine a qualitative value for the future degree of alignment, or even just to analyze the potential performance of each possible partner in a partner selection process.

Using the Matlab® Fuzzy Logic tool, it is possible to configure the fuzzy mechanism, taking into account the requirements and specifications. The triangular and trapezoidal membership functions are used in the fuzzification process (Figure 59; 60). The inputs and outputs are the PKAIs from the estimator tool and the CD classification, respectively. Therefore, the membership functions were specified taking into account the CN requirements.

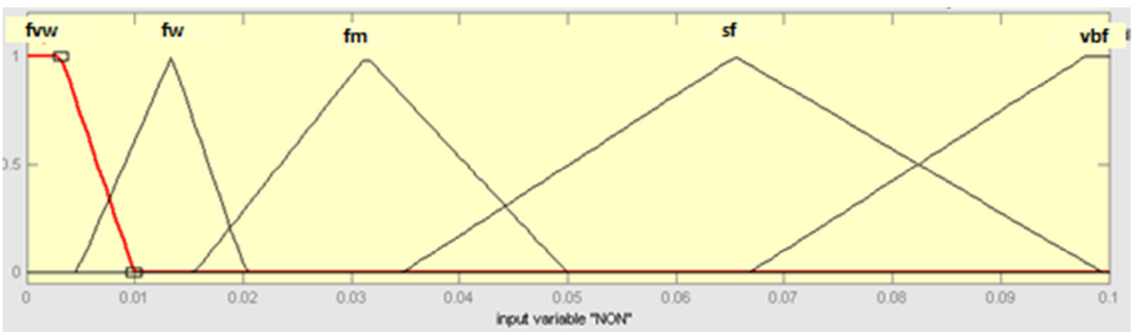

Figure 59. Variable "NON" fuzzyfication

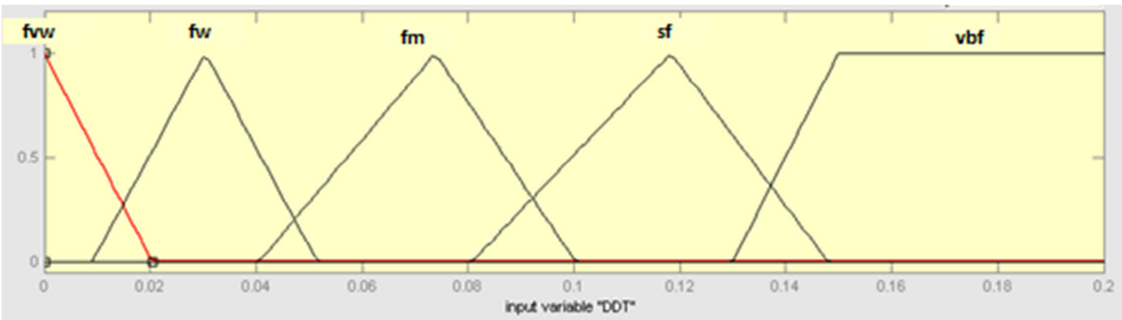

Figure 60. Variable "DDT" fuzzyfication

In fact, the Fuzzy Logic is generally used when there is not enough knowledge and certainty about the system to be controlled therefore it presents interesting characteristics that make it possible to model nonlinear systems more easily. With this nonlinear system modeler, it is possible to achieve a better definition, decrease the modulation error and control more complex systems. Therefore, in order to obtain the fuzzy result it became necessary to translating the states of fuzzy variables into real and concrete values (defuzzyfication process). To do that, the centre of gravity method, known as centroid, was used. This method consists of calculating the fuzzy set mass centre.

Then, it was possible to achieve a 3D graph (Figure 61) that represents the nonlinearity desired for each of the nodes of the CN. As the KAI values increase there is a decrease in the reliability of the partner selected to fulfill a certain CN node's requirement. Thus, the navy blue color means that a certain partner "fits very well" and the color yellow mean that it "fits very badly". From the analysis of the selected partner ("*GFilms*"), it was possible to conclude that the Fit Degree obtained was "High".

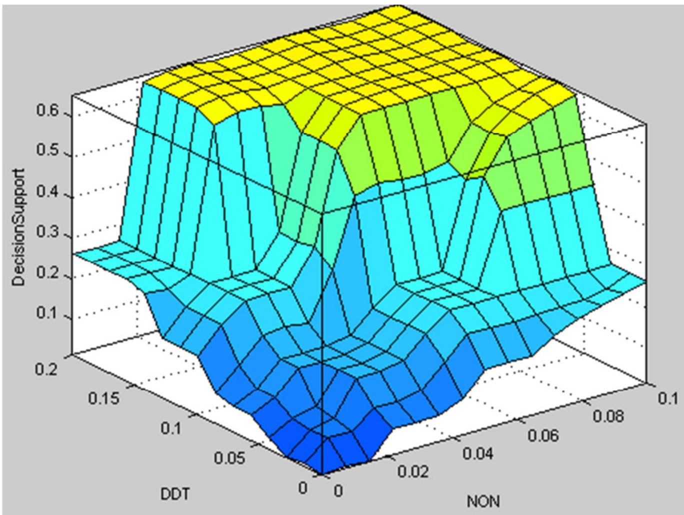

Figure 61. 3D graph results

In sum, the aim is to find a simple, intuitive and knowledge based methodology to calculate and define the shape of the control surface of a CN alignment by using a fuzzy logic tool. In fact, this target would be very complicated and computationally expensive to be achieved by using non-fuzzy methods because the more complex the system, the greater should be the degree of the polynomial that emulates this alignment system prediction. Indeed, this 3D graphical representation clearly defines the behavior of the system that supports the assessment of the alignment.

Thereafter, using the same approach and methods for the other CN participants, the Fit Degree obtained for participants B (*GPackage*) and C (*GAlimentary*) were respectively "VERY HIGH" and "LOW". In fact, element C (Figure 62) represents the bottleneck of the production system and, because of that, partner C is the one that contributes the most to the misalignment of the CN. In line with this information, the CN manager can determine how the identified partner must improve its performance to benefit the network or simply replace the partner in order to improve the overall behavior of the system. Moreover, if this methodology was automatically applied in a CN, retrieving performance data in real-time, this could be an important asset to the system management because it makes it possible to forecast and anticipate malfunctions and under-performances in the network. Therefore, it is possible to avoid high levels of nonconformities and delays in deliveries, with less resource and time spending. In conclusion, partner C is impacted by the inefficiency of the suppliers.

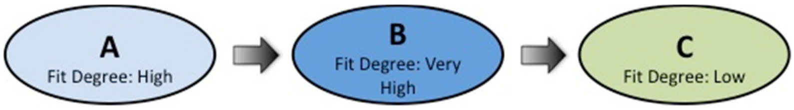

Figure 62. Fit Degree results

In summary, the predictive Fit Degree process (Figure 63) evolves from definition of KPIs, choice of KAIs, application of PVE tool for obtaining the predictive KAIs (PKAI), establishment of standard specifications (SS) and determining the Compliance Degree (CD) by using a comparison of the PKAI with SS values until calculating the PDA (Fit Degree).

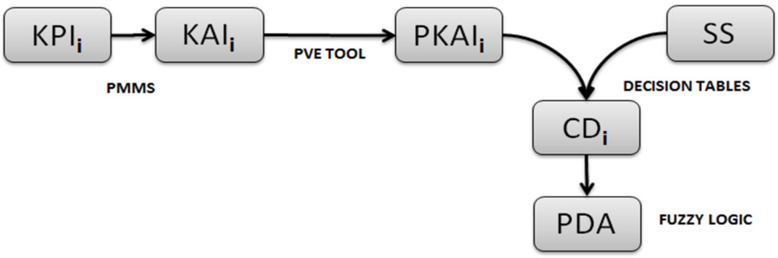

Figure 63. Fit Degree process

5.4.4 Case summary

In 2009, companies "*GFilms*", "*GPackage*" and "*GAlimentary*" intended to observe the performance of the inter-organizational processes in working within a collaboration strategy. In this case, it was found that the prediction of future alignment may contributes to the decision making during the operation time, specifically to perceive alignment of partners in future moments of the CN life-cycle. In fact, it aims to know previously the alignment between the partner performance and the performance targets of CN. Therefore, in this case, the Fit Degree is used to determine the predictive alignment for every participant (Table 65) with regard to the targets established by the CN, i.e. the PDA.

Table 65. Checking performance to alignment assessment

CN Partners	Task 4: Assess the PDA
"GFilms"	HIGH
"GPackage"	VERY HIGH
"GAlimentary"	LOW

In conclusion, with this alignment assessment, the CN can improve their results in terms of quality and productivity. The partners can better visualize what efforts should be spent to improve the overall performance of the CN and can also plan the intra- and inter-organizational processes more accurately.

5.5 Concluding Remarks

In this chapter two application cases were presented. The aim was test the alignment measurement approaches proposed in Section 3.3. The systematic methodology to implement a PMMS in CNs was used then the methods for calculate degree of alignment were performed.

For the first case, the Pet Shop Retailers, the following achievements and findings were obtained, respectively:

1. The CN was composed by small-sized companies which desired to increase competitiveness by reducing costs and increasing bargaining power with suppliers. Moreover, this CN did not have a PMMS and thus could not assess whether the objectives that led to the creation of the CN were being met.
2. An approach for measuring alignment was developed and used to find subjective and descriptive values for the degree of alignment. This assessment was based on the CEO's perceptions using motivational factors (trust, performance, reliability, knowledge) and also on the DEA method for performing a benchmarking analysis. These alignment measurement approaches (subjective and descriptive) was performed simultaneously with the PMMS implementation process at the three measurement moments (partner selection, agreement and run time).

Therefore, the alignment measurement process was carried out initially using a subjective approach with motivational factors at the CN formation moment and subsequently was also used at the agreement moment. However, because to the CN typology and respective business environment be formed by a congregation of partners that acting in the same branch, an descriptive approach using a benchmarking analysis was developed in order to measure the alignment using KPIs related to the intra-organizational processes of all participants. Thus, the subjectivity that existing in the approach on motivational factors was complemented by an approach that uses descriptive measures for comparing the performance of each partner in order to make it possible to understand the level of efforts required to improve the overall performance of the CN.

Subsequently, in the second case, the G3 Supply Chain, the following achievements and findings were obtained, respectively:

1. The CN was composed by medium-sized companies which desired to increase competitiveness by reducing costs and increasing bargaining power with suppliers. Moreover, the CN participants there were their own PMS and thus it has contributed to use the performance and alignment methods to assess whether the CN participant efforts contributed to accomplish the benefits that the collaboration strategy.
2. A predictive approach for measuring alignment was developed and used to assess whether the CN participant efforts contributed to the inter-organizational alignment. This assessment was based on the prediction paradigm and also on the PVE tool/Fuzzy Logic toolkit for performing a predictive alignment measurement.

In order to achieve these challenges, the Key Alignment Indicator (KAI) was introduced as critical indicator which translates the main performance measurements able to assessing performance in collaborative networks. Thereafter, a predictive performance management framework was developed inspired in tools normally used in the control theory. It was proposed the integration of neural networks with Kalman filters as the main pillar of the predictive performance engine (PVE tool), aiming to extract knowledge from each partner's behavior and to estimate future performance using current leading performance data. Furthermore, a Fuzzy Logic approach was explored in order to assess, in an automated way, the performance behavior of each partner as a single entity.

