Collaborative Relationships in Supply Chain Management:

A Case of Project Management Social Network Analysis

Doctoral Thesis

To achieve the university degree of

Doktor der montanistischen Wissenschaften

Submitted by

CARLOS ANTONIO MEISEL DONOSO, MSc

to

Chair of Industrial Logistics

Montanuniversitaet Leoben

Leoben, May 2016

Affidavit

I declare in lieu of oath, that I wrote this thesis and performed the associated research myself, using only literature cited in this volume.

Date **Signature**

Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich diese Arbeit selbständig verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfsmittel bedient habe.

Datum **Unterschrift**

"Collaboration is a process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible"

Barbara Gray
Professor of Organisational Behaviour
Pennsylvania State University

Dedication

I dedicate this dissertation to my loving family, especially to my wife Adriana Portela. This work could not have been completed without their love.

Acknowledgements

First of all, I would like to express my deepest and sincerest gratitude to my advisor, Univ.-Prof. Dr. Helmut Zsifkovits for his constant support and his thoughtful suggestions, guidance and consistent encouragement throughout my study. I would also like to extend my sincere gratitude to my second advisor, Univ.-Prof. Dr. Nobert Seifter for his comments and suggestions.

Thanks and appreciations are extended to my brother Jose David Meisel who generously shared his time, insights and experiences regarding social network analysis.

I would like to thank Dr. Gilberto Hernández for his academic rigor and passion, and valuable advice on life.

I would also like to gratefully acknowledge the support and assistance of my colleagues at the Department of Industrial Logistics. Special thanks go to all my German friends for their friendship and support throughout this tough process.

Highest thanks to my family. Without them, none of this would have been possible. They loved and believed in me.

I am especially grateful to my wife Adriana Portela for giving me the opportunity to follow my dreams and the love to make them a reality.

Thank you all from the bottom of my heart!

Leoben, May 2016
Carlos Antonio Meisel Donoso

Abstract

The globalization of markets coupled with rapid and revolutionary advances in technology-based communication have been allowed many global organizations to work across corporate boundaries to undertake, manage, and succeed in their supply chain efforts. Under this new scenario the traditional project management has begun to change in favour of more collaborative project management, focused on tracking project work processes, with geographically dispersed project team members not belonging to the same organization, and efficient and effective sharing of information and knowledge among its project team members.

Many academics and practitioners have studied different aspects of this new collaborative project management scenario. However, it appears clear that empirical studies have not paid much attention to the contributory factors that enable collaborative relationships in the Supply Chain Distributed Project domain. The Collaboration Characterization Project Management model proposed in this study constitutes a practical tool that can be used to both characterize and understand collaborative relationships among Project Team Roles and to appraise the influence of the contributory factors into the shaping of the overall structure of the Collaboration Intensity Network.

To validate the postulates proposed in this contribution, three empirical case studies by means of a Social Network Analysis were conducted. Two approaches were used: first, visual and descriptive analyses were conducted to depict and describe the main properties and characteristics of the network formed by Project Team Roles in a Supply Chain Distributed Project, as well as to recognize subgroups of actors working together in those networks. Second, Exponential Random Graph Models were used both to test inferences from certain network sub-structures (endogenous factors) and to test positive influence of the contributory attributes (exogenous factors) on the Intensity of Collaboration dimension.

The visual and descriptive analysis results shows that Project Managers in the three networks analysed were the main source of relationships coming into and leading out of the node. Moreover, they were the most active, the closest to other actors, had the greatest authority, as well as being the most intermediate and nearest to all actors in the network. The Exponential Random Graph Models results provide a line of empirical evidence that indicate that the set of attributes proposed in this research (except Employee's Seniority) perform well in capturing the heterogeneity of the actor through the nodal attributes, as well as in capturing the local forces gave rise to the formation of edges in the Collaboration Intensity Network. Moreover, the modelling results indicate that actors matching on exogenous attributes, as well as actors forming partnerships on the basis of existing shared partners, can be associated with greater-than-chance probabilities to exhibit collaborative behaviours. It is worth noting that the results indicate that the longer the duration of the project, the higher the likelihood that complex collaborative behaviours will be exhibited in a network.

Table of Contents

1 Problem Statement and Objectives 1
1.1 Introduction 1
1.2 Research Question 2
1.3 Research Objectives 4
1.4 Organization of the Thesis 5
1.5 Contributions of the Research 6
1.5.1 Theoretical Contributions of the Research 6
1.5.2 Practical Contributions of the Research 8
2 Literature Review 9
2.1 Collaborative Business Relationship Concept 9
2.2 Collaborative Network Scenarios 14
2.3 SCM Knowledge 17
2.3.1 Defining SCM 17
2.3.2 Drivers of SC Change 23
2.4 Distributed Supply Chain Management Projects 28
2.4.1 Supply Chain Management Projects 28
2.4.2 SCM Project Knowledge Areas 30
2.4.3 SCM Project Drivers 36
2.4.4 Distributed Project Management (DPM) 38
2.5 Understanding the Collaborative Relationships in Organizations 41
2.5.1 Supply Chain Collaboration Efforts 42
2.5.2 Maturity Models 50
2.6 Social Network Analysis for Business Applications 59
3 Building the Collaboration Characterization Project Management Model (CCPM Model) 63
3.1 Contributory Factors to Enable Collaborative Relationships 63
3.1.1 Strategic Relationships 64
3.1.2 Tactical Relationships 65
3.1.3 Interpersonal Relationships 67
3.2 Dependent Variable 70
3.3 Collaboration Characterization Project Management (CCPM) Model 70
4 Empirical Research 72
4.1 Research Design 73
4.1.1 Data Collection 73
4.1.2 Measures 76
4.1.3 Analysis 80
4.2 Case Study A: Large-Scale Project 89
4.2.1 Data Collection 89
4.2.2 Descriptive and Visual Analysis 89
4.2.3 Stochastic Modelling 105
4.3 Case Study B – Standard Project 111
4.3.1 Data Collection 111
4.3.2 Descriptive and Visual Analysis 111
4.3.3 Stochastic Modelling 121
4.4 Case Study C – Small Project 125
4.4.1 Data Collection 125
4.4.2 Descriptive and Visual Analysis 125

4.4.3 Stochastic Modelling 135
5 Findings and Discussions 140
5.1 Partial Results of Case A 140
5.2 Partial Results of Case B 141
5.3 Partial Results of Case C 143
6 Conclusions and Evaluation of the Research 145
6.1 Consolidated Results 145
6.2 Shortcomings and Further Research 149
7 References 151
8 Appendix 166
8.1 Appendix 1: Project Categorization According to ABC Classification 166
8.1.1 Case Study B – Standard Project 166
8.1.2 Case Study C – Small Project 167
8.2 Appendix 2: Code in R 168

List of Figures

Figure 1: Research design ... 6
Figure 2: Motivation for collaboration in terms of hierarchy of needs ... 12
Figure 3: Examples of joint endeavour ... 13
Figure 4: Examples of Collaborative Networks ... 15
Figure 5: Evolution of supply chain management ... 19
Figure 6: Supply chain management framework: processes, network structure and key links 20
Figure 7: Generic structure of a supply chain network ... 20
Figure 8: Supply Chain management collaboration processes ... 21
Figure 9: Supply chain management fundamental components ... 22
Figure 10: Scope of supply chain management ... 22
Figure 11: Drivers of supply chain management change ... 24
Figure 12: The four driving forces of the globalization process ... 25
Figure 13: Supply chain flexibility dimensions ... 26
Figure 14: Stages in a project life cycle ... 28
Figure 15: Traditional supply chain structure ... 43
Figure 16: Supply chain structure under VMI ... 44
Figure 17: Supply chain structure under ECR ... 45
Figure 18: Supply chain structure under CR ... 46
Figure 19: CPFR Process steps – from VICS – CPFR Model ... 47
Figure 20: Supply chain structures under CPFR ... 48
Figure 21: CPFR model ... 49
Figure 22: Gaps in supply chain visibility ... 49
Figure 23: n-tier CPFR modelled on the network effect ... 50
Figure 24: The five maturity levels of the Capability Maturity Model ... 52
Figure 25: The Business Process Management Maturity Model ... 53
Figure 26: Project Management Process Maturity (PM)² Model ... 54
Figure 27: PM Solutions' Project Management Maturity Model ... 55
Figure 28: Organizational Project Management Maturity Model OPM3 ... 56
Figure 29: Organizational Project Management Maturity Model P3M3 ... 57
Figure 30: The Supply Chain Management Maturity Model ... 58
Figure 31: Structure of the CCPM model ... 71
Figure 32: Estimating and testing the goodness-of- fit of an ERG Model ... 83
Figure 33: Alternating k-triangle configuration ... 85
Figure 34: Alternating k-two paths configuration ... 85

Figure 35: Network of PTRs organized by degree centrality 90
Figure 36: Network of PTRs organized by in-degree centrality 91
Figure 37: Network of PTRs organized by out-degree centrality 92
Figure 38: Network of PTRs organized by closeness centrality 93
Figure 39: Network of PTRs organized by betweenness centrality 94
Figure 40: Network of PTRs organized by communities 95
Figure 41: Network of PTRs organized by communities 96
Figure 42: Network of PTRs organized by level of management 97
Figure 43: Network of PTRs organized by native language 99
Figure 44: Network of PTRs organized by frequent communication language 99
Figure 45: Network of PTRs classified by organization 100
Figure 46: Headquarters' sub-network of PTRs organized by divisions 102
Figure 47: Subsidiary's sub-network of PTRs organized by divisions 103
Figure 48: Sub-network of PTRs classified by organizations 104
Figure 49: Sub-network of PTRs organized by employee seniority 105
Figure 50: Simulation results for dyadic dependence ERGMs of table 25 109
Figure 51: Network of PTRs organized by degree measurements 112
Figure 52: Network of PTRs organized by closeness centrality 112
Figure 53: Network of PTRs organized by betweenness centrality 113
Figure 54: Network of PTRs organized by communities 114
Figure 55: Network of PTRs organized by communities 115
Figure 56: Network of PTRs organized by level of management 116
Figure 57: Network of PTRs organized by native language 117
Figure 58: Network of PTRs organized by Frequent Communication Language 118
Figure 59: Network of PTRs classified by organization 119
Figure 60: Sub-network of PTRs organized by employee seniority 120
Figure 61: Goodness-of-fit tests for models of table 28 124
Figure 62: Network of PTRs organized by degree measurements 126
Figure 63: Network of PTRs organized by closeness centrality 127
Figure 64: Network of PTRs organized by betweenness centrality 127
Figure 65: Network of PTRs organized by communities 128
Figure 66: Network of PTRs organized by communities (modularity) 129
Figure 67: Network of PTRs organized by level of management 130
Figure 68: Network of PTRs organized by native language 132
Figure 69: Network of PTRs organized by frequent communication language 132

Figure 70: Network of PTRs classified by organization 133
Figure 71: Sub-network of PTRs organized by employee seniority 134
Figure 72: Goodness-of-fit tests for model 4 of table 31 138

List of Tables

Table 1: Definitions of the concept of collaboration ... 9
Table 2: Requirements for collaboration ... 11
Table 3: Examples of Continuous Production-Driven CNOs ... 16
Table 4: Examples of Opportunity-based CNOs ... 17
Table 5: Definitions of the concept of project management ... 29
Table 6: Overview of project integration management processes ... 31
Table 7: Overview of project scope management processes ... 32
Table 8: Overview of project time management processes ... 32
Table 9: Overview of project cost management processes ... 33
Table 10: Overview of project quality management processes ... 34
Table 11: Overview of project human resource management processes ... 34
Table 12: Overview of project communication management processes ... 35
Table 13: Overview of project risk management processes ... 35
Table 14: Overview of project procurement management processes ... 36
Table 15: Supply chain management project drivers ... 37
Table 16: Supply chain management projects classified by result types ... 38
Table 17: Enabler for geographically distributed project ... 40
Table 18: Project categorization according to ABC classification ... 73
Table 19: Example of PTRs categorized by an organizational structure's attribute ... 78
Table 20: Structural parameters and nodal attributes used in the ERGM ... 86
Table 21: Structural parameters for the ERGM ... 88
Table 22: Nodal attributes for ERGMs ... 89
Table 23: Top ten ranked PTRs based on centrality measures ... 98
Table 24: Top ten ranked PTRs based on centrality measures ... 100
Table 25: Stochastic models predicting the Collaboration Intensity Network ... 106
Table 26: Top ten ranked PTRs based on centrality measures ... 116
Table 27: Top ten ranked PTRs based on centrality measures ... 118
Table 28: Stochastic models predicting the Collaboration Intensity Network ... 122
Table 29: Top ten ranked PTRs based on centrality measures. ... 131
Table 30: Top ten ranked PTRs based on centrality measures ... 133
Table 31: Stochastic models predicting the Collaboration Intensity Network ... 135
Table 32: Main characteristics of the Collaboration Intensity Networks in selected SCDPs 147
Table 33: Contributory factors enabling collaborative relationships in selected SCDPs ... 148

List of Abbreviations

BPM	Business Process Management
BPMMM	Business Process Management Maturity Model
BPMM	Business Process Maturity Model
BPO	Business Process Orientation
CMM	Capability Maturity Model
CCPM	Collaboration Characterization Project Management Model
CNOs	Collaborative Networked Organizations
CPFR	Collaborative Planning, Forecasting and Replenishment
CSC	Collaborative Supply Chain
DSS	Decision Support Systems
DPM	Distributed Project Management
ECR	Efficient Consumer Response
ERGMs	Exponential Random Graph Models
EE	Extended Enterprise
GWDegree	Geometrically Weighted Degree Statistic
GWDSP	Geometrically Weighted Dyad-wise Shared Partner Distribution
GWESP	Geometrically Weighted Edgewise Shared Partner
GWT	Geometrically Weighted Term
GCI	Global Commerce Initiative
ICTs	Information and Communication Technologies
MCMC	Markov Chain Monte Carlo
QMMG	Quality Management Maturity Model
SCDP	Supply Chain Distributed Project
SCM	Supply Chain Management
SCMP	Supply Chain Management Project

SCN	Supply Chain Network
SCOR Model	Supply Chain Operation Reference Model
SDP	Software Development Process
SEI	Software Engineering Institute
SNA	Social Network Analysis
OGC	Office of Government Commerce
OPM3	Organizational Project Management Maturity Model
POS Data	Point of Sale Data
PEMM	Process Enterprise Maturity Model
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PTRs	Project Team Roles
$(PM)^2$	Berkeley Project Management Maturity Model
P3M3	Portfolio, Program and Project Management Maturity Model
RAM	Responsibility Assignment Matrix
VMI	Vendor Managed Inventory
VE	Virtual Enterprise
VO	Virtual Organization
VT	Virtual Team
VICS	Voluntary Inter-Industry Commerce Standards

1 Problem Statement and Objectives

1.1 Introduction

In the past few years, many businesses have tried to address the increasing pressure of markets, customer requirements for more flexibility and quicker response, and decreasing economic growth, with cost-cutting programs and greater concentration on core competencies.[1] Nowadays, due to the globalization of markets, business is undergoing a transformation from the industrial to the information age, where revolutionary advances in information and communication technologies have led to a new and more competitive, unstable, and complex environment. In this new business environment, there is greater pressure than ever before to control and reduce costs, to increase flexibility, to deliver products with excellent quality on time, and to focus on core competencies while increasing customer satisfaction. Survival in this environment in which organizations must operate demands a new approach as a strategy to compete.

In this context, efficient and optimized business practices must be built on a foundation of standardized business processes that are themselves based in collaborative practices and efficient and standardized means of communicating business data.[2] It is worthwhile to highlight the role played by new Information and Communication Technologies (ICTs) in this new environment, as a communication and collaboration-supporting mechanism to bridge the spatial distance between trading partners.[3]

This environment has led to a change in the project management paradigm. Traditional project management–encompassing single projects at a single location and more concerned with a top-down management view, scheduling, and project input and outputs than with project process—has begun to change in favour of more collaborative project management. Under this new paradigm, project management is more focused on tracking project work processes and efficient and effective sharing of information and knowledge among project team members. Task interdependence and member distribution across time will make high levels of collaboration essential to project success.[4]

Supply chain efforts pushed by this new technological paradigm have given organizations the opportunity to bring together their distributed workforce and work together despite being physically separated. Indeed, an increasing number of supply chain efforts (in the form of projects, programs or portfolios) have allowed the formation of distributed project teams with skilled team members from different locations, organizations, and cultures.[5] The use of the new ICTs, as Bardhan *et al.*[6] suggest, can reduce the negative effects of physical team

[1] Prahalad and Hamel (1990)
[2] Seifert (2003)
[3] Amaral *et al.* (2011)
[4] Chen *et al.* (2003)
[5] Jonsson *et al.* (2001)
[6] Bardhan *et al.* (2012)

dispersion on project performance by enabling information exchange and close collaboration among project team members.

Taken together, globalization pressures coupled with rapid and revolutionary advances in technology-based communication are allowing many global organizations to work across corporate boundaries to undertake, manage, and succeed in their supply chain efforts. Supply Chain Distributed Projects (SCDPs[7]) with team members belonging to different organizations and located in more than one geographic location and time zone, contributing to different phases of a project, are a growing practice in many organizations and industrial sectors.[8]

The Collaboration Characterization Project Management (CCPM) model proposed in this study constitutes a practical tool that can be used to evaluate the positive correlation between contributory factors and the Intensity of Collaboration dimension. Put another way, this model should allow companies to assess both the ability of the Project Team Roles (PTRs) to work collaboratively and to appraise the impact of the contributory factors in shaping the Collaboration Intensity Network[9] formed by PTRs. To validate both the postulates and the model here proposed, some empirical case studies of SCDPs (in this case, warehouse implementation projects) were conducted. The relationship between PTRs and the characteristics of the associated ties between them were evaluated by means of a Social Network Analysis (SNA). In order to do that, two approaches were used: first, a visual and descriptive analysis, and second, a stochastic network method using Exponential Random Graph Models (ERGMs). Visual and descriptive analyses were conducted to depict and describe the main properties and characteristics of the network formed by PTRs in a SCDP, as well as to recognize subgroups of PTRs working together in this network. ERGMs were used both to test inferences from certain network sub-structures (endogenous factors) and to test positive influence of the contributory attributes (exogenous factors) on the Intensity of Collaboration dimension.

1.2 Research Question

In the past years many researchers have been interested in collaborative relationships between project teams in a company as well as across companies along the Supply Chain. Distributed projects are difficult to manage; therefore effective management of business processes is needed, as well as the tuning of ICTs in order to support the project management teams in the distribution and creation of shared information and understanding.[10]

The role of ICTs as essential mechanisms to enhance collaborative relationships among distributed project team members has received greater researcher interest in the last decade. For instance, Qureshi suggested a model of project management with special focus on ICTs as support for collaborative relationships. Thus, an organization in a distributed project can focus on those functions that it does best (*core functions*) and rely on the distributed partner to carry

[7] An organizational forms characterized by a temporary group of geographically dispersed individuals not belonging to the same organization that work together towards a common goal

[8] Bala *et al.* (2010)

[9] Collaboration Intensity Network is defined in this research as the degree or measure of closeness or strength of the Collaborative Relationship Ties (edges and non-edges) among partners in collaboration (PTRs belonging to a SCDP)

[10] Mohammad Jafari *et al.* (2010)

out the other functions. Moreover, for efficient and effective outputs, it requires cooperative attitudes; clear understanding of main objectives; communication and information exchange support by ICTs; adaptations; and flexible procedures, cultures and team members.[11] Effective communication was found to play an essential role in Distributed project team performance.[12] By the same token, Baker suggests that the inclusion of video to audio-based communication can result in a significant improvement in decision making.[13] As the business process are supposed to be performed by many companies distributed along the supply chain, the management of these process is becoming complex and makes it almost impossible for a single user to manage the process. Thus, supporting tools like a decision support system (DSS) for team members will be needed.[14]

In recent years, there has also been more research attention paid to the networking concept as applied to the business context. For instance, the results of the Two THINKcreative workshops held in Portugal and a panel held in association with the BASYS'02 conference in Mexico have contributed to the identification of potential modelling approaches for Collaborative Networked Organizations (CNOs), and have also identified a major challenge in how to model and understand social networks formed by virtual members. Some examples of research topics in this direction are: Graph Theory; Semiotics, Normative Models and Multi-agents; Network Analysis; Game Theory; Temporal and Modal Logic; Metaphors; Theories of Complexity; and Dynamic Ontologies.[15] Another important finding of these workshops was the clear necessity for future research in the area of CNOs. For instance it was concluded that CNOs can be discussed from many perspectives and that there is no single modelling approach that can efficiently support all perspectives. Thus, the main intended and required characteristics to be modelled must be clearly understood before an appropriate modelling approach can be chosen. Put differently, future research must be pursued directed toward adapting existing modelling tools as well as understanding their applicability for the domain of CNOs.

Many academics and practitioners have studied different aspects of distributed project teams. However, it appears clear that empirical studies, based on a social network viewpoint, have not paid much attention to the contributory factors that enable collaborative relationships in the SCDP domain. Modelling collaborative relationships through the use of SNA has the advantage of allowing the researchers to include emphasis on both technical issues and on social and organizational aspects of the interactions in the same analysis.

This study is particularly interested in modelling collaborative networks where interactions are strongly supported by information technology and systems. The domains of interest and of relevance to this research are SCDPs, collaborative relationships and SNA. This study focuses especially on how to characterize and understand collaborative relationships in SCDPs in which their team members are dispersed across multiple organizations, space and time, as well as overcoming the gaps found in the literature regarding the applicability of SNA modelling tools for CNOs, specifically in SCDPs.

[11] Qureshi (2006)
[12] Willcocks (2003)
[13] Baker (2002)
[14] Pereira *et al.* (2001)
[15] Camarinha-Matos and Afsarmanesh (2004)

The research question arises from challenges observed in the Supply Chain Management (SCM) domain, and specifically those influenced by globalization and rapid advances in ICTs. So, the research was carried out to answer the following two questions:

- How can collaborative relationships among Project Team Roles in Supply Chain Distributed Projects be characterized and understood?

- Which attributes enable Collaborative Relationship among Project Team Roles in Supply Chain Distributed Projects?

To answer these questions, the *Collaboration Characterization Project Management (CCPM)* model to assess collaborative relationships is proposed in this study. This model, together with the methodology applied, constitutes a practical tool that can be used to both characterize and understand collaborative relationships among PTRs in SCDPs and to evaluate the influence of the contributory factors into the shaping of the overall structure of the Collaboration Intensity Network.

As the main purpose of this study is to describe and understand the collaborative relationships among project team members in SCDPs and to find empirical evidence of the positive influence of the contributory factors identified in the literature review on the Intensity of Collaboration among dispersed project team members, a SNA modelling approach was selected. Social Network Relationships among project team members can be modelled as social networks in which the nodes of the network represent people and the links of the network represent the mode in which activities are coordinated, from single information sharing to real collaboration in which members in the relationship—formally and informally, through repeated sequences of interactions—jointly seek and implement solutions.

In summary, “this model, together with the methodology applied, constitutes a practical tool that can be used to assess both the ability of its PTRs to work collaboratively and to appraise the impact of contributory factors on the shaping of the Collaboration Intensity Network formed by the PTRs.

1.3 Research Objectives

The overall objective of this research is to:

- Develop and validate a theoretical framework that can be used to characterize and understand collaborative relationships among project team roles in Supply Chain Distributed Projects.

Specific objectives include:

- Identification of contributory factors (attributes) that, according to the existing literature, enable the development of collaborative relationships among supply chain trading partners.

- Building a theoretical framework to characterize and measure collaborative relationships among project team roles in Supply Chain Distributed Projects.
- Validation of the theoretical framework through the examination of some empirical case studies.

1.4 Organization of the Thesis

The outline of this thesis is organized in chapters 1-6 as follows: First, chapter 1 introduces the problem statement and objectives as well as the organization of the thesis and contributions of this research to theory and practice.

In chapter 2, a literature review is conducted to gain an understanding of the meaning of collaboration and the influence of collaborative relationships on supply chain performance. Then, a discussion about SCM as well as project management knowledge and practices is presented. With globalization pressures and the advances of ICTs, a new paradigm has emerged whereby companies are utilizing skilled team members dispersed around the world to manage global distributed projects in a collaborative manner. So, a discussion focused on how the supply chain should face this paradigm shift, encompassing distributed projects in which their team members are dispersed across multiple organizations and separated by distance and time zones is presented. Finally this section explores the evolution of a variety of collaborative planning initiatives such as supply chain collaboration efforts and maturity models. These have been proposed as an attempt to address to what extent organizations, as well as the supply chain as a whole, are managing their business processes supported by sustained collaboration practices.

Chapter 3 identifies key success factors, which according to the existing literature have influenced the development of sustained collaborative relationships along the supply chain. Based on those contributory factors identified in this section, a theoretical framework (the CCPM model) to characterize and measure collaborative relationships along SCDPs is proposed.