For this CN, which is composed of three independent organizations, two KAIs were selected: number of orders with nonconformities and delay in delivery time. For each of them, a series of leading factors were defined and described in order to supply the performance estimator engine with the suitable data capable to support the performance estimation with more reliability. After the predictive key alignment indicators were calculated, these values were then compared with the target values and introduced into the fuzzy logic engine in order to evaluate the predictive degree of alignment (PDA). From this case, the partner which can be considered the bottleneck of the network was identified.

Moreover, it was only used two KAI vectors, such as:

- Legging Measure (output): PDA (Fit Degree);
- Leading Indicators (predictors): The PKAIs DET and NON.

In conclusion, the application cases presented in this chapter were able to demonstrate the viability of applying the alignment prediction concept and stressed the need for different approaches for each CN. Such approaches evolved from a subjective approach supported by simple mathematical methods, thereafter passing by a descriptive approach that uses math methods of medium degree of complexity, to a predictive approach that uses more complex mathematical tools. Therefore, it is necessary to develop and test different approaches and methods to apply them into different CNs.

Complementing this, the need to use ICT solutions for better integration of the participants of a CN was addressed. It also referred to a web service solution that was developed and applied in this research, the so-called CNPMS Manager.

Chapter 6

Conclusions

This chapter is to present the research conclusions and their major achievements and findings. The research questions are highlighted with explanations of what was interpreted and also suggestions are made for future works in the context explored in this thesis.

6.1 Main Conclusions

This research was initially developed to understand how performance management could help collaborative networks improve the alignment of their participants with the strategic objectives. By measuring the performance of intra- and inter-organizational processes and comparing them with the established targets it becomes possible to obtain a measurement that reflects the alignment of CN participants.

The research development sought to ensure the proper conduct of an investigation supported by the recent concepts and statements for the themes explored and thus make it possible to solve the research questions. Furthermore, research methodologies were used to evaluate and validate the thesis proposals used in this research. The practical applications occurred in a real-life business environment where favorable conditions were sought to enable the adaptation of methods, techniques and tools. The framework developed for performance management in collaborative networks, so-called CNPMS, was implemented in collaborative networks of small and medium-sized enterprises that agreed to establish a partnership with the researchers.

Following these developments, this thesis was written to inform both the academic and business communities about the findings and the achievements reached. At the beginning of this research, the justifications (context and relevance) for this work were properly substantiated. The objectives, challenges and motivational aspects were also determined in order to obtain theoretical information for the proposals that this research aims to disseminate.

Furthermore, during this research inductive and deductive reasoning (looping) was applied to successfully integrate the concepts and methods for introducing new tools which are able to measure and manage performance in collaborative networks.

Considering that theory in collaborative networks management is still in its early phase, it is feasible that conceptual approaches are not yet supported by a sustainable theoretical basis, especially since most applications contain a high level of trial and error related to the proposals for new methods and tools to support decision-making.

However, it was possible to see that in this research some aspects are relevant to the success of collaborative networks, these include:

- the effective selection of partners,
- the perception of the benefits that can be earned, the formulation of strategies and goals,
- the measurement processes of intra- and inter-organizational performance,
- the focus on achieving strategic and inter-organizational alignment between participants
- the collection of data and information from previous collaborations (performance repository).

Another important factor with regard to the key aspects of performance (such as cost, response time, quality, reliability, agility and flexibility) is the ability to use key performance indicators to support the strategic assumptions and its modifications. Therefore, the adoption of performance management systems becomes a critical tool that supports decision-making processes. This statement led the researchers to develop tools for performance management systems by introducing a new paradigm that provides predictive approaches to measuring performance and thus calculating a value representing the future alignment of the CN. This was completed using innovative tools for performance prediction and for alignment classification.

The main outcomes of this research were possible due to the approaches and tools developed as well as practical applications to test and validate the proposals. These outcomes can be distinguished in two distinct levels, primary and secondary.

Primary level:

- A theoretical proposition on the alignment measurement in CNs using key alignment indicators (KAIs);
- Using the paradigm of performance prediction to apply a theoretical proposition for the measurement of future alignment in CNs, i.e. alignment prediction;
- Application of the Euclidian distance method, Data Envelopment Analysis, and Neural Networks in order to provide a toolkit that can instantiate the alignment of CNs in small- and medium-sized businesses;
- Development and application of a fuzzy expert system to measure/rank the predictive degree of alignment, the metric Fit Degree.
- Realization of practical applications using two cases of CNs with different typologies.

Secondary level:

- Designing a conceptual framework for a performance management system in collaborative networks, i.e. CNPMS framework;
- Using the Soft System Methodology to design an implementation methodology for a Performance Management System (PMMS);
- Development of a tool to estimate (Performance Value Estimator-PVE) the predictive measures of performance;
- Development and implementation of an application software to support the integration of participants in a CN, i.e. CNPMS Manager;

The starting point came when the assessment of the SSM methodology made it possible to elaborate a systematic approach to be applied in collaborative business. This provided knowledge and confirmed the viability of the approaches and methods used in the first study case. After evaluating the results of this case, new approaches were proposed and new tools were implemented for the other application case (Table 66).

Table 66. Research actions in the business cases

Research Actions	System, Methods and Tools	Pet Shop Retailers	G3 Supply Chain
1. Data collecting	Participant- Observation	used	used
2. Design of Performance Management System	CNPMS framework	used	used
3. Performance indicators selection	Use of theory	used	used
4. Performance monitoring	PMMS results	used	used
	CNPMS Manager	-	used
5. Development of measurement tools	Euclidian Distance	used	.
	DEA	used	.
	PVE	-	used
6. Alignment assessment - Questionnaire	Fit Degree	used	-
PVE tool / Fuzzy expert system	Predictive Fit Degree	-	used

Indeed, the actions undertaken in each case contributed to answering the research questions and go beyond them by proposing innovative tools and theoretical propositions. It can be said that one of the great merits of this research is that it has developed and tested innovative tools for collaborative networks that have proved effective in terms of supporting decision-makers when conducting CN strategies.

The achieved outcomes in the empirical part of the research may contribute from a performance assessment viewpoint to the effective management support as an activity that allows instantiate the alignment of the CNs. This means that the practice of measuring intra- and inter-organizational processes is relevant and helps decision-makers promote effective strategies as part of the concept of collaboration.

Therefore, the main contributions that were extracted from the research questions are:

***Research Question 1*: How to assess performance in CNs, and what network typologies, measures and performance management models must be considered?**

1. Using the alignment measurement concept for assessing performance in CNs;
2. Applying specific alignment measurement approaches for different CNs.

***Research Question 2*: How to achieve alignment between participants of a CN?**

1. Fitting the main intra- and inter-organizational processes;
2. Aligning targeted performance with real performance;
3. Assessing performance and alignment during specific CN life-cycle moments;
4. Supporting the integration of participants of a CN through ICT technologies.

***Research Question 3*: How to quantify the inter-organizational alignment in a CN?**

1. Developing alignment measurement approaches;
2. Developing tools to support alignment measurement methods;
3. Defining specific criteria for alignment classification.

In fact, in this research various approaches, methods and tools that aim to help decision-makers of collaborative networks were proposed, developed, and implemented. The main aim is to contribute for improving network performance and increase the alignment of intra-and inter-organizational processes.

6.2 Explanations on the research questions

Initially, this study sought to evaluate whether the problem-situations could be robustly reasoned on concepts and methods that could highlight the importance of performance management and alignment in collaborative networks. The idea was to create an intuitive methodology for developing measurement systems and performance management approaches that consider interactive mechanisms and their respective technological supports in order to support the decision-making process. It is therefore necessary to explain the research steps in order to outline what will be assessed and to propose methods to resolve these issues.

The research path can be broken down as follows:

- Studying issues related to managing collaborative networks and performance management, including aspects relating to inter-organizational alignment;
- Understanding the benefits of companies operating in collaborative networks and the factors that can guide them and motivate them for strategic and inter-organizational alignment;

- Assessing and comparing the characteristics of the contemporary performance management systems for collaborative networks;
- Developing a framework for performance management in collaborative networks, which could be tested and validated and also making it applicable as a management tool in real-life situations;
- Developing methods and tools to measure the predictive performance and alignment in order for enhancing the design of the PMMS.

However, a theoretically oriented interactive framework should be properly developed in order to quickly and consistently support performance-based decision making. In fact, it is considered that applying a consistent methodology to implement a PMMS can decisively contribute to supporting and improving the CN's performance.

Furthermore, throughout this work it became increasingly apparent that the opportunities to design methods and tools to meet the assumptions guiding this research are manifold. The possibility of using estimating tools to obtain future performance was particularly clear and can be extended to predicting the alignment based on past and current data. This statement altered the research and it focused on both understanding the problems studied as well as developing practical applications.

Consequently, during the research, methodologies were applied to explore the main issues relating to the research path. Exploratory research and surveys were adopted to describe the phenomenon studied and provide information that was relevant at later stages when conducting the exploratory case study. Therefore, the survey questions are presented and explained as follows.

What is a collaborative network and what are its main features?

Collaborative networks are groups of organizations that aim to integrate their resources, knowledge and combine risks to achieve certain strategic objectives. They decide to work together because they believe that alone they would not be able to meet the challenges posed by the markets in which they operate. Furthermore, this strategy may allow them to reduce uncertainty and be more competitive. Moreover, responsibilities relating to inter-organizational processes and the respective resources are shared and the participants work together in order to plan and solve strategic and operational problems. Collaborative networks also involve the interoperation of different organizational systems that must be integrated and orchestrated in order to guarantee effectiveness in the inter-organizational processes, leading to suitable performance levels.

However, this new model requires the alignment of inter-organizational processes with regard to the accomplishment of CN targets that is supported by appropriate technologies and infrastructure support, management tools, and performance measurement solutions. Therefore, participants must reach an agreement on the common strategic objectives and performance targets. It is also necessary to create common rules and structures of integration in order to regulate relations between the participants. Additionally, the formation of a CN is a process that involves trust and alignment.

This new paradigm has been sustained by rapid innovations in information and communication technologies due to technological advances. What is more, today's social and business environment is characterized by constant change, ephemeral markets, volatile demand and short life-cycle of products and services. Thus, this environment is progressively changing the standardization approaches to customization, time-to-market, flexibility in production, and the delivery of complex products and processes.

In addition, the CN life-cycle paradigm helps determine the CN's planning activities and can be conceived more widely according to the following phases: business opportunity detection, partner search and selection, design & setup, operation, evolution and dissolution. This thesis proposes that there are key moments in the CN's life cycle which are relevant to evaluating the degree of alignment in order to show decision-makers whether there is a strong relationship between CN structures and inter-organizational processes, i.e., the internal fit. These key moments are stated to occur during the following situations: partner selection, agreement and operations.

In order to assess the CN's performance, an effective PMMS can help reconcile the performance of each participant and the overall performance of the CN by providing instances of performance in key moments of the CN's life-cycle. This may be one of the main challenges that needs to be overcome since not all participants are ready to provide data (or interested in providing data) on their own performance, including those that are key to the success of the network and those who may disturb it. Therefore, it is essential that they agree to guarantee the reliability of performance data.