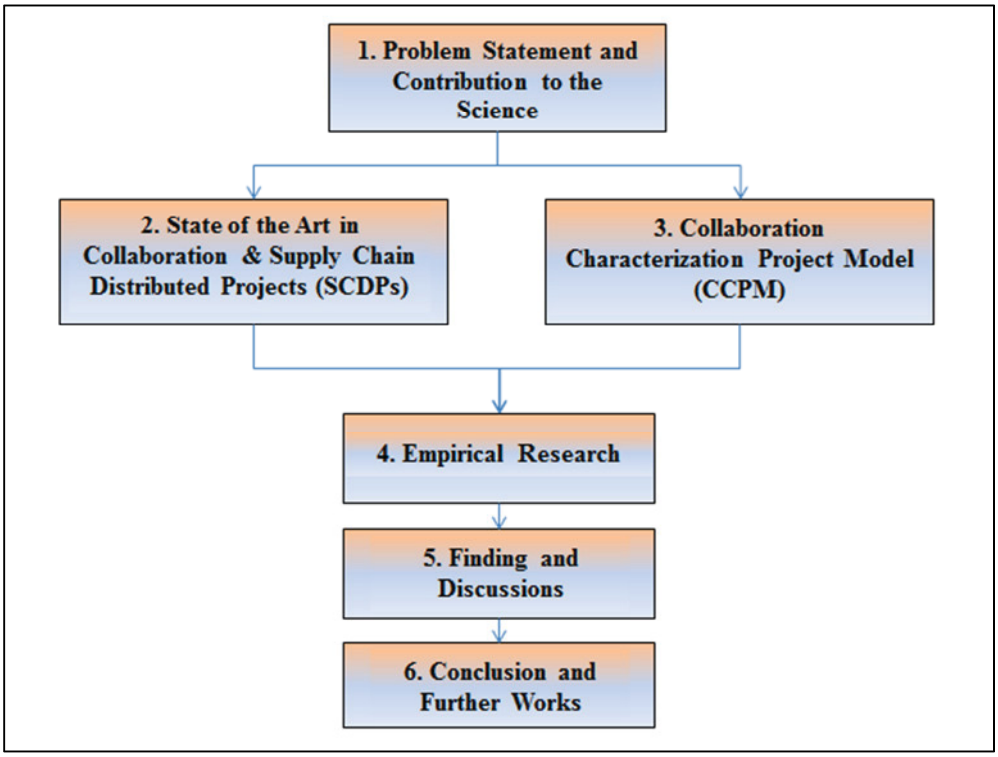
In chapter 4 a case study research is carried out as a mechanism to validate the theoretical model presented in chapter 3. The empirical research was carried out using a case study methodology. Three case studies were performed, the purpose of which is to: 1) describe the main characteristics of the observed project networks—i.e. which are the key actors in the networks, who is collaborating with whom—and give a line of graphical evidence on the effects of the identified attributes in the Collaboration Intensity Network formed by the PTRs; and to 2) assess the influence of the contributory factors in shaping the overall structure of the Collaboration Intensity Network formed by the PTRs, i.e. to find what explains collaboration among project team members.

The explorative empirical research analysis followed two approaches: First, some visual and descriptive analyses were conducted. The empirical data were collected from email relationships and from calendaring and scheduling information data stored in the database module of a Lotus Notes application. Then a pseudo-code programmed in Mathematica was used to depurate and build the collaborative network. Finally, the software Gephi was used to depict and describe the main properties and characteristics of the network formed by PTRs in a SCDP. Second, stochastic modelling using ERGMs was performed to evaluate the positive correlation between contributory factors and the Collaboration Intensity Network formed by the PTRs.

Chapter 5 summarizes the main results of the explorative empirical research. They offer a line of empirical evidence that both local structural dependencies (endogenous factors such as Joint Actions, Information Sharing Structure, and Mutuality) and nodal attributes (exogenous factors such as Organization, Level of Management, Trust and Cultural Diversity and Background) proposed in the theoretical model strengthen the probability that PTRs will succeed in establishing collaborative relationships.

Finally, Chapter 6 provides some discussion and principal findings of this research as well as highlighting fields for future research in supply chain collaborative domains. Figure 1 depicts the research design of this work.

Figure 1: Research design



Source: Original research

1.5 Contributions of the Research

1.5.1 Theoretical Contributions of the Research

The primary contribution of this research to the body of knowledge is centred on the development and validation of a conceptual framework: the *CCPM model*. Having examined each of the three cases, the results from the SNA have validated the CCPM model proposed in section 3.2. Thus, the proposed model can be used to understand collaborative relationships between PTRs and the characteristics of the associated Collaborative Relationship Ties between them in SCDPs. In addition, as the Hypothesis "*Higher levels in the attributes to enable collaborative relationships increase the Intensity of Collaboration among the PTRs in SCDPs"* was validated: It appears that the presence of the entire set of attributes in all the dimensions proposed[16] strengthens the probability that PTRs will succeed in establishing collaborative relationships. That means, those attributes on the three dimensions proposed (strategic, tactical and interpersonal) are associated with a higher probability of PTRs exhibiting collaborative behaviours and therefore need to be addressed to successfully manage collaborative relationships in SCDPs.

Traditional analytical modelling approaches have primarily focused on how to gain understanding of the technical aspects of a particular system, while the social aspects of the system have not been taken into account. These approaches, however, are not well suited to modelling the structural and behavioural intricacies of complex systems. This gap, according to Bellamy and Basole,[17] can be overcome through the use of network analysis approaches.

Following the gap found by Bellamy and Basole, another important contribution of this research is posited: the application of SNA as a methodological approach to understand how networking and collaborative relationships occur in the field of SCDPs. SNA is a widely-used tool in fields with complex relationships within entities, but it has not been applied to the field of SCDPs. A Google search of "SNA" (as of August 2015) results in about 1,240,000,000 hits, an impressively large number. But a quick perusal of those hits show comparatively little in the domain of either SCM or project management, despite the popularity of SNA in the academic world, particularly in the field of sociology. On the other hand, SNA has been gaining acceptance among business consultants as a dynamic and effective tool to explore and exploit complex datasets with the objective of revealing the hidden connections that drive how work gets done. There is a growing recognition by academics and practitioners of the SCM community of the benefits social networks analytics can provide to understand the structural and behavioural aspects of a complex system like a supply chain network. For instance, Rozwell[18] argues that SNA can help organizations to gather business intelligence on employee relationships, depict information flows and value exchanges inside their organizations and help supply chains to proactively seek patterns that can be used to determine if they correspond to business opportunities or disruptions. It seems that SNA will emerge as an innovative approach with many potential applications in the fields of logistics and SCM over the next years. SNA applies to a wide range of business problems, including, among others: Knowledge Management and Collaboration; Team-building; Human Resources; Sales and Marketing; and Strategy.

It is worth highlighting that the framework proposed and validated in this research not only aids the project management community (academics as well as practitioners) to evaluate the influence of contributory factors to enable collaborative behaviours in SCDPs, but can also be used in many other fields interested in understanding how networking and collaborative relationships occurs between actors in network communities.

[16] with the exception of the attribute of employee seniority; there was not compelling evidence to confirm or reject
[17] Bellamy and Basolle (2012)
[18] Rozwell (2009)

1.5.2 Practical Contributions of the Research

The modelling of SCDPs' networks can help to (1) depict the principal properties and characteristics of a distributed project network; (2) provide insight on how the collaboration is structured in a SCDP and what explains collaboration between PTR; and (3) give a line of empirical evidence regarding the associated effects of the attributes in the Collaboration Intensity Network formed by the PTRs. Thus, this contribution, through the modelling of Collaborative Networks, helps to provide a set of metrics that would allow managers to identify collaborative links among PTRs, to recognize PTRs perceived as leaders and the role they play within in the network, and to recognize subgroups of PTRS working together (i.e., connected components, bi-connected components, triads, clusters and communities).

The current procedure and methodological steps used in this dissertation to debug, depict, characterize and understand collaborative relationships among PTRs in SCDPs, constitute another important practical contribution of this research. Firstly, email relationships, as well as calendaring and scheduling information data stored in the database modules of application suites like Lotus Notes, were used as a main source for social network data; this information was exported to a Flat File (.dat). Secondly, using the software Mathematica and its manipulation functions, a Pseudo-code was developed to debug the initial data and depict the social network of a SCDP (PTRs and their relationships with other PTRs in the network). Thus, key information data regarding the number of nodes in each network and collaborative relationship biased in one direction or another among PTRs was extracted using the Pseudo-code presented in section 4.1.1. Finally, using the software Excel, Gephi, and R, some visual and descriptive analysis and ERGM were applied in order to understand the main characteristics of a project network, as well as to gain understanding of the local structural forces and nodal attributes that influence the creation of Collaborative Relationship Ties over an entire Distributed project network.

2 Literature Review

This literature review provides an overview of the concepts that are relevant for this study. Firstly, it outlines a review about concepts of collaborative relationships in the business context and how they have been influencing supply chain performance. Based on these statements, this work adopts a definition for collaborative relationships. Then next section describes some of the most common definitions about the concepts of SCM found in literature, a work definition for the concept of SCM as it is understood in this study is presented as well as six drivers of change for the supply chain as improvement issues to be managed for the Supply Chain Projects are identified. Many authors have claimed that due to globalization and the rapid advances in ICTs a paradigm shift has appeared whereby the supply chain requires new ways of doing old tasks. The next part of this section outlines a new way of working for the SCM in which a structured, collaborative and measurable approach that exploit project management knowledge and technics should be applied as a means of achieving the operationalization of the supply chain improvements strategies. So, a discussion focused on how the supply chain is facing this new environment, encompassing distributed projects formed by skilled team members dispersed across multiple organizations and worldwide is presented. The last part of this section presents a discussion about the evolution of a variety of collaborative planning initiatives such as supply chain collaboration efforts and maturity models, which have been proposed as an attempt to address to which extend organizations as well as the supply chain as a whole are managing their business process supported by sustained collaboration practices.

2.1 Collaborative Business Relationship Concept

The concept of collaboration is derived from the Late Latin "c*ollaborare*", from the Latin word com- together + laborare to work, meaning "*to work together*". [19]

In order to understand and model Collaborative relationships in the context of business, it is compulsory to first focus on the very base notion of collaboration. Although almost everybody has a general notion about what collaboration is, this concept is often confused with other terms like cooperation, coordination and communication.

In an attempt to bring a base concept of CR and distinguish its differences with respect to the other related concepts, some definitions of collaboration in supply chain are presented in the table 1 below.

Table 1: Definitions of the concept of collaboration

Source	Definition / Main characteristics
Narus and Anderson (1996)	As the cooperation between independent but related organizations sharing resources and potentialities to achieve the most extraordinary customer needs.
Lambert *et al.* (1999)	Understand collaboration as a particular degree of relationship between supply chain partners as a vehicle to share risk and

[19] Collins English Dictionary –Compete & Unabridged 10th Edition

	benefits that results in greater success for the firms in relationship than would be achieved when acting in isolation.
Simatupang and Sridharan (2002)	Two or more organizations working together to plan and execute their operations with higher profits than can be achieved by acting alone.
Bowersox *et al.* (2003)	Originates when two or more organizations freely agree to integrate human, financial, and/or technical resources in an effort to create a new, more efficient, effective or relevant business mode.
Stank *et al.* (2003)	A decision process among interrelated actors, involving the joint ownership of decisions and collective responsibility for outcomes.
Bititci *et al.* (2004)	Collaboration refers as a group of independent organizations working together, sharing resources, information, systems and risk for achieving common goals and mutual benefits.
Crum and Palmatier (2004)	Collaboration is characterized as "cooperative behaviour" or "joint decision making" between companies, and encompasses a willingness, versus a requirement, to engage in inter organizational efforts.
Supply Chain Council's SCOR Collaboration Technical Committee[20]	Define collaboration as *"a relationship built on trust that is benchmarked by the commitment to the team objective and where consensus may not always be achievable but where nothing takes place without the commitment of all involved"*. Three levels of collaboration are defined: - Data exchange collaboration: when partners in collaboration (intern or extern) exchange information, mainly to complete day-to-day requirements. Information Sharing can be one way or two ways. - Cooperative Collaboration: when partners in collaboration (intern or extern) share information systems and tools having all of them access to information at the same time. - Cognitive Collaboration: this is the highest level and involves "work together requiring intellectual skills and cognitive activities among the partners.
Golicic *et al.* (2003) and Parung and Bititci (2005)	Defining different levels of collaborations which can be associated to the use of different levels of resources, risk and benefits sharing. These are: - Coordination: involves communication and information sharing with small aligning and mutual agreements so that more efficient results are achieved. - Cooperation: involves resource sharing with medium levels of mutual agreements for achieving compatible goals. - Collaboration: it implies, sharing information, resources, risks, responsibilities and benefits sharing with high levels of mutual agreements. Actors are more closely aligned looking to achieve common goals and desired outcomes.
Finley and Srikanth (2005)	Comprise diverse units working together, sharing processes, technologies, and data to maximize value for the entire group and the customers they serve.