In summary, collaborative networks are an emerging trend and their expertise in managing this new strategy must be obtained straightaway by any type of organization because it may be, in many cases, the last chance for them to survive to the increasing business challenges.

What are the benefits that organizations can obtain in a collaborative network?

When an organization decides to participate in a CN, their decision-makers expect that this strategy of collaboration will bring certain benefits. In every situation there are different purposes motivating organizations to adhere to the CNs, but undoubtedly increasing their competitiveness and reducing the uncertainties that directly affect investments are the primary motives. However, these benefits must be properly defined so that the organization can measure them during the operation of the CN in order to assess whether they are being accomplished.

With regard to benefits which can be earned they include: increased flexibility, reduced costs, increased responsiveness, improved capacity, increased asset utilization, enhanced customer satisfaction, increased market share, reduced time-to-market, enhanced design innovations, increased quality, improvements in skills and knowledge, decreased risk of failure, upgrades for technological support and the promotion of complementary skills. The collaboration strategy it is also proposed to lead to the generation of economies of scale and thus ensure greater bargaining power in relation to their customers or suppliers.

Furthermore, when the collaboration strategy aims to increase customer satisfaction and increase market share, the participants can undertake joint marketing activities and learn best practices for customer services through employee vocational training, as well as sharing common suppliers, logistics services and asset security. Such activities were observed in the Pet Shop Retailers Case.

Within the manufacturing industries, the collaboration strategy makes it possible to improve capacity, increase asset utilization, reduce time-to-market, enhance design innovations, increase quality, improve skills and knowledge, support technology upgrades and promote complementary skills. Specifically, in the G3 Supply Chain Case it was possible to see that these benefits were addressed, specifically with regard to delivery time and product quality, in order to improve performance.

In summary, when the collaboration strategy is applied, several benefits can be obtained that range from reducing costs to improving the skills and knowledge of the participating organizations, helping the organizations that constitute the CN to be more prepared when facing the challenges presented by the market.

What are the methodologies and approaches adopted by performance management systems in real-life environments nowadays?

Basically, a performance management system (PMMS) is based on a collection of management concepts and measurement tools which are translated into a conceptual framework which includes the functionalities that are necessary to plan, measure, analyze and report process outputs. This system must support the decision-makers in identifying new challenges to maintain or improve their business performance.

In fact, a transition is occurring from traditional approaches of performance measurement to a symbiosis of measurement functions and performance management knowledge. Thus, it is necessary to design and implement a PMMS to provide accurate information to the process decision-makers who will use concepts and methods to manage the business performance.

Therefore, the purpose of the performance measurement system is to link the observer to the process. Indeed, a performance measurement system (PMS) can manipulate information and data relating to the process outputs in order to transform it into input data (KPIs) that is used to instantiate the performance within the selected perspectives and approaches. Nevertheless, defining an appropriate set of categories of performance measures that meet the needs of the strategic purposes represents a critical step towards the establishment of an effective PMMS.

In this research, it is considered that a PMS consists of tools to measure the performance by considering the following aspects: indicators, metrics, the structure of the system functionalities, application software for compiling and processing the data. On the other hand, a PMMS consists of designing and improving the conceptual framework for performance management, setting KPIs, determining the KPI targets, acting as a bridge to supply data for analyzing and solving problems and, in particular, define approaches that determine measures, analysis criteria and evaluation models that underlie the design of the system model.

Thereafter, while in the process of measuring performance it is more important to define the design, collection and handling of data. In performance management it is more important to define how the results of the measurement process should be used in order to improve the processes being monitored. Thus, many subjects to finding solutions to the problems observed by a PMMS have been addressed, such as: hard- and soft-problem approaches, optimization and forecasting problems, operations management, business strategy formulation processes and marketing performance evaluation.

With regard to collaborative networks, some models have different purposes, such as measuring the benefits that can be achieved, selecting partners by measuring past performance, improving the skills of participants in the CN, differentiating the performance measurement criteria between participants and the overall network performance, and others focus specifically on the performance of supply chains.

In this research, the theoretical suggestions and the conceptual tools proposed denote the intention of designing a conceptual framework for performance management and alignment in CNs and introducing tools to measure and estimate performance. The main aim is to guarantee that the measuring methods are effective due to performance indicators derived from the organization's strategy. This is to help decision-makers improve processes and reach the alignment of participants surrounding the CN strategies.

How can we design a performance management system according to its referenced approaches and methodologies to assess performance in collaborative networks, to make inter-organizational processes more effective?

According to the literature, the performance assessment is composed of measuring, analyzing and communicating the performance values obtained for processes and activities related to the targets based on pre-determined and application-dependent criteria. These values are compared with the target values in order to make it possible to detect failures or variations in processes, thus comparing the targeted objectives with the achieved results.

Therefore, it is prudent to develop a conceptual framework to determine the performance management functionalities that can establish the requirements for the PMMS, where the leading and lagging data are managed in a performance repository. This approach also uses the life-cycle paradigm to enable the evaluation of the CN's performance from the moment of conception, including the partner selection stage, until its dissolution or metamorphosis.

With the goal of designing a conceptual performance framework to develop a PMMS, it is essential to use concepts and methods to establish key elements for the design of this system and also the effects that this may have on performance evaluation. Furthermore, the conceptual performance framework should consider the main functionalities which exploit the performance requirements, methods, and tools for performance management.

Thus, it is also possible to include existing performance management models that are suitable for the conceptual framework designed to develop and apply a performance management system. Therefore, it must consider several demands when designing the performance management framework, including: increasing flexibility, capacity achievement, increasing market share, increasing asset utilization, enhancing customer satisfaction, reducing costs, reducing time to market, increasing quality, enhancing skills and knowledge and decreasing the risk of failure.

Next, the research questions that guided this research for achieving theoretical and practical outcomes are discussed.

<u>Research Question 1</u>: How to assess performance in collaborative networks, and what network typologies, measures and performance management models must be considered?

The performance assessment and evaluation is a difficult task for organizations. Although the focus is usually on the measurement of financial performance, some approaches that deal with organizational processes are used by decision-makers to look for performance management on production operations, such as manufacturing, purchasing, inbound logistics and distribution. Thus, in a balanced approach, measures of financial performance are important for strategic decisions, but controlling the day-to-day operations is best accomplished by using specific measures. In particular, when a collaboration strategy occurs, the measurement of performance of intra- and inter-organizational processes ensures that the partnership is under control.

There are many typologies of CNs which can be characterized according to certain attributes including: relationships (the types of connections between network nodes), context (background information on the network context), motivation (strategic targets of the network); actors (the type of network nodes), resources (the contents of the links between network nodes) and activities (added-value activities performed by the network). Furthermore, the collaboration strategy has specific purposes, such as: joint ventures, strategic alliances, virtual enterprises, virtual organizations, holdings, franchises, dynamic networks, value-added networks, extended enterprises, supply chains, enterprises networks, outsourcing, partnerships, clusters, collaborative networks, industrial districts and integrated logistics. Complementing this, the following networks represent the main functions that demand the formation of the CN: supplier networks, manufacturing networks, customer networks, standard coalition networks and technological cooperation networks.

There are also some interesting approaches which have been properly tested in real business environments that can provide models and systematic methodologies for managing performance. The Balanced Scorecard System (BSC) and the SCOR model which have been applied, respectively, in strategic planning and in operations improvement can be highlighted. The excellence models (Deming Price, PNQ, EFQM and Malcom Baldridge Price) can also be mentioned that are increasingly used worldwide for small, medium, and large-sized companies.

In fact, a PMMS is an important tool for decision-making in CNs. The definition of a specific set of categories for performance measures that will make it possible to monitor the performance of a collaborative network represents a critical step for the establishment of an effective PMMS. Therefore, an appropriate methodology should be used to help configure and implement this system in a collaborative network.

However, in this research, the alignment was used as the main focus to enhance performance management in CNs. Therefore, the alignment measurement subject was explored in depth in order to develop alignment measurement approaches for assessing performance in CNs as well as using them with specific measurement tools.

In addition, using performance measurement tools is essential to assess the degree of alignment of inter-organizational processes in order to achieve operational excellence in dynamic business networks, particularly when the partners involved are heterogeneous with regard to management approaches and business culture.

Therefore, due to a great variety of typologies, the collaborative networks are very distinct and so they need different approaches and methods to measuring alignment as the most proper concept to manage performance in collaborative networks.

***Research Question 2*: How to achieve alignment between participants of a CN?**

When organizations work together sharing strategies, resources and knowledge, they need to achieve a strong link between the business environment, inter-organizational structure, and the participant's internal processes. Thus, the concept of "Fit" seems relevant when trying to extract certain aspects within the organizational boundaries (competencies and resources) and others that deal with the business environment (opportunities and threats), this is the external fit. On the contrary, reducing the focus on strategy and prioritizing the alignment between organizational structure and organizational processes is possible to obtain a more targeted approach to the intra-and inter-organizational processes performance in relation to the structure of a collaborative network. This is the internal fit.

Indeed, in this work it was observed that when links between structural variables and processes are strong, this may induce a higher alignment degree in collaborative networks within environments with low uncertainty. Thus, assuming that collaboration can reduce the uncertainties of the business, then reaching a higher level of internal fit becomes the main concern for decision-makers when assessing the CN's performance. Therefore, the internal fit is linked to performance improvements that are necessary to ensure a greater degree of alignment between inter-organizational performance and the established performance targets.

Alignment in CNs can be seen as the accomplishment of activities designed and planned according to the strategies adopted and targets established. The alignment can assume different levels, such as strategic alignment, organizational alignment, operational alignment and team alignment. However, in this thesis it is established that each participant, individually, should be responsible for operational and team alignment while the strategic and inter-organizational alignments are covered under the scope of the CN strategy. Therefore, this research focuses only on the intra- and inter-organizational alignment.

The synergy derived from the interaction of participants promotes a combined effect that is greater than the sum of their individual efforts. Therefore, the inter-organizational alignment makes it possible to achieve sustainable gains through the synergy of resources and knowledge achieved within collaborative processes. Moreover, the performance achieved refers to the transformation of the strategy objectives into action through the alignment between process performance targets and reported process performance.

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<u>Research Question 3</u>: How to quantify the inter-organizational alignment in a CN?

When a CN assess the performance of inter-organizational processes it makes it possible to detect gaps, but it cannot precisely show whether the efforts of each participant contributes to improving the overall performance of the CN. Thus, the main objective of this research is to find metrics that make it possible to instantiate the alignment by focusing on compliance with the agreed performance targets.

As noted in the business cases discussed in the previous chapter, different approaches such as those presented below may be used in order to measure the alignment in collaborative networks:

1) The participants attempt to assess the performance results to infer the alignment of the network, related to the alignment factors perceived by each partner. Therefore, values for

motivational alignment factors can be obtained by using questionnaires regarding the perceptions of CEOs. The outcomes of this survey are transformed into numeric values which are used to determine a coefficient of misalignment that indicates the degree of alignment for the network, as seen in the application case presented in Chapter 5 (Section 5.3). However, the link between the performance achieved in inter-organizational processes and the perception of alignment measured by CN decision-makers appears to be too abstract. Consequently this method only induces decision-makers to understand which alignment factors must be dealt with more carefully in strategic planning and process reconfiguring.

2) The CN participants assess the performance outcomes by calculating the efficiency of each partner in terms of the key alignment indicators. They can then perform benchmarking techniques that show which CN participants are underperforming. It is clear that through the DEA approach it is possible to determine which participants can accomplish the performance criteria, ranking them in order to see which ones show a better performance when compared to others, as seen in application case presented in Section 5.3.

3) Participants assess the performance results using predictive measures which make it possible to predict future performance in order to improve the inter-organizational alignment. This assessment is proposed to determine future targets of the network operations. Therefore, the KPIs escalate into predictive KAIs which are compared with previously defined targets. Participant's performance can then be classified to determine the future degree of alignment. Tools for estimation and fuzzy classification are applied within a toolkit to measure the predictive degree of alignment, as seen in the application case presented in Section 5.4.

Following this last approach, the original topic “Alignment Prediction” was introduced as a result of the new paradigm of performance prediction. This approach breaks a performance management paradigm of waiting for the processes output data after a feedback period and also works on solving the problems that affect the overall performance. It makes it possible to use present and past performance data on potential participants in order to select partners when a new network is created. More specifically, a strong foundation is proposed for evaluation purposes to support the alignment prediction approach using a toolkit that consists of estimates (e.g., the Performance Value Estimator tool) and qualitative classification (e.g., the Fuzzy Expert System). In fact, the “Fit Degree” is an alignment metric that is obtained using the values of predictive states through key alignment indicators (KAI). The KAIs extracted from the existing set of key performance indicators (KPI) used in the PMMS are defined by the CN decision-makers.

Furthermore, Figure 37 previously presented in Section 3.3 shows a comparison between the examples of single organization and collaborative network. The first example is considered trivial and the use of KPIs is obtained by PVE tools embedded in the performance measurement systems of individual organizations. In the second situation (collaboration) the concept of alignment prediction based on performance prediction is introduced in order to use the KPI values and convert them into KAIs. A decision table is then used to classify partner compliance with targets. After this, a fuzzy logic tool provides a classification for the alignment in the CN. Therefore, this toolkit provides a metric that helps to accurately forecast the predictive degree of alignment.

Indeed, following the application cases shown previously, it is possible to demonstrate that the Fit Degree process should be applied in both short and long term CNs in order to make it an effective and continuous alignment among participants during the entire network operation. Furthermore, it also supports partner selection during the ramp-up and recycling of complex production systems. However, an important drawback is that partners must present a significant quantity of historical data in order for the PVE tool to model the behavior of the elements in the CN and predict future performance. The existence of this extensive data can strongly simplify the modeling process, avoiding the need to hire human resources with knowledge in mathematics. Thus, it helps CN managers to predict future alignment, based on present and past performance data, throughout the CN's life-cycle.

Therefore, the Fit Degree process includes the following tasks:

- Designing a PMMS for the CN (CNPMS framework)
- Collecting key alignment indicators and defining target values (PMMS)
- Applying the PVE tool (performance prediction)
- Classifying the Compliance Degree (decision table)
- Classifying partner's alignment using PKAIs Compliance Degree (alignment prediction)
- Calculating the Fit Degree (fuzzy logic)

In addition, not only alignment estimations can be calculated, but realistic targets can also be defined. Indeed, once the behavior of the elements belonging to the network has been defined, the CN manager is able to define the optimal scenario through the specification of the leading factors of the system and estimate the best performance that should be achieved helping them to outline achievable targets.

In summary, while KPIs measure the effectiveness and efficiency of the processes of an individual organization, this may not be useful for the CNs because the performance indicators may have individual settings that are very different for each partner. Therefore, it is possible to say that the research has developed from the belief that alignment could be measured using KAIs to the use of estimator tools and performance classifiers for determining future alignment in CNs.

Moreover, in this research practical applications that tried to find solutions for measuring alignment in collaborative networks were tested. In these application cases, methods and tools were introduced that range from subjectively classifying the degree of alignment to those using mathematical estimation and performance classification tools for classifying the future degree of alignment. Table 67 depicts the outcomes of the application cases developed, by describing: CN description, approach adopted, methods used, main concepts considered, frameworks, tools applied, achievements and findings.

Table 67. Outcomes of application cases

Use case / Outcomes	Pet Shop Retailers	G3 Supply Chain
CN Description	Small enterprise network; fully connected mesh topology; dynamic virtual organization typology.	Medium enterprise network; linear bus topology; supply network typology.
Approach	The CN Board assesses the performance results by using the motivational alignment approach which uses the questionnaire method and the Euclidian Distance method to infer the alignment. They also calculate the efficiency of partners regarding the KAIs and then performs a benchmarking method for reveal the CN participants that are underperforming.	The CN Board assesses the performance results by using predictive measures which make it possible to predict the results of future performance. This approach is used both for the selection of partners as for setting targets for the future alignment of the network operation.
Method	Implementing the PMMS; Defining the alignment factors and calculating the SDA; Collecting data (KAIs), Calculating efficiency (benchmark) regarding the targets criteria and calculating the DDA.	Implementing the PMMS; Collecting data (KPIS into KAIs); Predicting performance (PVE); Classifying the Compliance Degree; Classifying the PDA (Fit Degree).
Main Concepts	Performance Measurement and Management; Data Envelopment Analysis (DEA); Alignment	Performance Measurement and Management; Performance Prediction; Alignment Prediction
Framework and Tools	CNPMS framework – Questionnaire method – Euclidian distance method – Polar Graphic	CNPMS framework - Performance Value Estimator (PVE) – Fit Degree Classification Tool
Achievements	Fit Degree; Benchmarking classification;	Predictive KAIs – Compliance Degree; Fit Degree
Findings	The alignment degree obtained by a subjective approach; The alignment degree obtained by a descriptive approach; Performance benchmarking.	The alignment degree obtained by a predictive approach; Alignment prediction.

Consequently, each application considered a distinct approach for each type of collaborative network and it was experimented by utilizing different methods and tools. The methodology used in the second case was adapted using the concepts found along in this research. Therefore, the results obtained made it possible to observe the evolution from a subjective-descriptive approach to an objective-predictive approach.

Remembering these approaches, they are: measuring considering motivational factors, measuring the alignment considering a benchmarking analysis and measuring the alignment considering predictive performance indicators.

6.3 Main Contributions and Achievements

After applying concepts, methods and tools in the two application cases presented in Chapter 5, many contributions and achievements were found which validated the original purpose of this thesis, as well as others that emerged during the research. The two main strands of the results of this thesis were the approaches and the tools for measuring alignment.

One of the main theoretical contributions of this thesis was the application of scientific research methods that allowed developing an inductive-deductive approach of the problem situations that motivated this research. This includes the development and explanation of the survey questions. In addition, several methodologies for dealing with planning and development of approaches, methods and tools for measuring performance and alignment were provided both from the literature review as the initiative of the author and his research group. For example, the Soft System Methodology (SSM) was used in order to support the steps necessary to apply this conceptual framework for developing a performance management system (PMMS).

Furthermore, the two application cases were applied for different business environments and CN typologies. In case Pet Shop Retailers were applied two approaches for measuring alignment, subjective and descriptive, which address both the aspects of the decision-makers perceptions by using alignment motivational factors as those performance indicators using a benchmarking tool to assess the performance of the CN participants. Consequently, collaboration networks of small companies can use such approaches and tools in a simple manner in order to assess the degree of alignment at different CN life-cycle moments. An integrated DEA method for the evaluation of the more effective participants of the CN using data extracted from a set of common performance measures was used. Thus, all decision-making units (CN participants) can be compared to each other using benchmarks to determine whether the best partners are meeting the standards of excellence.

Furthermore, in case G3 Supply Chain was used the predictive alignment measurement approach which breaks the necessity of feedback period before to act in solving problems of inter-organizational processes that generally motivate the lack of alignment between pre-defined performance targets and performance outcomes. Thus, it was used a predictive approach for evaluation of the most effective CN participants by using reliable past and present data and for predicting the inter-organizational alignment. Defining the predictive KAIs the future alignment of the CN can be predicted then motivating decision-makers to plan and implement solutions that might be effective on monitoring performance as well as determining new targets in partner selection process.

Complementing this, two original topics are presented: the PVE tool that uses Neural Networks and Kalman Filter to improve its estimates results and the Alignment Prediction concept leveraged by the new paradigm of performance prediction for detecting future performance data of each participant. By using the degree of compliance of the performance outcomes with performance targets, makes it possible to achieve accurate values for the degree of alignment by using fuzzy logic tools to classify CN participants originated from both historical data and factors that affect the processes.

6.4 Future Research Work

This research presents the emerging paradigm of alignment prediction in order to replace traditional approaches of collecting past performance data to set goals and then monitor performance. This innovative approach is supported by tools that consider performance estimation supported by a data fusion approach, both for the characterization of complex system alignment and to support decision-making towards improvement actions.

Thus, as future research work, it is relevant to develop methods and algorithms based on linear programming capable of assessing and evaluating the overall degree of alignment in supply chain application cases. Therefore, the CN managers could be helped by a tool capable of ranking companies according to their estimated efficiency. For that, the strategy of the network should be taken into account in order to support partner selection, always envisioning future alignment.

Indeed, this ongoing research intends to develop and explore a series of innovative and intuitive applications to be integrated with the toolkits here presented. The approaches explored in this document are currently being applied in industrial scenarios in order to improve it and also to identify different real-life business situations worthy of support tools. Thus, many practical applications can be executed for different typologies of CNs regarding distinct topologies and cooperation-collaboration characteristics. Moreover, many mathematical tools can be proposed and tested for supporting distinct approaches.

For the two application cases presented, it is possible to propose some improvements (Table 68) in the approaches used in order to gain the attention of all researchers interested in exploring the methods and tools applied in this research.

Table 68. Further work proposals

Approaches	Further works
Subjective approach	Using different motivation factors for the different decision-making moments
Benchmarking approach (DEA)	Can be applied in partner selection activity
Alignment prediction approach (PVE-Fuzzy expert system)	Can be applied in different CN typologies and uses more than 2 variables (KAIs)
Benchmarking prediction approach (DEA with PVE-Fuzzy expert system)	Can be applied in process improvement actions

In addition to the applications suggested, several others can be developed using the approaches proposed in this thesis. In fact, the aim is not only to determine the best approach for each type of network, but also to help the decision-makers use the most appropriate systematic method to assess network performance and act on continuous improvement of alignment.

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Appendix A

Artificial Neural Network

The Artificial Neural Network (ANN) basically imitates how the human nervous system processes information to take action. In the human brain, neurons communicate using short duration electrical signals. Neurons send and receive a huge amount of information between them. The neurons are interconnected by branching fibers called axons. The voltage pulse travels along these paths carrying information, so that a threshold value of signal is exceeded. Here, the term "network" refers to the system of artificial neurons that range from a single node to a large number of nodes that are connected to each other.