[20] Ayers (2004), in Chapter 8

Min *et al.* (2005)	Encompass two or more organizations sharing the responsibility of exchanging common planning, management, execution, and performance measurement information.
Sanders and Premus (2005)	Represents an affective, mutually shared process where two or more organizations work together, have mutual understanding, have a common vision, share resources, and achieve collective goals.
Kahn *et al.* (2006)	Involves a process based on trust, mutual respect, information sharing, joint ownership of decisions, and collective responsibility for outcomes.
ECOLEAD Consortium (2007)	This initiative introduces an additional level to the three previous levels described above by Golicic *et al.* (2003) and Parung and Bititci., (2005). Thus, networking level is added. It involves communication and information exchange for mutual benefits. Furthermore each of the above concepts constitutes a "building block" for the next definition. So, coordination extents networking; cooperation extents coordination; and collaboration extents cooperation.
Bititci *et al.* (2009)	Collaboration provides an instrument by which opportunities are maximised and at the same time risks are minimised by bringing together the right mix of competences and creating critical mass to increase the competitive advantage of the organizations involved.
Bahinipati *et al.* (2009)	*A business agreement between two or more companies at the same level in the Supply chain or network in order to allow greater ease of work and cooperation towards achieving a common objective.*
Shuman and Twombly (2010).	Collaboration wraps up coordinating specific activities and exchanging of appropriate information to leverage resources having the purpose to seek the objectives among counterparts. Collaboration brings the possibility of accessing hard and soft issues (resources, knowledge, relationships), others have and using each party's resources to achieve common goals and benefits.

Several studies in extant literature have established some main requirements for collaborative relationships. A summary of these requirements are presented in table 2.

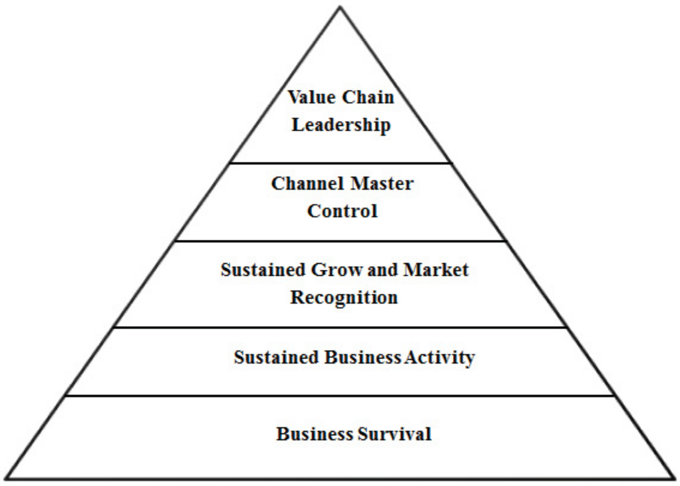
Table 2: Requirements for collaboration

Source	Requirement for Collaboration
Shuman and Twombly (2009)	• Must have a purpose. • Requires an environment of trust and transparency. • Relationships currencies. In fact, parties must believe that they give and get balance over the time. • Takes place in networks.
ECOLEAD Consortium (2007)	• Parties share a common goal. • Takes time, effort and dedication. • As a process requires setting standard steps e.g. definition of scope, structure, policies, assessment measures, identify risks and

	plan contingencies, among others and establish commitment to collaborate.[21] • Parties share responsibilities, information, resources, benefits and risks. Notice that sharing does not mean equality. • Parties share a mutual trust. • Collaboration occurs in a "collaboration space". It can take place at the same time (synchronous collaboration) or at different times (asynchronous collaboration). It may also happen in the same place (collocated environment) or in different places (remote or virtual environment).[22]

The Technical Committee of the Supply-Chain Council[23] has defined 5 levels of motivation for collaboration in terms of a "hierarchy of business needs". These levels are similar to Maslow's hierarchy of needs (see figure 2). If the customer forces the change (customer pull), the power of decision of an organization is constrained and the motivating force is likely to be at level one or two in the pyramid. On the contrary, is one organization is pushing the change, the motivating forces might be at levels 3, 4 and 5 and might drive the creation of a new niche in the supply chain and its projects are moving beyond cost reduction to increase market shares and incomes.

Figure 2: Motivation for collaboration in terms of hierarchy of needs



Source: ECOLEAD Consortium (2007)

Based on the concepts above mentioned, and in order to understand and model collaborative relationships in the context of business, this endeavour agrees on the definition presented by ECOLEAD Consortium[24] and proposed the following working definition for collaborative relationships:

---

[21] Giesen (2002)
[22] Winkler (2002)
[23] Ayers (2004), Chapter 8
[24] Viera *et al.* (2009)

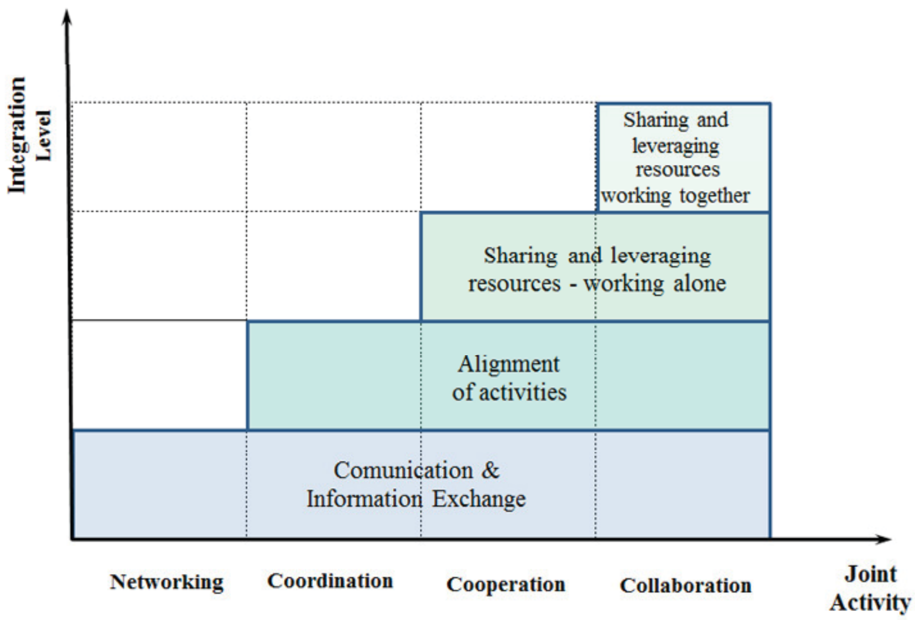
So, collaborative relationships are defined as the highest and demanding form of integration. Thus collaboration extents and includes all the other integration concepts (see figure 3). Therefore, networking, coordination and cooperation are included in the concept of collaboration.

Networking, as the less demanding form of integration, involves only communication and information exchange for mutual benefits. Then coordination extends networking. So, this level of integration in addition to communication and information exchange, wraps up some tuning /alignment of activities, so more efficient outcomes are achieved.

A more demanding joint endeavour is cooperation. It also extends coordination. Therefore, in addition to the information exchange and tuning of activities it involves sharing and leveraging resources for achieving common benefits and goals. Indeed, cooperation is achieved by division of some work package activities among the partners in relationships. The traditional supply chain represents a good example of a cooperation process.

Finally, the most demanding joint endeavour is collaboration. It extends the previous forms of integration. Thus collaboration is an interactive, constructive, and knowledge-based process in which partners in relationship communicate and share information, leverage resources and coordinate activities to plant, implement and controlling together a set of activities to achieve a common goal beyond what the partners' capacity would allow them individually to accomplish. [25]

Figure 3: Examples of joint endeavour



Source: ECOLEAD Consortium (2007)

[25] Hartono and Holsapple (2004)

This definition implies mutual engagement of two or more partners, coordinating specific activities, and exchanging of appropriate information to leverage resources having a defined purpose. This purpose is usually translated to a joint goal or a problem to be solved by partners in relationships. It requires an environment of trust, reciprocity, flexibility, interdependence and commitment[26], and thus takes time, effort and dedication. Likewise, parties in collaboration must believe that they give and get balance over the time, in order to build trust, reciprocity and commitment.

In fact, collaboration can be seen as a process of relationship currencies, in which the partners in collaboration could have the possibility of accessing the resources, knowledge and relationships others network members have and using each party's resources for mutual benefits[27]. However, collaboration did not happen all the time. So there are periods, where the members work cooperatively. Thus they work alone and independently on their assigned work packages. Then come periods where they joint together (physically or virtually) to integrate their results and get further in order to solve the joint problem or to achieve the common goal. Thus, collaboration and cooperation differs in terms of their depth of interaction, integration, commitment, and complexity. Likewise, collaboration occurs over time as members in relationship formally and informally through repetitive sequences of interactions search and implements solutions jointly.

2.2 Collaborative Network Scenarios

Globalization trends and new advances in information and communication technologies have defined new frontiers in business environment scenarios. In fact this trend has been playing an important role for organizations in terms of integrations and flexibility requirements.

Collaborative Networks have emerged in this sequence as an organizational form consisting of a variety of members (e.g. organizations and people) that are largely self-governing, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals. A main characteristic of these networks is that their members collaborate in order to solve the joint problem or to achieve common or compatible goals, supported by the shared belief that together can achieve goals and better benefits that would not be possible when acting in isolation.[28]

During the last years, various manifestations of Collaborative Networks in different application domains have emerged. Due to this and in an attempt to consolidate this knowledge the ECOLEAD Consortium has developed a taxonomy to address and consolidate the different collaborative networks manifestations. As a result of this endeavour, 14 different organizational forms of collaborative networks were identified.

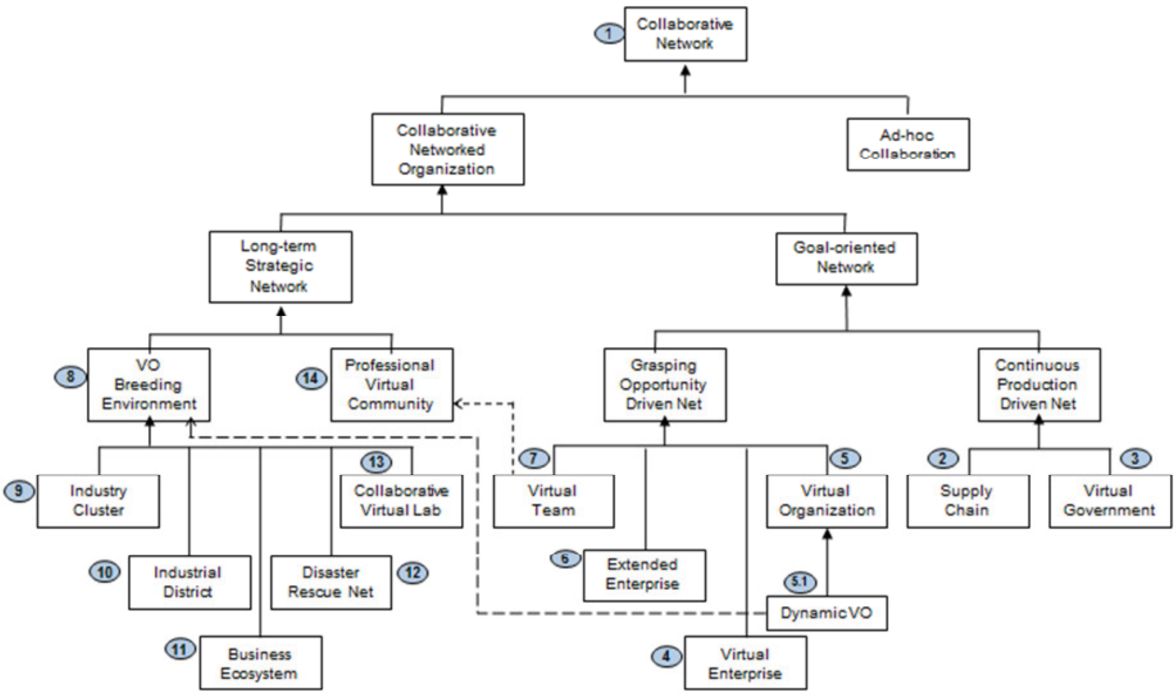
Although not all Collaborative Networks involve some kind of formal organizational structure, most of them are characterized by having defined roles and responsibilities, and some governance rules for their members. These kinds of networks are called "Collaborative

[26] *Ibid.*
[27] Shuman and Twombly (2010)
[28] Camarinha-Matos and Afsarmanesh (2005)

Networked Organizations (CNOs)". On the other hand, there are other more improvised forms of collaboration in networks, in which their members may volunteer to collaborate forming virtual communities (e.g., network formed in case of a natural disasters, or members working together hoping to achieve a social cause). These kinds of Collaborative Networks are characterized by both lack of an organizational structure and pre-plans, as well as absence of rules and procedures on how activities should proceed. Thus, roles and responsibilities are not always clearly defined. These spontaneous not business-oriented manifestations of collaboration in networks can be called "ad hoc forms of collaborations" (see figure 4).