The ANN basically imitates how the human nervous system processes information to take action. In the human brain, neurons communicate using short duration electrical signals. Neurons send and receive a huge amount of information between them. The neurons are interconnected by branching fibers called axons. The voltage pulse travels along these paths carrying information, so that a threshold value of signal is exceeded. Here, the term "network" refers to the system of artificial neurons that range from a single node to a large number of nodes that are connected to each other:

- Continuous adaptation to different conditions
- Response to new situations
- Modeling of more common and complex systems with non-linear behavior
- Fitting the tolerance to structural and parametric changes
- Rejects input noise
- Provide a faster processing capacity

Furthermore, the ANN is important in a wide range of applications. The tool's characteristics include: a continuous learning capability, which enables it to continuously adapt to different conditions, respond to new situations and more common and complex modeling systems with non-linear behavior; fit tolerance to structural and parametric changes; reject input noise and finally, offer a faster processing capacity. However, one of the major applications of the NN is forecasting. In fact, there are a series of characteristics which make the neural networks an attractive and valuable tool for forecasting tasks (Farahat, 2005).

According to Minin (2006), the Artificial Neural Network

> *"it is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process."*

In the human brain, neuronal activity is based on communication between neurons. This communication is possible due to a series of fine structures called "dendrites" (Figure 64). Electrical impulses are emitted by each neuron via the axons, which are very fine linkages that are divided into thousands of branches with nerve endings (synapses). These nerve endings convert the axon's activities to electrical effects that inhibit or excite the activity of the axon. Learning occurs when these activities are processed in order to influence other neurons (Minin, 2006).

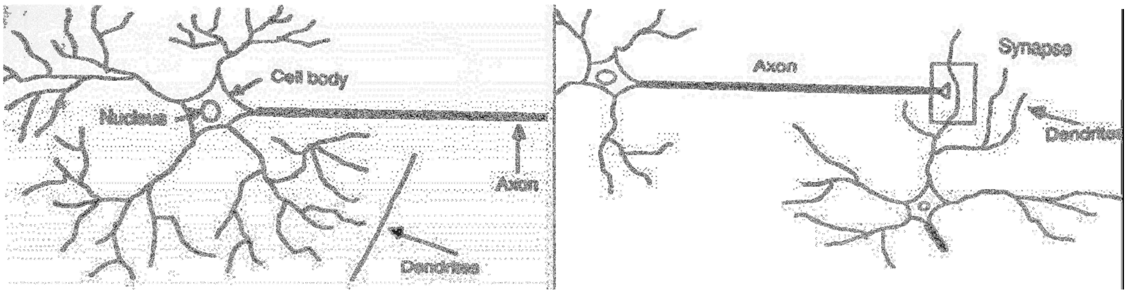

Figure 64. The components of a neuron and the synapse phenomenon (Minin, 2006)

In reference to the synapse phenomenon, Jain, Mao and Mohiuddin (1996), state that

> *"The synapse's effectiveness can be adjusted by the signals passing through it so that the synapses can learn from the activities in which they participate. This dependence on history acts as a memory, which is possibly responsible for human memory."*

The neuron's firing mechanism that initiates the learning process is most commonly the McCulloch and Pitts (MCP) neuron model. The system inputs are weighed and their weight has an effect on the decision-making process. These weighed inputs are added together and if their sum exceeds a preset threshold, the neuron fires; if not it will not fire. Each input is multiplied and added to the other weighed inputs before they are sent to the node activation. Following this, the activation is compared with a threshold. If the activation exceeds the threshold, the unit produces a high-value output. If not, the output is zero. In summary, the output value of each neuron Y_i depends on the potential of the neuron, the threshold (or bias) and the activation function σ (Almeida, 2010).

Figure 65 shows an example of the behavior of neurons/nodes (Gurney, 1997).

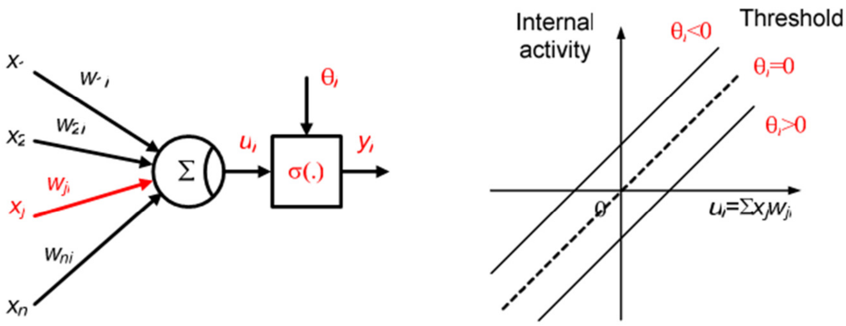

Figure 65. Basic diagram of an artificial neuron and internal neuron activity

Basic diagram of an artificial neuron and internal neuron activity, where:

Xj is the input stimuli (0 or 1) and represents the state of neuron j;

Wji is the synaptic weight between neuron j and i;

Θ is a bias value (or threshold);

Y_i is the neuron i output;

σ is the activation function.

The ANN is a nonlinear tool used to support system modeling because it has data-driven self-adaptive capabilities that allow for the use of any continuous function with the desired accuracy. It can also use non-complex use examples from the past to emulate the system's behavior without prior knowledge of the relationship between input and output variables. Thus, as it considers the factors that can be anticipated and envisaged, this modeling approach makes it easier to predict future performance.

Indeed, the ANN can be applied to a wide range of subjects since it presents a series of characteristics that support the comprehension of complex systems, such as: a continuous learning capability, which enables the continuous adaptation to different conditions, the ability to respond to new situations, the ability to model complex systems with non-linear behavior; it fits tolerance to structural and parametric changes, rejecting input noise and finally, it offers a faster processing capacity.

According to Farahat (2005), the ANN architectures that are most commonly used and offer the best results in terms of demand forecasting, performance, cost, risk and other factors in manufacturing are: back-propagation (BP) and radial basis function networks (RBFN). In the forecasting domain, the RBFN is considered more accurate and less time consuming. As the input variables go directly to the hidden layer without weights, the RBFN models are simpler when compared to the BP architecture. In fact, the main problems of the back propagation architecture are the slow convergence, the difficulties of generalization and the arbitrary nature in network design. In fact, the RBFN has overcome these limitations and can provide better results.

In order to adjust the system more accurately and increase its emulation capability and reliability, neurons are linked together in the form of a network. This network may range from a single node to a large collection of nodes, in which each one is connected to every other node in the net. In the image below a circle represents each node and the weights are implicit in all connections (Figure 66). The nodes are distributed in a layered structure where signals flow from an input to an output, passing through a series of hidden layers.

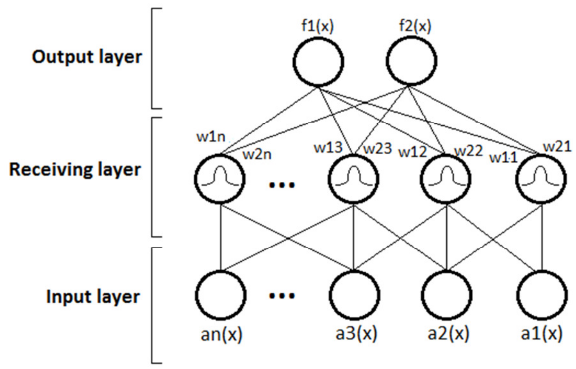

Figure 66. Simple example of neural network (RBFN)

Although the RBFN can be used to forecast performance the development of a neural network predictor is not simple and obvious. It is very important to consider the structure and number of layers, the number of nodes in each layer and the number of arcs that connect with the nodes. Furthermore, other aspects should be studied and selected, such as the activation functions of hidden and output layers, the training algorithm, standardization methods, training and test sets and performance measures.

As outlined by Camarinha-Matos and Afsarmanesh (2008), it is possible to use two modes of operation for the neuron's approach: the learning mode and the using mode. The learning mode is characterized by training to trigger (or not), by finding the right synaptic weights to guarantee that the output matches the desired output, according to particular input patterns. In the using mode, when an input pattern is detected, an output is generated according to the set of weights the network learned in the previous phase.

These features will be explored in the following topics on task prediction due to the speed of processing and the ease of transformations. In fact, a NN makes it possible to carry out arbitrary non-linear mappings and these features will be explored in the following sections of this document. Furthermore, this tool presents a continuous learning capability which allows it to respond to new situations (generalization). It tolerates parametric and/or structural changes, thus making this tool very robust (Almeida, 2010).

NN can be used successfully in conjunction with other applications to deal with several types of problems. With reliable historical data to train the network is possible to develop applications that can include information to classify VBE participants according to their availability and suitability for emerging collaboration opportunities, their historical data (data mining) on cases of past collaboration and the likelihood of success of potential consortiums (Camarinha-Matos and Afsarmanesh (2008).

Appendix B

Kalman Filter

Indeed, with the ANN modeling approach it is possible to emulate and anticipate the expected performance of a complex system. Nevertheless, it is necessary to be cautious with the use of a NN since there are a lot of causes and factors that can affect the performance of a NN tool. In relation to estimation and including the use of computer applications, the generation of noise in measurement creates unknown states where the representation of estimates usually have noise derived from measurements. In many complex systems control is not able to measure every variable. Consequently, the Kalman Filter can infer the missing information using indirect (and noisy) measurements and also predicts the likely future course of dynamic systems that people are not likely to control (Almeida, 2010).

This mathematical tool was developed by Rudolf Emil Kalman (Kalman, 1960) for optimizing the estimation of state models and has importance in modern control and system theories because it significantly improves applications in the field of control engineering and management areas.

Indeed, the Kalman Filter is a tool that was developed for use in the optimization of calculations of state estimation models. This filter is known to be effective in supporting the calculations of estimates for states in the past, present and future. Thus, this tool is normally applied to optimize the estimation of state models in order to estimate the momentaneous states of linear dynamic systems perturbed by white noise. In fact, it was a great discovery in the statistical estimation theory because it made it possible to achieve results that without it would have been very difficult to achieve, especially when automation, robotics subjects, economics, manufacturing management and stock market forecasting, are addressed.

According to Welch and Bishop (2006), the Kalman filter is

> *"a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean of the squared error. The filter is very powerful in several aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modeled system is unknown."*

Basically, the Kalman filter is designed to assist estimate the "state" snapshot of a linear dynamic system perturbed by white noise if you look at this tool at a higher level of mathematical abstraction (Bolland and Connor, 1997), where we can define measures linearly related with the state that are corrupted by white noise.

Thus, using the approach of Welch and Bishop (2006), the following equation is used to estimate the state $x \in \Re^n$ of a discrete-time controlled process that is governed by the linear stochastic difference equation, where x is the parameter that is being measured:

$$x_k = Ax_{k-1} + Bu_{k-1} + w_{k-1} \qquad (1)$$

The estimate is related to the predictors through the observation equation, or measurement:

$$y_k = Hx_k + v_k \qquad (2)$$

The variable w_k represents the process noise and the variable v_k represents the measurement noise. In addition, they are assumed to be independent (of each other), white, and with normal probability distributions.

The matrix A, in the difference equation (5), relates the state at previous time steps with the state at a current time step, in the absence of a driving function or process noise. However, in this approach it is considered that the time is constant. This means that this situation does not change at every time step. In addition, matrix B represents the optional control input for the state x. Furthermore, matrix H in the measurement equation (6) relates the state to the measurement y_k. As in the previous equation, time is considered constant, which means that this situation does not change with each time step or measurement. Nevertheless, in practice it is considered that for the process noise covariance $\boldsymbol{Q}$ and measurement noise covariance $\boldsymbol{R}$ matrices the same consideration is applied.

According to Libonati, Trigo and DaCamara (2007), the advantages of using the Kalman filter when compared to other statistical techniques include that fact that it recursively updates the regression coefficients. For instance, it makes it possible to adapt to changes in the model of numerical weather predictions and also to different weather situations which may vary significantly throughout the year. And yet, when compared with other techniques, the Kalman filter does not require a large data set.

The Kalman algorithm can be used in practical applications in military or aeronautical programs to support navigational and guidance systems, radar tracking algorithms for anti-ballistic missile applications, sonar ranging and satellite orbit determination, seismic data processing, nuclear power-plant instrumentation, Global Positioning System (GPS) and many other applications (Almeida, 2010).

The Kalman filter is also used to predict the price of commodities, market values of shares, meteorology states and other situations which are highly influenced by stochastic factors in dynamic systems and for difficult situations. To control a dynamic system, it is crucial to observe and follow what the system is doing. However, it is not always possible or desirable to measure all of the variables that it is necessary to control. Therefore, in order to overcome this problem, from indirect measurements the Kalman filter may act as a means of predicting the missing information (Linsker, 2008; Bolland and Connor, 1997).

In Almeida's (2010) survey on Kalman filter characteristics, he indicates that the Kalman Filter makes it possible to model the estimation problem by distinguishing between what can be observed in the system (or process), that is the phenomenon, and the result of what is really happening, the nounema, and specifically the state of knowledge of the nounema that can be deducted from the phenomenon, firstly characterizing the real-life situation and then proposing metrics for evaluating the states studied that relate to the phenomenon. Furthermore, this tool can be suitable for digital computers as it allows for the possibility of developing algorithms because it uses a finite representation of the estimation problem, by a finite number of variables (Almeida, 2010).

Therefore, the Kalman filter was used in order to eliminate the possibility of non-controllable errors (where possible) that can originate from the modeling system or from the leading and lagging factors measured. However, only sometimes it is possible to accurately extract the mathematical model that describes the system's dynamics then it is essential to express gaps in the knowledge more precisely and use them to estimate the state of the dynamics. Due to the fact that this filter is capable of supporting estimations for past, present and future states, even when the system modeling accuracy is unknown, this tool is normally applied to optimize the estimation of state models. Consequently, by incorporating these two significant approaches, both Neural Networks and the Kalman filter, it was possible to develop a tool that was able to predict the evolution of the behavior of complex systems, minimizing the different errors and noise that can disturb the normal assessment of the performance of the system.

Extended Kalman Filter

The Kalman filter, basically, addresses the general problem of trying to estimate the state of a discrete time controlled process that is governed by a linear stochastic difference equation. However, when a process is estimated to be non-linear, a mathematical filter must be used to linearize the current mean and covariance (Welch and Bishop, 2001). This is not useful when analyzing complex non-linear systems that are not Gaussian. According to Almeida (2010) "*this filter, gives an approximation of the optimal estimate, and so the system's non-linearities turn into a linearized version around the last state estimate. For this approximation to be credible, it is necessary for this linearization to be an efficient approximation in the entire uncertainty domain associated with the state estimate*". In addition, according to Welch and Bishop (2006), the Extended Kalman Filter (EKF) it is an ad hoc state estimator that uses the linearization to approximate the optimality of Bayes' rule. However, the EKF may diverge if the consecutive linearizations are not sufficiently efficient within the associated uncertain domain.

Appendix C

CNPMS Manager

With regard to using information systems to support interaction between organizations and for data collection for further analysis, the main objective should be to obtain reliable values for the degree of alignment. Thus, the operations necessary for computing data compiled from certain sources (e.g., CN participants) require a software application that can run between all CN participants in a clear and objective way.

The tremendous growth in Information and Communication Technologies (ICT) in recent years has made it possible to develop application software in an easier and faster way. However, its configuration must comply with the concepts and methods to create the architecture that follow the requirements of data management, interoperability, and also the web platform, if applicable.

Especially for small and medium enterprises in CNs, it is not crucial to use grid services in software applications since these companies may apply a specific module for performance management using web service solutions. According to Khan (2008), cf. Foster (2002), "a Grid is a system that: coordinates resources that are not subject to centralized control ... using standard, open, general-purpose protocols and interfaces ... to deliver nontrivial qualities of service."

According to Benharref *et al.* (2011), "A Web service is any application that exposes its functionalities through an interface description and makes it publicly available for use by other programs. Web services can be accessed using different protocols, different component models, and running on different operating systems."

According to Chapell (2009), "A Web service contract is essentially a collection of metadata that describes various aspects of an underlying software program, including:

- the purpose and function of its operations
- the messages that need to be exchanged in order to engage the operations
- data models used to define the structure of the messages (and associated validation rules used to ensure the integrity of data passed to and from the messages)
- a set of conditions under which the operations are provided
- information about how and where the service can be accessed"

Therefore, for supporting this research it is appropriate to design a software application, called CNPMS Manager, which is a web-based software. It can provide the necessary interactivity to manage the performance data and also deliver the performance and alignment results to the CNs participants. The service model adopted in this case is classified as a task service which is based on the nature of the logic it encapsulates, the reuse potential of this logic, and how the service may relate to domains within its enterprise (Chapell, 2009).

Indeed, in this work a similar path is used to that adopted by Seifert (2009) to design the web service application architecture, but in this case a different circumstance occurs. The CNPMS Manager is a software application designed to help the users perform singular or multiple related specific tasks to provide information on performance in a CN. Basically, this consists of requesting data from the participant organizations in order to compile these data for a performance dashboard. Thus, the CN has the performance data in a repository (database) of performance that can be used for the analysis of past and present and also to supply data for the PVE tool to analyze the future of the overall performance of the CN.

Although this solution is restricted to only the functional aspects of performance management, this aims to be opened to other partners (e.g., clients, third parties) and does not require a considerable amount of computer and network resources to be deployed and used, contrary to the limitations cited by Benharref *et al.* (2009).

This application is advantageous to communicate the values of KPIs or KAIs to the network participants. Each participant enters the data on their performance, as well as a broker (or manager) that can also enter data related to the inter-organizational processes, and then these results can be assessed in several ways, including: analysis and interpretation of the data available, application of the PVE tool for the prediction of KPIs or KAIs and determining the Degree Fit.

The CNPMS Manager is a Web service based on a service-oriented architecture (Figure 66), which contains:

- A Windows platform for the server operating system
- A SOAP Webserver 1.2 for the data-base server
- Delphi 7 for server technology for the session-tracking
- OpenSSL to fulfill the safety requirements by using encryption technologies
- IDE is the Eclipse development platform
- Access by IP, unique for all participants

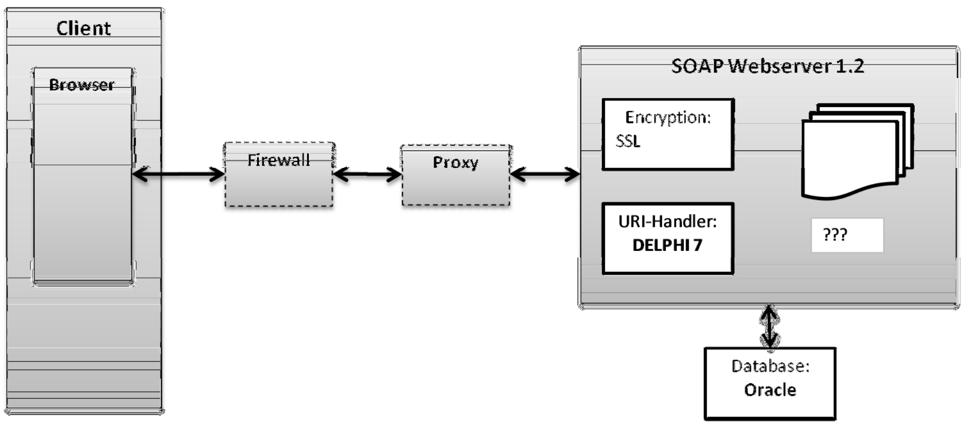

Figure 67. CNPMS Manager architecture (adapted from Seifert [2009])

This application software consists of at least the following stages: functional requirements, systems engineering requirements, configuration, implementation and validation tests. The CNPMS Manager consists of the following core functions:

- Software administration
- Enrollment process for participants and KPIs

- Data collection
- Software management (data and information delivery; results evaluation)

User administration - Each participant organization must determine which of their employees has the login and password to access the CNPMS Manager. Therefore, this web application must support multiuser access and then authorization procedures have to be completed.

Enrollment process for participants and KPIs – The participants are registered with the associate information and the KPIs are also registered with code/name, dimension unit, utilization profile and category of measures.

KPI data collection – The KPI values are collected by users and managers to enter these data. The information requirements are: the KPI, KPI category, dimension unit, the value and the collection period.

Report and performance analysis – After entering the data it is possible to request a report with the performance measured values, but only after all of the data have been entered. The performance analysis process can then be performed.

The main relevant tasks in this software application are defining the authorization procedures (username/password), entering the participant information, entering the categories for the KPIs, entering the dimension unit, entering the KPI values and requesting the report.

The menu for running the CNPMS Manager contains the following table: participant register and authorization access, participant register, KPI register and report requesting. Having turned on the software application, then a Login screen appears to certify the user in order to run the software application (Figure 68).

Firstly, the participant organization must be chosen and confirmed. The ID must then be certified and the particular password is typed in. The Login button is then selected.

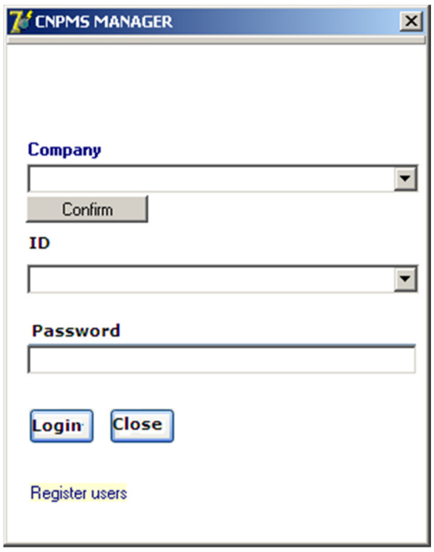

Figure 68. CNPMS Manager - Login screen

The menu screen opens in order for the user to work on the desired task.

In summary, the data input steps are the following:

- Choose the company name and enter password > Enter
- Choose a category (a) KPI, > Enter
- Enter the values for KPIs in the table (a) > Enter
- Choose a category (b) KPI,> Enter
- Enter the values for KPIs in the table (b) > Enter
- Observe the two tables, > Validate OR > Modify
- Close

In sequence, the participant information is recorded in the "participant's form" (Figure 69) as depicted below. The respective participant user can only enter the KPI values of its own organization. However, the web service manager can access the entire system.