Among the CNOs, some networks are characterized by the high levels of intense collaboration among its members and usually are oriented toward a common goal. These are called Goal-oriented CNOs. As opposed to the previous ones, are defined the long-term strategic CNOs as another type of integration focused on providing the basic infrastructure and environment to support the agile and fluid arrangement of collaboration networks when business opportunities arise. Indeed, in this special type of integration low levels of collaboration, but mostly cooperation is practiced among their members. VO breeding environments and professional virtual communities represent these kinds of networks.

Figure 4: Examples of Collaborative Networks



Source: ECOLEAD Consortium (2007)

Among the various types of CNOs distinguish by the ECOLEAD Consortium, of special relevance for this work are Goal-oriented CNOs. The Goal-oriented CNOs can themselves be either governed by on-going production/service provision activities, or governed by the aim of catching a single opportunity. Examples of these networks in table 3 and table 4 are presented.

Table 3: Examples of Continuous Production-Driven CNOs

Source	Definition	Main characteristics
Collaborative Supply Chain (CSC)	A long-term network of different interrelated enterprises each having clear roles in the manufacturing value chain and directly linked by one or more of the upstream and downstream non-linear network of relationships having the purpose to serve the final customer. Supply chain members working jointly with the objective to plan, execute and control supply chain processes with greater success than when acting in isolation.[29]	- Goal-oriented constellation. - Long-term duration. - Driven by on-going production activities.
Virtual Government	Delineate an alliance of governmental organizations that come together to combine their services to bring integrated services to the citizen through a common front-end.[30]	- Goal-oriented constellation. - Long-term duration. - Driven by service provision activities.

The first case of CNOs labelled as Continuous Production-Driven, in figure 4 includes those networks that have long-term durations as the case of supply chains. These networks remain relatively stable relationships between their members during its life cycle. Clear definitions of roles and responsibilities characterize these types of integrations.

In this research special attention is devoted to CSC networks and therefore some additional definitions are presented. For instance, Narus and Anderson, state a CSC network as the relationship among independent but interrelated firms to share resources and logistics capabilities to meet the customer needs and at the same time, each trading member can exploit profit-making opportunities that they cannot create alone[31]. Lambert *et al.* defines a CSC network as a two or more supply chain members who work jointly within a particular degree of relationship as a means to sharing risks and rewards and in return for its contributions, each member involved achieve higher business performance than would be achieved by firms individually.[32] In a similar vein, Simatupang and Sridharan state that a CSC is the network of different interrelated firms directly linked by one or more of the upstream and downstream flows of products, services, finances and information working jointly with the objective to plan, execute and control supply chain processes with greater success than when acting in isolation. Supply chain members, through close cooperation, can effectively match demand and supply increasing the overall performance of the supply chain and at the same time improves dramatically the customer service.[33]

The second case of CNOs within the Goal-oriented networks, the so-called Opportunity-based CNOs in Fig. 3 are short-term networks triggered by a specific collaboration opportunity as the case of a virtual enterprise. That kind of networks will dissolve once their objective is accomplished. The term “virtual” here used for these organizations, responses to the fact that

[29] Cox *et al.* (2001)
[30] Camarinha-Matos and Afsarmanesh (2006)
[31] Narus and Anderson (1996)
[32] Lambert *et al.* (1999)
[33] Simatupang and Sridharan (2002)

these networks acts or pretend to act as a single unit when on the reality they are not a single legal entity and, are commonly geographically distributed. Examples of these networks are presented in table 4.

Table 4: Examples of Opportunity-based CNOs

Source	Definition	Main characteristics
Virtual Organization (VO)	Delineate a temporary joint of independent enterprises in one whose members are geographically apart but that come together to share resources and skills to achieve its mission/objective and whose relationships are supported by information and communication technologies.	- Goal-oriented constellation - Temporary network - Triggered by a specific collaboration opportunity - Appearing to others to be a single, unified organization with a unique real physical location. - Widely usage of communication and coordination mechanisms enabled by information technologies.
Virtual Enterprise (VE)	Delineate a temporary or semi-temporary network of independent enterprises in one whose members are geographically apart but that come together to communicate, share resources, skills and core competences and cooperate in order to achieve a business opportunities or goals and to share the achieved revenues. A virtual enterprise is in fact treated as a particular case of a virtual organization.	
Extended Enterprise (EE)	Characterize organizations in which a leading organization extends its line of influence to all or some of its suppliers. An EE can be associated as a particular case of a VE.	
Virtual Team (VT)	Refers to a organizational form characterized by a temporary group of geographically dispersed individuals not belonging to the same organization that work together towards a common goal such as realizing a consultancy job, a joint project, etc. Usually this kind of network, use Information and communication technologies as their main interaction environment.	

Source: Based on Camarinha-Matos and Afsarmanesh (2006)

2.3 SCM Knowledge

2.3.1 Defining SCM

The term SCM appears to have been coined in the early 1980s by R.K. Oliver and M.D. Webber;[34] they bring up the benefits of integrating the internal functional areas of procurement, manufacturing and sales distribution. In the same direction, various definitions of a SCM, considering only an internal supply chain that orchestrate functional departments

[34] Oliver and Webber (1982)

involved in the flow of materials and information from inward to outwards ends of the business were adopted in the past several years[35]. La Londe and Master and Lambert *et al.*[36] define a SCM as the alignment of independent firms involved in manufacturing and bringing products or services to the end customer. Meanwhile, Harland *et al.*[37] differentiate the traditional supply chain concept from the supply network concept. They argue that, whilst a traditional SCM tends to concentrate on linear flows of material, services and related information, supply chain network encircle the complexity of networks involving all tiers from the initial supplier to end-consumer. More so, they have extended the traditional internal supply chain concept (intra-business concept) to the concepts of Supply Network (inter-business concept). So they are considering three additional levels of management: Dyadic Relationship with immediate partners, Chain Relationships including relationships from the supplier's supplier to the customer's customer, and the Network Relationships of interconnected companies. By the same token, Christopher[38] recognizes, a lack of precision in the term "Chain", suggesting that the supply chain is the network of organizations that are involved through downstream linkages (i.e., supply) and upstream linkages (i.e., distribution), to produce products and services to the final consumers. He further emphasizes that the key to success is the way that firms manage these relationships with suppliers and customers on an integrated basis. Stock and Lambert[39] reinforce this idea, by arguing that the way to achieve competitive advantage lies on partnerships based on mutual trust and the desire to increase the overall performance of both the individual companies and the supply chain as whole whilst simultaneously achieving the customer requirements.

As defined by the Council of SCM Professionals[40], SCM includes planning and management of all activities involved in sourcing and procurement, transformation, and logistics management activities. Special remarks are given to alignment of the collaborative relationships with supply chain partners, which can be suppliers, intermediaries, third party service providers, retailers and customers to facilitate integration of supply and demand management within and across companies.

Moreover, Mejza and Wisner, in their exploratory study offer empirical evidence to support the notion of a SCM as an umbrella business discipline that deals with the building of inter-organizational relationships throughout the integration of a wide scope of supply chain processes[41]. By the same token, Mentzer *et al.* are portraying SCM as a strategic level concept, considering SCM to be "the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole".[42]

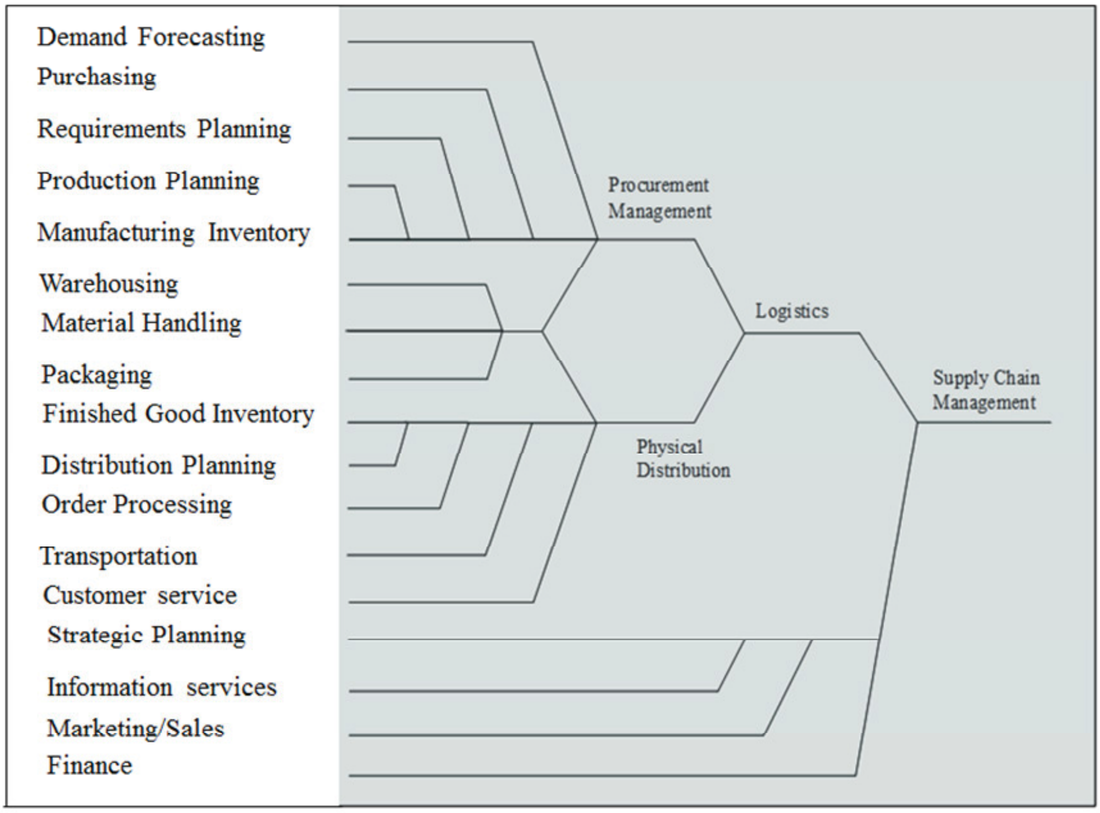
More so, some authors believe that the new concept of SCM is an evolutionary concept that includes previous concepts like procurement management, physical distribution, strategic

[35] Houlihan (1984); Jones and Riley (1985); Stevens (1989); Saunders (1994)
[36] La Londe and Masters (1994); Lambert *et al.* (1998)
[37] Harland *et al.* (2001)
[38] Christopher (1992)
[39] Stock and Lambert (1992)
[40] Council of Supply Chain Management Professionals (CSCMP)
[41] Mejza and Wisner (2001)
[42] Mentzer *et al.* (2000)

planning, and finance (see figure 5). It is worthwhile to highlight that coordination, integration, collaboration and relationships building both across functional departments within an organization and throughout multiple supply chain trading partners seem to be within the purview of SCM.

Lambert, Cooper, and Pagh go further and understand SCM as the integration and managing of key business processes linked across the functional areas within a company and along the upstream and downstream activities of a supply chain from end customer through original supplier. These processes interact throughout the different supply channel members for the purpose of adding value for end consumers and stakeholders.[43] They propose a SCM three-component framework to encompass the essence of SCM: the structure of the supply chain, the supply chain business processes, and the SCM components (see figure 6).