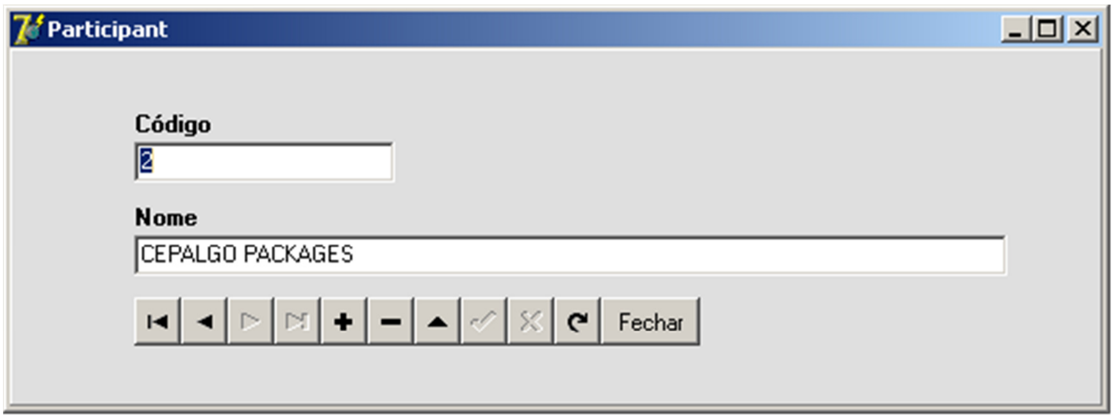

Figure 69. CNPMS Manager - Table of participants

After the participants have logged on, then the KPIs are recorded one by one in the "KPIs form".

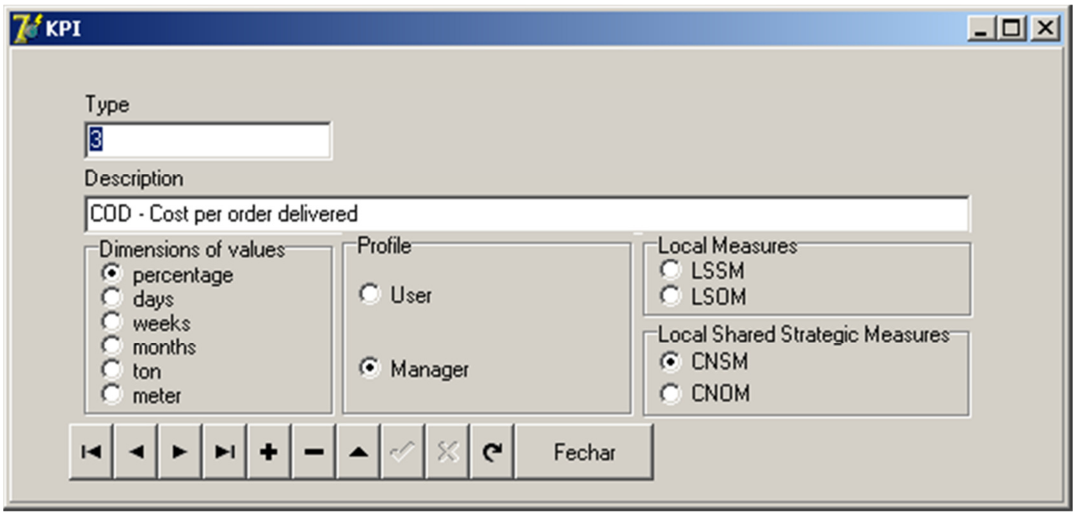

Figure 70. CNPMS Manager - Table for KPIs

Once the KPIs have been recorded in the database on this software application, these KPIs can be entered either by the CN manager as by the users defined by the participants. The CN manager enters the data regarding the collaborative measures and the participant's user enters the data regarding the local measures of each participant in the CN (Figure 71).

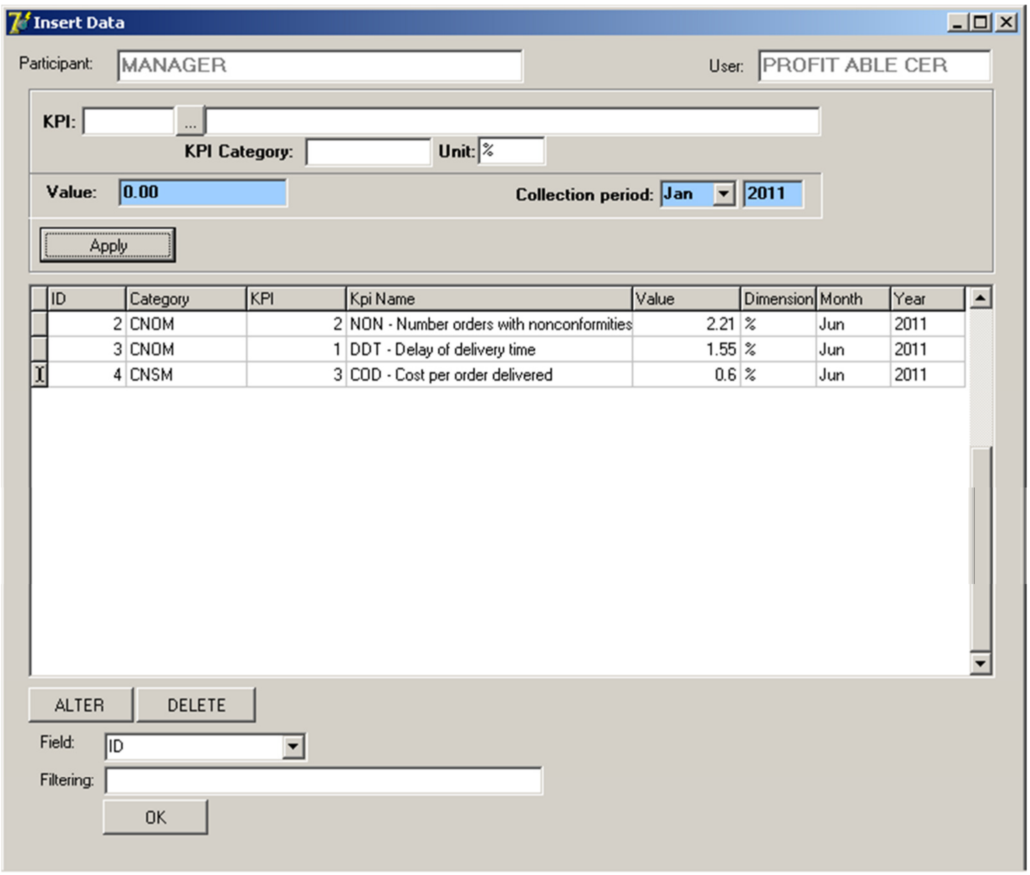

Figure 71. CNPMS Manager - Insert data form

Once the KPI has been chosen then the name, the category and the dimension unit are all shown. Thus, the value is inserted as well as the collection period and the year and then the "APPLY" button is pressed in order to insert the value for the KPI in the database. This is completed for all the KPIs of a certain category and they appear on the screen. If necessary, after entering the data they can be changed or even deleted.

In this table it is also possible to search the KPIs, to change or delete them. If this is necessary, then there is a filter to help search for the KPI in question.

Finally, it is possible to request a report of results for a certain period. Furthermore, to visualize the report and print it, the steps are the following:

- Choose the company name and enter password > Enter
- Access the “Report” in the menu bar
- Request the pdf report, > Enter
- Request the report printing, > Enter
- Close

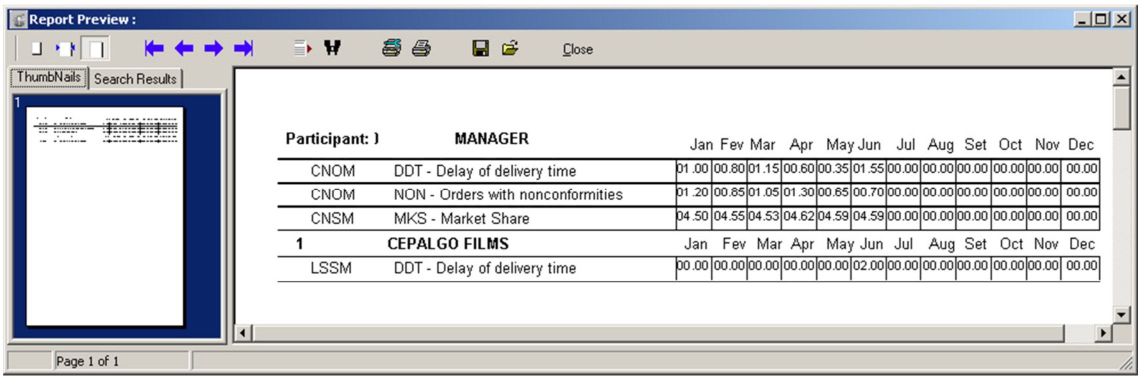

Figure 72. KPI's results report

Using this web service solution to integrate the CN participants seems to be a useful approach that can be applied in collaborative networks that consist of small and medium-sized organizations. However, this solution is just to exchange data in order to replace the recorded performance values in a database, or performance repository that allows the decision-makers to analyze and identify gaps occurring in each partner's processes as well as in the inter-operational processes of the CN.

In fact, another solution can be developed to publicize this performance information on the CN participants and respective stakeholders. A Web Dashboard released on the Internet can be appropriate for anyone that is able to access corporate data in the form of graphics, reports and blogs.

In summary, this software application aims to link the CN participants in order to collect performance data on each one to supply the CNPMS Manager with these data.

In addition, user "managers" and "participants" have different responsibilities in providing data. The user "manager" conducts the following tasks:

- managing the CNPMS Manager
- validating the network participants
- providing login and password details for the user “participants”
- cataloging the categories of KPIs (e.g., collaborative measures and participant measures)
- collecting data of the collaborative measures and introducing them in CNPMS Manager

The user “participant” conducts the following tasks:

- managing the performance measurement system of its own organization
- collecting data of individual measures and introducing them in CNPMS Manager

Thus, the performance data are compiled in the database of this application and stored, not only for your viewing and analysis, but also for use in other applications such as the PVE tool and the alignment classification tool, the Fit Degree.

Finally, this tool can be very useful for reporting the CN performance results and it also serves as a data repository that can be used for predictions.

Appendix D

Fuzzy Logic

Indeed, one of the main advantages of applying the concept of alignment prediction is its ability to analyze the future alignment of a CN. Consequently, Fuzzy logic can be relevant in the development of a toolkit including the PVE tool, making it possible to analyze the performance of each potential partner during the partner selection process, and evaluate the overall network performance during the running time.

Fuzzy Logic was introduced in 1960, by Lotfi Zadeh, in order to respond to problems with non-probabilistic uncertainties (Driankov, Hellendorn and Reinfrank, 1993). From that moment, this technology has been widely applied to support decision-makers in the classification of problems, computer vision and many other subjects.

Fuzzy Logic is the opposite of certainty and precision. Indeed, this technology is normally used when there is not enough knowledge and certainty about the system that needs to be controlled. Moreover, this represents an interesting tool for modeling non-linear systems, which are the most common in the real world. With this non-linear system model, it is possible to achieve a higher definition, decrease the modulation error and control more complex systems. Therefore, it is possible to argue that everything that cannot be clearly defined is classified as fuzziness.

The Fuzzy system model is divided into four main stages (Figure 73): Fuzzification, rule based definition (Knowledge based definition), inference mechanism and defuzzification.