Figure 5: Evolution of supply chain management



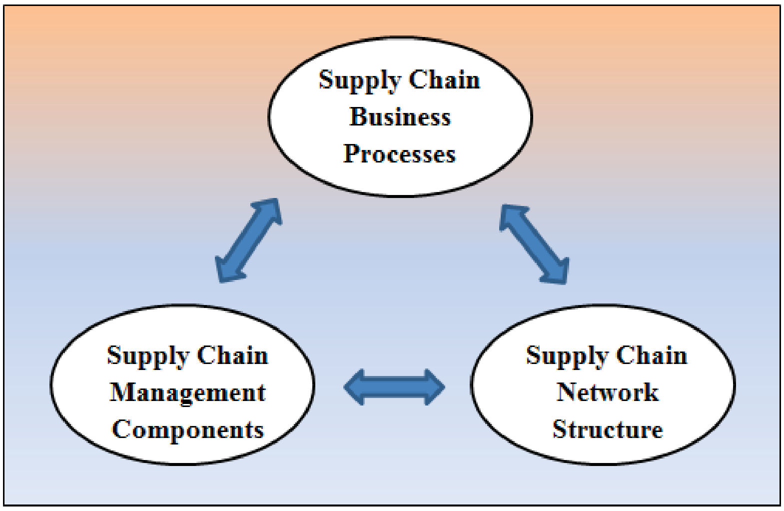
Source: Ballou (2007)

This supply chain network structure encompasses three structural aspects: (1) the members of the supply chain, (2) the structural dimension of the network, and (3) the different types of processes links across the supply chain (see figure 7). When determining the network structure of a supply chain three structural elements should be identified. First of all, it is necessary to identify who the members of the supply chain are and distinguish them between primary and supporting members. Thus, to identify who should be considered as key member of the supply chain. Then, the structural dimensions of the supply chain allows the focal company to identify the horizontal structure (number of tiers across the supply chain), vertical structure (number of suppliers and/or customer at each tier level), and the horizontal position

[43] Lambert *et al.* (1998)

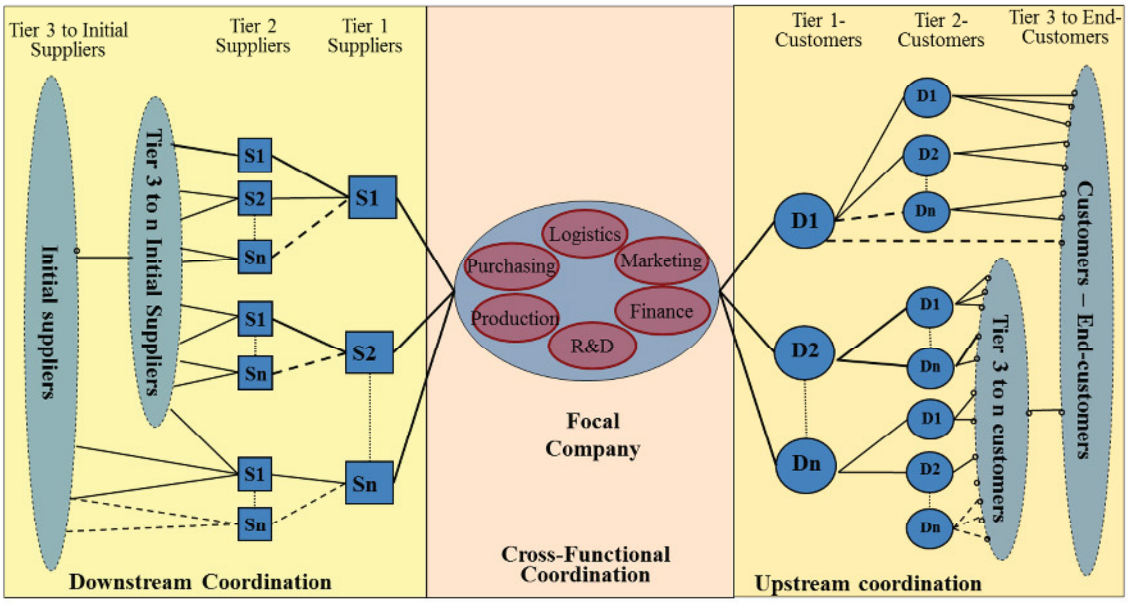
of the focal company in the network. Finally the executives should decide how closely they should integrate and manage the different types of business process links identified in this model.

Figure 6: Supply chain management framework: processes, network structure and key links



Source: Lambert, Cooper and Pagh (1998)

Figure 7: Generic structure of a supply chain network



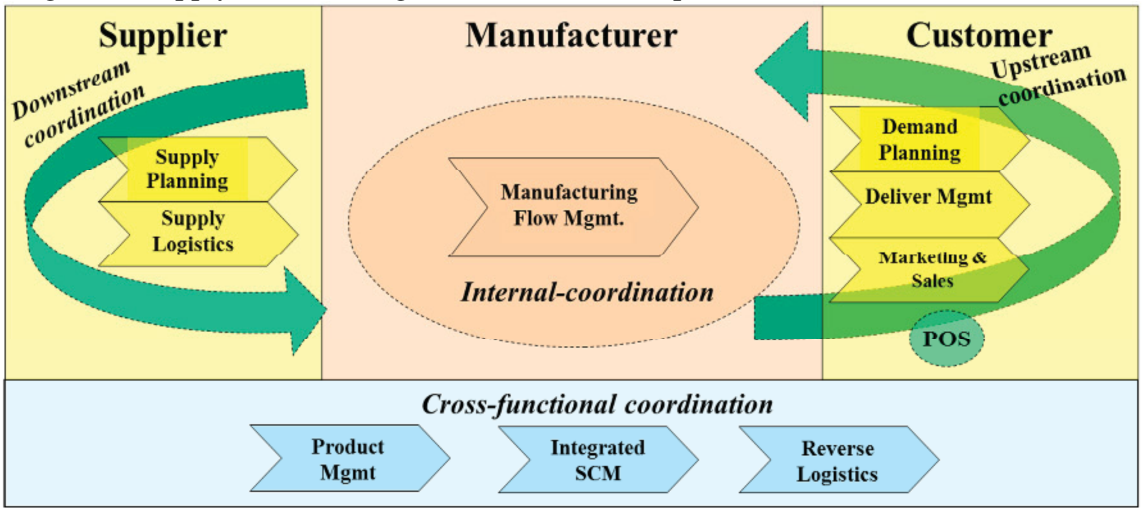
Source: Based on Lambert, Cooper and Pagh (1998)

The second component of the above model here explained, is oriented to the matter that the executives should thoroughly identify, analyse and decide which key supply chain business process to integrate and manage. As a starting point the member of the Global Supply Chain forum identified seven key business processes that could be linked across the supply chain. By the same token, Gruat la Forme *et al.*[44] have identified nine relevant processes at 4 different levels for the supply chain (see figure 8).

---

[44] Gruat La Forme *et al.* (2007)

Figure 8: Supply Chain management collaboration processes



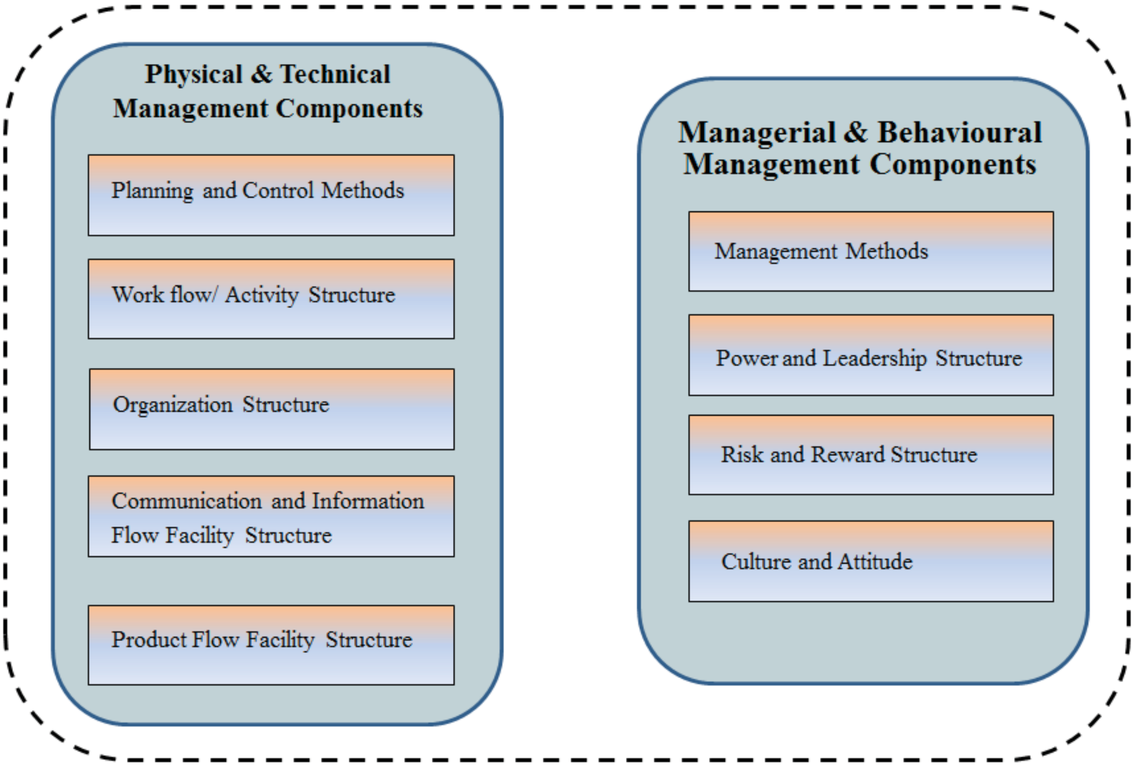
Source: Based on Lambert, Cooper and Pagh (1998)

The SCM components, is the third element of the SCM framework (see figure 9). Management components are the joint activities that management establishes to integrate and manage each process link through the live of the relationship. Lambert *et al.* propose 9 components classified in two groups. The first group includes the physical and technical components e.g. planning and operating controls, work flow/activity structure, organization structure, communication and information flow facility structure and product flow facility structure. The second group is comprises by the managerial and behavioural components e.g. management methods, power and leadership structure, risk and reward structure sharing and culture and attitude. The scope of integration and management to apply for a business process link depends on the number and intensity level, ranging from low to high, of components added to the link. Put differently, since the drivers for integration are dynamic and differs from process link to process link, the level of integration should vary depending on the criticality of the process and over the time.[45]

Encompassed within this trend, Ballou distinguish three different levels in SCM, namely: logistics operations, cross-functional coordination, and inter-organizational coordination (see figure 10). Logistics operations as that part of the supply chain processes that includes managing activities and processes such as planning, procurement, material flow management, operations, inventory management, transportation, warehousing, distribution, customer service and all the related information systems used to monitor these activities from the point of origin to the point of consumption and final disposal, to comply with the customer requirements. Cross-functional coordination referred as a horizontal business function focused on building collaborative relationships with other traditional business functions within a particular firm. Finally, inter-organizational coordination has to do with coordinating and collaborating products flow among (forward and backward) supply chain trading partners.[46]

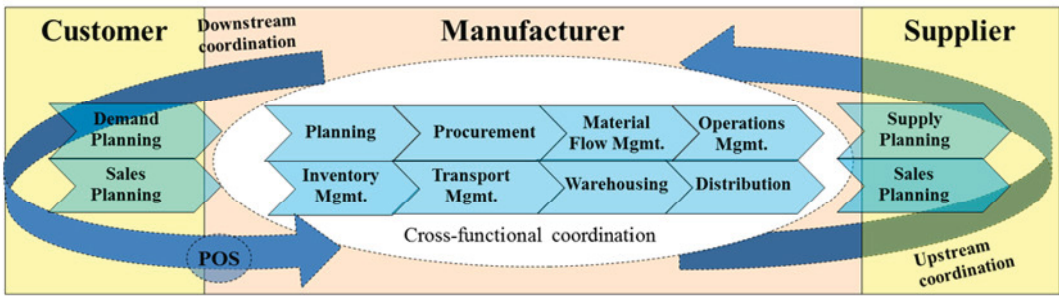
[45] Lambert, Emmelhainz and Gardner (1996)
[46] Ballou (2007)

Figure 9: Supply chain management fundamental components



Source: Lambert, Cooper and Pagh (1998)

Figure 10: Scope of supply chain management



Source: Based on Ballou (2007)

All of the above definitions suggest that the SCM is not only concerned with more than simply the process of management the efficient, effective movement and storage of materials and related information from the supplier's supplier to the customer's customer, but also with the need to create closer relationships both across functional departments within an organization and between the supply trading partners. Put another way, this endeavour understand that the domain of SC is broader. It domain not only include two or more different but interrelated firms which often become involved in supply chain processes to integrate the purchasing, manufacturing, warehousing, transportation, customer service, demand planning, supply planning across the supply chain to control the effective flow of goods and services, related information and associated funds from end user to source of origin, but also should include the understanding and alignment of collaborative relationships with supply chain partners to facilitate integration of supply and demand management within and across companies.