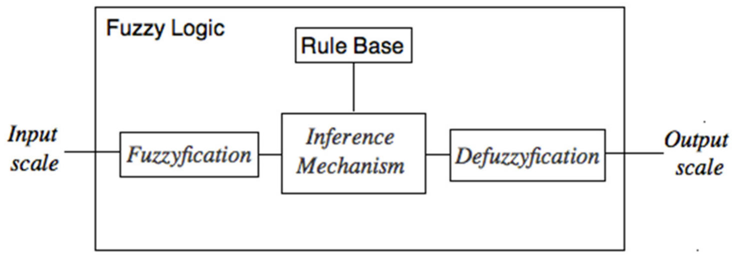

Figure 73. Fuzzy logic

Fuzzification - The first step in defining a fuzzy controller is specifying the system's fuzzy inputs and output. Each fuzzy variable is set up by states which are sets that have a membership function associated. In a simplified way, membership functions can be seen as a graphical representation of the magnitude of each input's participation (Figure 74).

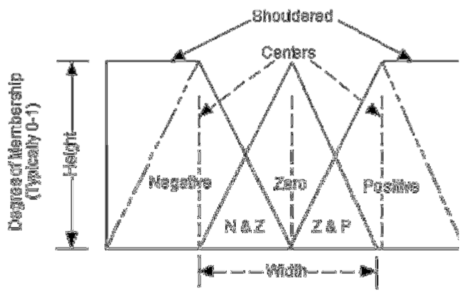

Figure 74. Membership functions

Rule Definition - This is the second stage that should be performed during the definition of the fuzzy system. Indeed, in order to develop a reliable fuzzy system, it is essential to have appropriate knowledge about the system that will be modulated. Thus, to setup the fuzzy logic control, a rule database made of "if X is A, and Y is B, then Z is C" rules is required. To gather and organize knowledge about the relationship between these inputs and corresponding output linguistic values, a rule matrix is normally used. Figure 54, shown previously, illustrated the requirements and specifications regarding the KPIs for the Collaborative Network in a clear and simple way.

Inference and Aggregation Mechanisms - When the rules that model the system that is being studied are defined, it is important to define the contribution of each rule for the fuzzy system. Indeed, to develop the current work, the Mamdani-type that rules the prototype was used, as depicted in Figure 75:

Rule 1: $If\ x\ is\ A1\ and/or\ y\ is\ B1\ then\ z\ is\ C1$

Rule 2: $If\ x\ is\ A2\ and/or\ y\ is\ B2\ then\ z\ is\ C2$

Rule 3: $If\ x\ is\ A3\ and/or\ y\ is\ B3\ then\ z\ is\ C3$

Antecedent Consequent

Figure 75. Rule matrix

In this method (Driankov, Hellendorn and Reinfrank, 1993), the contribution of each rule to a final solution is given by the following equation:

$$D_i(z) = \min(s_i(x_o), \mu_{c1}(z)) \quad (1)$$

where si(x0) shows the power of antecedent and μc1(z) the output degree of membership. In order to calculate the output fuzzy set, the aggregation of the contribution of the different rules was conducted using the maximum operator:

$$C_{aggregation}(z) = \max(D_1(z), D_2(z), \dots, D_n(z)) \quad (2)$$

Defuzzification - Finally, to obtain the fuzzy result, it was necessary to translate the variable fuzzy states into real and concrete values. To do this, the centre of gravity method, also known as centroid, was used (figure 76). This method consists of calculating the fuzzy set mass centre.

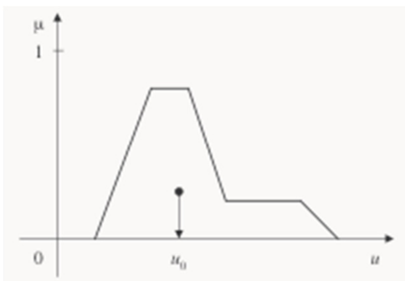

Figure 76. Defuzzyfication

Indeed, fuzzy logic consists of the introduction of degrees of inclusion/relevance of each element in a given set. This means allowing an element to belong to a particular set to a greater or lesser degree. This is also known as degrees of membership or degrees of truth (Camarinha-Matos and Afsarmanesh, 2008). Through the concept of membership function, we can numerically describe our understanding of a given attribute and iteratively tune it until reaching the desired accuracy (Oliveira Jr. and Aguiar, 1999). The degree of membership of an element in the universe of an argument in relation to the fuzzy set can take any value in the range (0,1). This can be seen as an extension of Boolean logic, in which the variables can acquire intermediate degrees of truth or falsity, represented by fractional values between 0 and 1.

According to Oliveira Jr. and Aguiar (1999), Fuzzy Logic can be described as "*a set of methods based on the concept of fuzzy set and fuzzy operations, which enables realistic and flexible modeling systems. The most notable aspect of this methodology is the ability to capture in a mathematical model, intuitive concepts such as degree of satisfaction, comfort, fitness, others*". It refers to the modeling of degrees of uncertainty existing in natural language and it is widely used to develop expert systems.

Thus, through Fuzzy sets it is possible to address many real-life scenarios. In most cases, the uncertainty is captured more adequately than with probabilities without requiring significant statistics and expert knowledge about the complex problems which can be translated in the most suitable way for the formulation of problems. However, Fuzzy sets do not replace probabilistic models when they are effective in certain situations, but it is possible to develop fuzzy-probabilistic methods for uncertainty.

A fuzzy sets survey, conducted by Tanscheit (2xxx), has a set A, that belongs to a universe X, the elements of this universe undoubtedly belong or do not belong to that set and can be expressed by the characteristic function $f_A(x)$:

$$f_{\mathrm{A}}(x) = \begin{cases} 1 \; se \; e \; somente \; se \; x \in A \\ 0 \; se \; e \; somente \; se \; x \notin A \end{cases} \quad (3)$$

Moreover, a fuzzy set A in a universe X is defined by a membership function $\mu a(x)$: $X \rightarrow [0,1]$, which is represented by a set of ordered pairs:

$$A = \{\mu_a(x)/x\} \;\; x \in X \quad (4)$$

where $\mu a(x)$ indicates how x is compatible with the set A. A given element can belong to more than one fuzzy set, with different degrees of relevance.

For instance, in a study of quality perception a compliance degree of performance targets can assume determined values as: good, medium and bad. Indeed, the decision-makers might choose something like "good, medium and bad", where good is a value that expresses reliability and bad is a value that expresses non-reliability. This represents the comparison of the performance values obtained with stipulated targets for performance values. When the operational performance is 40%, the quality level is considered "bad", when it is 50% it is considered "medium" and when it is 70% it is considered "good" (Figure 77). Consequently, it is possible to determine when a bad "state" becomes a medium "state" or when a medium "state" becomes a good "state". Therefore, the fuzzy sets can be named as a linguistic variable that assume values that can be described using fuzzy sets represented by membership functions (Tanscheit, 2007).

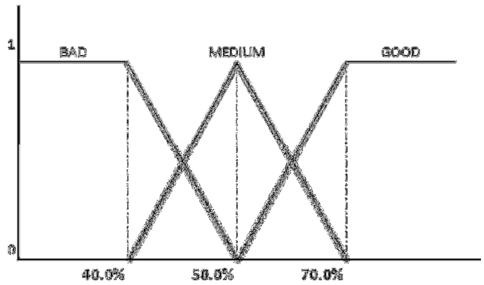

Figure 77. Membership function for the compliance degree of performance targets

Moreover, it is important to understand the expert's logic so that it can be transformed into a mathematical model where N is the variable name, T(N) is the set of names of linguistic values of N, X is the universe of discourse, G is the syntactic rule that generates N as a composition of term of T(N) and M is the semantic rule that links each value generated by a fuzzy set G in X. Having established this, the linguistic variable is characterized as follows:

- N: operational performance
- T(N): {bad, medium, good}
- X: 0-100%
- G: performance is not bad and not very good
- M: links the value generated in G to a fuzzy set and its membership function expresses its meaning

Translating this approach into an alignment measurement that congregate some predictive KPIs, transformed to KAIs, then it is possible to recommend the following characterization for measuring alignment in CNs:

- N: alignment degree
- T (N): {highest, high, medium, low, lowest}
- X: 0-100%
- G: alignment is not the highest and not the lowest
- M: links the value generated in G to a fuzzy set whose membership function expresses the alignment degree

Therefore, with this characterization it makes it possible to determine alignment values that translate the uncertainty of the intuitive concepts dealt with here.

Membership functions can be set from the expertise and the perspective of the user. However, standard of relevance functions are often used, such as triangular, trapezoidal and Gaussian (Figure 78).

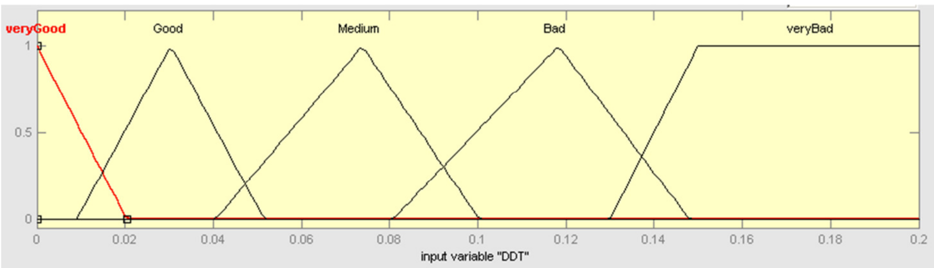

Figure 78. Alignment measurement fuzzy characterization (example)

According to Camarinha-Matos and Afsarmanesh (2008), there some examples of the potential applicability of fuzzy logic in CNs, including: "*supervision and assessment of performance in CNs, modeling and assessment of enterprise agility, negotiation and decision making in consortia formation, partners' selection, modeling agents' interactions, simulation for analysis of emergent behavior, implementation of auctions, negotiation in resource sharing / access, others*".

Appendix E

Deterministic-Stochastic System

When the type of factors is known, it is useful to represent this constraint with a mathematical tool called the Deterministic-Stochastic System:

$x(t+1) = Ax(t) + Bu(t) + q(t)$ (1)

$y(t) = Cx(t) + r(t)$ (2)

where:

A,B,C,D – the state modeling variables

r(t+1) – the system space-state in time period t+1

$x(t)$ – the current system space-state

$u(t)$ – the system input

$y(t)$ – the system output

$q(t)$ – the process noise introduced by the dynamics of the stochastic process

$r(t)$ – the noise from the time series observing and measuring processes.

As $q(t)$ and $r(t)$ are unknown signals which strongly affect the observer's performance, it is normal to perceive these disturbances as random factors that are modeled as ergodic stochastic processes. The following equations present the model of the deterministic and stochastic approaches, respectively:

$x_d(t+1) = Ax_d(t) + Bu(t)$ $x_s(t+1) = Ax_s(t) + q(t)$ (3)

$y_d(t) = Cx_d(t) + Du(t)$ $y_s(t) = Cx_s(t) + r(t)$ (4)

Assuming that $y_d(t)$ and $y_s(t)$ are used without errors, it is possible to estimate $x_d(t)$ and $x_s(t)$, respectively, with a stable observer:

$\hat{x}_s(t+1) = A\hat{x}_s(t) + K\left[y_s(t)\text{-}C\hat{x}_s(t)\right]$ (5)

$\hat{y}_s(t) = C\hat{x}_s(t)$ (6)