In the last decades, changes in the business environment have contributed to the development of SCNs. Thus, some actors have viewed SCM as an inter-organizational Supply Chain Network (SCN) of autonomous or semi-autonomous business entities involved, through upstream, cross-functional and downstream links, in the relevant business process that work together to design, produce, deliver goods or services to the end customer.[47] Is a new vision of the SCM as the management of the integral network of interconnected business processes by keeping the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer and finally to customer. It involves coordinating and integrating flows within and among companies.[48]

This leads to the conclusion that the term "SCM" is increasingly giving place to "SCN", where the supply chain thinking must incorporate a holistic and systemic understanding of both downstream and upstream non-linear network of relationships serving the final customer.

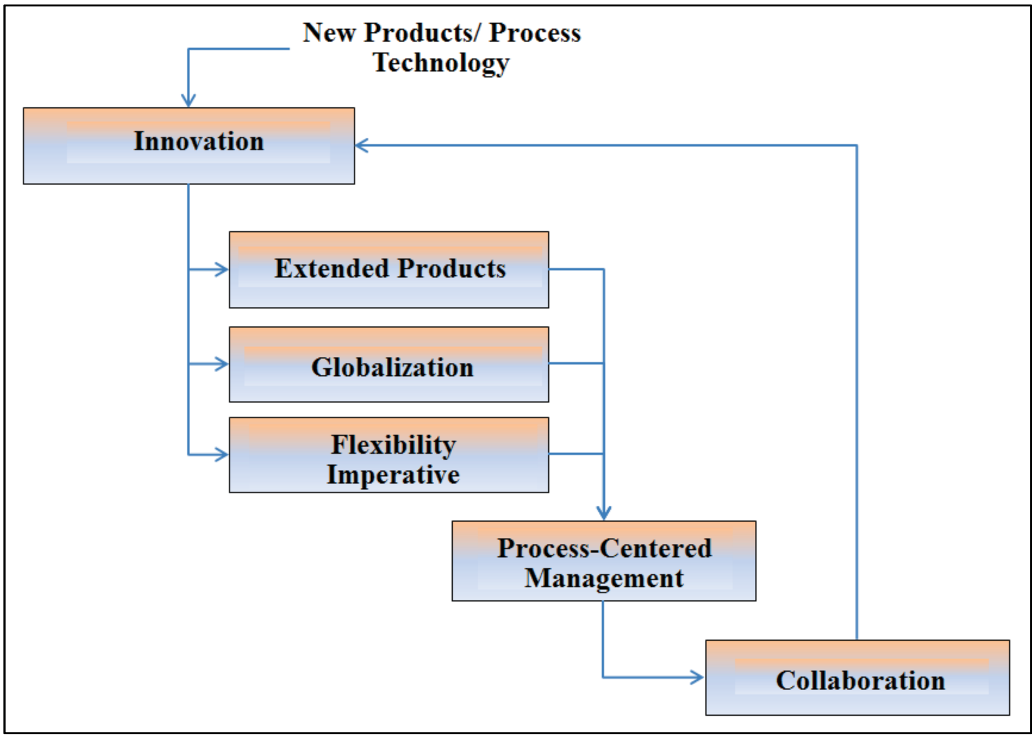
2.3.2 Drivers of SC Change

The Project Management Institute (PMI)[49] has described SCM as an application area for project management knowledge and practice. By the same token, Ayers[50] argue that SCM relies on project management knowledge and practices to better achieve strategic goals. The author of this study affirm that without a doubt, effective supply chain managers will be the ones that combine supply chain daily work with application of the project management knowledge and practice to develop and execute supply chain strategies. In this direction the author presents a framework to model a connection among the six supply chain drivers identified: Innovation, Extended Products, Globalization, Flexibility, Process-centred management and Collaboration (see figure 11).

The first driver identified is Innovation, in either product or process. This driver is considered the engine of change in a supply chain. It is well known that a totally new product will require new suppliers as well as new distribution channels for the product. Changes in process technology (process innovation) may alter the way that the product is produced. Certainly, innovation pushes supply chain change. This need of change come annually in the strategic planning process or when things are no longer work well and the company is forced to react. Then three drivers are identified as the ones that shape the direction, scope and form of the products and services as well as the supply chains required to deliver them: Extended Products, Globalization and Flexibility.

[47] Lee and Billington (1993); Lambert, Cooper and Pagh (1998)
[48] Krajewsky and Ritzman (1999); Schroeder (2015)
[49] The Project Management Institute is the world's leading not-for-profit professional membership association for the project, program and portfolio management profession. www.pmi.org.
[50] Ayers (2004)

Figure 11: Drivers of supply chain management change



Source: Based on Ayers (2004)

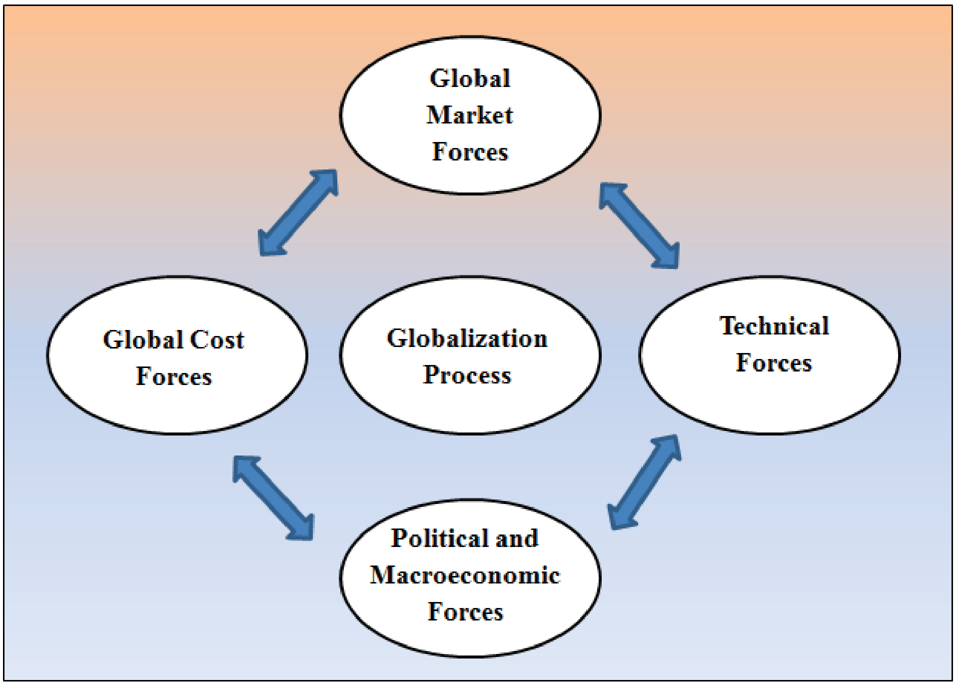
Customer buying decision begins with a need for the base product, but quickly moves to extended product. The hand book of SCM provides a definition of base and extended products. The base product is the physical form of the product. The extended product includes other characteristics that influence a purchase decision like availability, delivery, service, reputation, among others.[51] Supply chain managers should monitor when the output of product and process innovation create needs to change an existing supply chain, then design a supply chain to fit the innovation or at least to incorporate the innovation into the best fit supply chain already functioning in the company. However this is challenging, because base product and extend product management usually are likely managed by separated departments in a company. This division of responsibilities constitutes a barrier for a company to be effective in the implementation of changes.

Business today is becoming borderless and firms and their supply chains cannot ignore the influence of external global factors such as market forces, technological forces, cost forces and political and macroeconomic forces. These factors are shaping the global environment and are driving the development of the supply chain competitive strategy (see figure 12). In the field of supply chain projects three related drivers are recognized: new sources, new market and rationalization. New sources force changes upstream in the supply chain. New Markets do the same downstream. Rationalization suggest that the business must look continuously for opportunities to optimize business processes, diminish cost, increase customer satisfaction, gain a competitive advantage, and face any breakdown caused by

[51] Ayers (2006)

uncertainties in the global market.[52] It is seems for many supply chain managers that globalization influences range from upstream suppliers to downstream customer.

Figure 12: The four driving forces of the globalization process



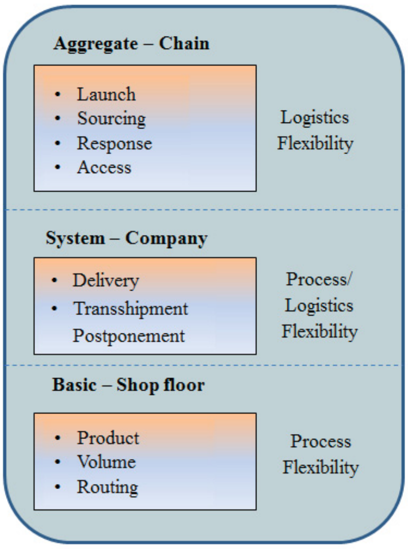
Source: Lee and Lee (2007)

The last driver emerging from the outputs innovation is the supply chain flexibility. Flexibility reflects the ability of a system to change or react with little penalty in time, efforts, cost or performance.[53] According to Ayers, a broader spectrum of the flexibility incorporate three levels of flexibility: management mind set, long term and short term. As product, process and markets changed, the supply chain must face the changes otherwise can put in dangerous the company's' future. Thus, Flexibility has to be a real priority in the minds of the managers. Long term flexibility is understood as the matching between the supply chain design and customer requirements. Short term flexibility corresponds to the response time and production flexibility. It is worth to highlight that these three levels are interdependent. Thus means flexibility muss be recognized as a real priority in the minds of supply chain manager to achieve long term flexibility; and long term flexibility is a pre-requisite to get short term flexibility.[54] Meanwhile SCOR define Agility (include Flexibility and Adaptability) as the ability to respond to external influences and market changes in order to gain or maintain a competitive advantage. It is defined as a performance metric at the strategic level 1 in the Supply Chain Operation Reference Model and measure by four metrics: Upside supply chain flexibility, upside supply chain adaptability, downside supply chain adaptability, and overall value at risk.[55] Zhang *et al.* split up flexibility in to two dimensions: flexible competencies (defined internally at the organization) and flexible capabilities (perceived by the customer).[56]

[52] Ayers (2004)
[53] Upton (1994)
[54] Ayers (2004)
[55] SCOR 10 (2010)
[56] Zhang *et al.* (2003)

Sanchez and Perez develop a framework of supply chain flexibility which includes three levels of flexibility: basis, system and aggregate. The basic level of flexibility comprises shop floor capabilities that have impact on supply chain. It includes three flexibility dimensions: Product, Volume and Routing. The following level of flexibility (system flexibility) includes three flexibility dimensions: Delivery, Transshipment and Delivery. The top level of flexibility (aggregate flexibility) is linked to the customer supplier relationships; it includes four flexibility dimensions: Launch, Sourcing, Response and Access. In addition they include two main aspect of the flexibility: process flexibility of each supply chain plant and logistics flexibility, related to different logistics strategies adopted either to distribute product to the market or to procure a component from a supplier (see figure 13).

Figure 13: Supply chain flexibility dimensions



Source: Adapted from Sanchez and Perez (2005)

The output of product and process innovation is processed and transformed in requirements for SCM processes and collaboration; the last two drivers presented in the model. The importance of a process-centred management approach is not new. Reengineering, Quality Management Systems, Total Quality Management, Sic-Sigma among others were successful process-oriented movements in the last decade. Ayers[57] tackles three scenarios to manage projects for supply chain improvements: 1) bottom-up projects originating in a functional department, claiming for local savings; 2) Top-down projects coming from business top level, crossing department boundaries, claiming success for the entire organization; and 3) projects beyond top-down (i.e., those that extent organizational boundaries).

Projects in this last category seek to reduce costs, optimize processes and increase customer satisfaction in the supply chain; (i.e., look to leverage and improve the supply chain competitiveness). However, there are many obstacles to projects of this type, such as physical dispersion, lack of trust, poor cost accounting, pointless performance measures, and lack of skills among others. In fact, involving all shareholders in a tight collaboration, seeking to solve problems and bring mutual benefits to all supply chain partners is not an easy task. Today's marketplace requires organizations to be based not around tasks, but process

[57] Ayers (2004)

oriented. This new scenario is giving way to "virtual organizations" that are created to accomplish a strategic goals or to achieve business opportunities and then are dispersed when their objectives are achieved.[58]

Collaboration is recognized for practitioners and academics as a highly adopted practice in supply chain field.[59] Collaborative practices have become a well-established research domain.[60] There are enough evidences about the need of collaboration in building and improving efficient and sustainable supply chains. By the same token the Supply Chain Council's has incorporated collaboration in its SCOR model as one of the key activity at level 3 processes (Process Element Level) that can support companies to compete companies in its chosen markets. Another good example of an industry's response to the need for supply chain collaboration efforts is the CPFR reference model for the retail industry provided by the VICS CPFR committee. Based on this general framework, CPFR discusses its four collaboration scenarios (Retail event collaboration, DC replenishment collaboration, store replenishment collaboration and collaborative assortment planning); collaboration roles (who of the partners in collaboration is responsible for collaboration task) and organizational implications to integrate collaborative process across corporate boundaries.[61]

Many researchers have recognized collaboration as a vehicle to establish closer and long term partnership relationships within supplier and customer along the supply chain[62]. Goffing *et al.* emphasize the need for identifying potential supply chain partners with whom an organization should liaise with[63]. However, a good selection about the partners with whom working closely should be performed[64]. According to Horvath and Spekman *et al.* supply chain collaboration has been recognized as a means of achieving competitive advantages[65]. The existing literature describes two types of collaboration within the supply chain context: First the intra-firm collaborative efforts among functional departments within a firm[66]; second, cross-organizational collaborative efforts among supply chain partners.[67] Elaborating on this, Ayers state, that effective performance of both internal collaboration and partnership between supply chain members, allows collaboration leading to innovation, the first drivers of supply chain change above presented.[68]

So, to be competitive at the new supply chain scenario, supply chain managers must monitor and examine each supply chain driver and its impacts as driving forces of change, and then been proactive in managing the drivers rather than having them manage you. Thus, the supply chain managers must evaluate whether the organization's project portfolio is enough in term of dealing with the drivers. It is worthwhile to mention than the drivers for a change (innovation, extended products, flexibility and globalization) are all issues to be taken into account in supply chain strategic planning which usually are at the bottom of many supply

[58] Ross (1998)
[59] Simatupang and Sridharan (2005)
[60] Pagell (2004)
[61] VICS CPFR (2004)
[62] Gattorna and Walters (1996); Christopher (2011); Gunasekaran *et al.* (2001)
[63] Goffin *et al.* (2006)
[64] Vereecke and Muylle (2006)
[65] Horvath (2001); Spekman *et al.* (1998)
[66] Dieh (2001); Wilson (2001)
[67] Ireland and Bruce (2000); Barrat and Oliveira (2001)
[68] Ayers (2004)

chain project. Thus, project are taking an increasing share of the companies works, displacing ongoing and repetitive operations. Put differently, there is a tendency for the SCM knowledge areas to structure the continuous improvement based on "management by projects".

2.4 Distributed Supply Chain Management Projects

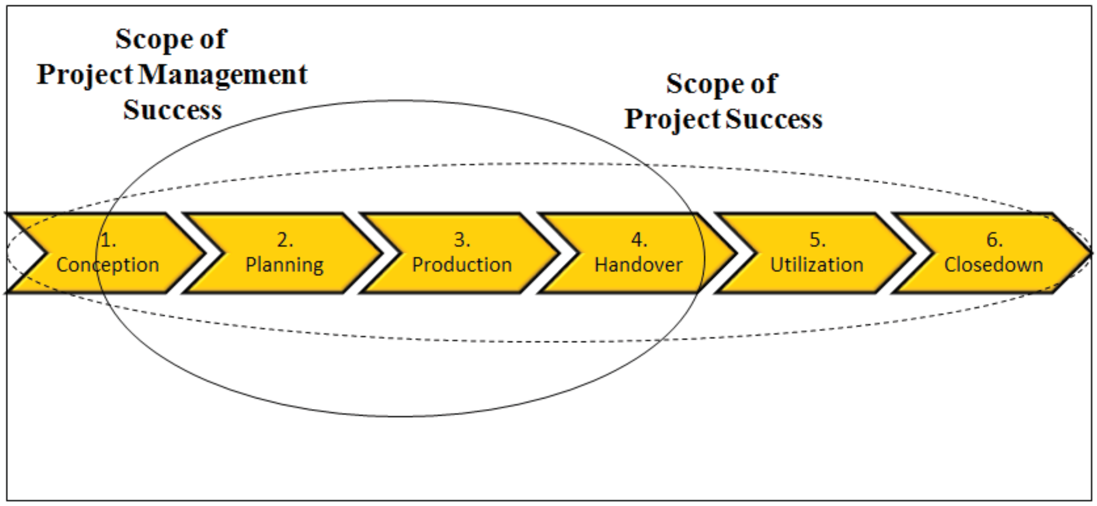
2.4.1 Supply Chain Management Projects

Turner[69] defines a project as: "*An endeavour in which human, (or machine), material and financial resources are organized in a novel way, to undertake a unique scope of work, of given specification, within constraints of cost and time, so as to deliver beneficial change defined by quantitative and qualitative objectives*".

The Project Management Institute's guide to the Project Management Body of Knowledge (PMBOK)[70] defines a project as a temporary endeavour leading to provide a unique product, service or result. The word temporary refers that any project must have defined start and end dates. The end is achieved when the project's objectives has been completed, or when the project is finished, because the objectives cannot be achieve, or when the project need does not longer exists.

However it is worthwhile to realize that the handover of the project is not the same as the end of the goods or services that the project delivers. Put differently, project management success and project success are not necessarily directly related (see figure 14).

Figure 14: Stages in a project life cycle



Source: Adapted from Munns and Bjeirmi (1996)

[69] Turner (2008)
[70] PMBOK® Guide (2008)

According to Munns and Bjeirmi[71], the focus, of project will tend to be of a long-term nature, pointing to the expected total life of the project. In contracts, project management is focused to the short-term life, until delivery of the project for use; therefore more concerned with the planning, production and control looking to succeed in delivering projects with appropriate performance standards, on time and within the budget (the triple constraint).

In attempt to bring a base concept of project management applied to supply chain context, some definitions of project management are presented in the table 5.

Table 5: Definitions of the concept of project management

Source	Definition- Main characteristics
Oisen (1971)	PM encompass *"the application of a collection of tools and techniques to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques structured to fit the task environment and life cycle (from conception to completion) of the task"*.
British Standard for Project Management BS60794 (1996)	Defined PM as: "*The planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance"*.
UK Association of Project Management (APM), (1995)	Understand PM as: "*The planning, organization, monitoring and control of all aspects of a project and the motivation of all involved to achieve the project objectives safely and within agreed time, cost and performance criteria. The project manager is the single point of responsibility for achieving this"*.
Burke (1993)	Understand PM as a specialized management technique, used to plan and control projects under a strong single point of responsibility.
Morris (1997)	PM include "*the process of integrating everything that needs to be done (typically using a number of special PM techniques) as the project evolves through its life cycle (from concept to handover) in order to meet the project's objectives"*.
PMBOK Guide (2008)	Describes a PM as "The application of knowledge, skills, tools and techniques to project activities in order to meet stakeholder's needs and expectations from a project."

As a summary from the previous definitions, a Project can be considered as a temporary endeavour devoted to be the achievement of some specific objectives, in which human, machines, material and financial resources are organized, to undertake a unique product, service or result, within constraints of cost and time. It has to be completed within a set of specifications, having defines start and end dates. In contrast, PM can be defined as the process of planning, organization, monitoring and controlling of all aspects of a project and the motivation of all the actors involved in it *(typically using a number of PM tool and techniques)*, in order to meet stakeholder's need and achieve the project objectives, within

[71] Munns and Bjeirmi (1996)

agreed time, cost and performance criteria. In summary, the author of this study agrees with Munns and Bjeirmi in distinguish between project and project management.[72]

The result of any project usually are measured in terms of three essential success criteria, called golden triangle (cost, time and performance), thus the success of a project relies on the punctual, accurate to quality and cost-effective delivery of materials, system and facilities. Typically, inside a mayor project there are many partner companies, stakeholders, suppliers, contractor involved. So, supply chain methodologies and processes can be applied to project management to ensure that the material, information and resources will be delivered as required, reducing delays and costs and promoting a successful result for the whole project.[73]

Following the contributions from Ayers[74], a Supply Chain Management Project (SCMP) in this research is outlined as an extension of the organization's overall strategy, conceived as the focal point of that strategy. Similarly, have the same three essential success criteria defined for normal projects. Thus, the success of a SCMP relies on the punctual, accurate to quality and cost-effective delivery of products, services or results. In addition have some additional characteristics:

1) Are strategic and important for the future of the business.
2) Require PM cross-functional coordination.
3) Projects are multicompany participation and broad sponsorship, so project management coordination across company borders is needed. New integration skills and knowledge is demanding.
4) Participants (internal departments, customers and suppliers are more likely to be described as partners instead of not uninvolved buyers and sellers.
5) In some cases, they have ambiguous deliverables. This requires special SCM knowledge and expertise to evaluate the deliverables for completion and to develop appropriate control responses.

2.4.2 SCM Project Knowledge Areas

In the section above a distinction between the project and project management, as well as how in the SCM domain a special area is being devote to the continuous improvement and achievement of the strategic goals through the use of project management technics were presented. In this section, further discussions will be devote to describe the nine knowledge areas of expertise and related knowledge requirements required for a project team in order to be successful on the context of project management but with a special focus on how project management technics can be applied as a means of achieving strategic plans for the supply chain improvements.

Regarding the nine knowledge areas of expertise, the PMBOK guide identifies four core elements which determine the deliverable objectives of the project: scope, time, cost and quality. Likewise, identify 5 additional areas, which provide the means of achieving the

[72] Munns and Bjeirmi (1996)
[73] Basu (2011)
[74] Ayers (2004)

deliverable objectives; namely: Integration, Human Resources, Communication, Risk, and Procurement. The following tables list the PMBOK processes for each knowledge area together with the process group to which the process is assigned.

2.4.2.1 Project Integration Management

According to the PMBOK guide, this knowledge area coordinate all aspects of the project (processes and tasks within the PM process groups) that are crucial to project completion, successfully engage stakeholders and meet project requirements. It, when properly performed, ensures that all processes in a project run smoothly (see table 6).

Table 6: Overview of project integration management processes

Knowledge Area / Process Group	**PMBOK Management Processes**
Initiating	- Project Charter Development: produce a document that formally authorizes the start of a project and document the initial requirements and expectation from the stakeholders
Planning	- Plan Development: use information from other planning processes, like strategic planning and return a project plan that is modified as the project proceeds. This plan provides baseline about how the project will be planned, executes, controlled, and closed.
Execution	- Plan Execution: control performance of the work defined in the PM plan and provides appropriated feedback to change it.
Controlling	- Control Project Work: encompass the tracking and reviewing the progress to achieve the deliverables defined in the project plan. - Integrate Change Control: process of reviewing all changes requests, approving changes and changes to the deliveries. It produces corrective actions that have to be incorporated into project plans, assuring that work results meet requirements.
Closing	- Close Project: delineate all the necessary activities to formally complete the project. It includes the acceptance of the product, service or result transition.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.2 Project Scope Management

Processes in this knowledge area are ranked with a special importance to the SCM improvement projects. Two questions regarding the scope of supply chain projects usually need to be addressed: 1) How to divide programs into project or project into phases, 2) what supply chain level set better for the supply chain project, thus whether it's departmental, business unit, or supply chain. The Management processed in this knowledge area are presented in the table 7 below.

Table 7: Overview of project scope management processes

Knowledge Area / Process Group	PMBOK Management Processes
Initiating	- Description of the project deliverable: a detailed description of the project deliverable is required. So this process encompasses the definition of supply chain improvement's deliverable, which can be a product, a service or a result.
Planning	- Scope Planning: during the project plan development process ongoing analysis of the project is performed. As a result the project scope of a supply chain project is adjusted with greater specificity as more information about the project is known. - Scope Definition: Using the output of the project plan, a refined work breakdown structure (WBS) is performed. The WBS split up the project into task and smaller and more manageable components or tasks. Thus WBS structures and defined the total scope of the project.
Controlling	- Scope Verification: is the process of formalizing acceptance of the deliveries of the project with the executive authority (steering committee). - Scope change Control: is the process of continuous monitoring and reviewing the status of the project and deliverables and changing the scope baseline.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.3 Project Time Management

Time management approach for the supply chain projects is similar to those needed for other types of project and encompasses the process required to do an effective time management of the project. The processes in this knowledge area outlines in the table 8 below.

Table 8: Overview of project time management processes

Knowledge Area / Process Group	PMBOK Management Processes
Planning	- Activity Definition: using the outputs of the WBS, this process defines the specific project activities to be performed to carry out the project deliverables. - Activity Sequencing: this process encompasses the identification and documenting of relationship and dependencies among the project activities sequencing them in the order they are performed. An output of this process is a Project Network Diagram. - Resource Estimation: the purpose of this process is to estimate the type and quantity of the resources required to accomplish the activities defined in the WBS. Some resource can be allocated from to the own resources the participating supply chain organizations have others must be procured from outside. It process provides a framework for management review and control. - Activity Duration Estimation: the purpose of this process is to estimate the times required to accomplish the activities previously

	defined in the WBS and provide a framework for management review and control. - Schedule Development: this process encompasses the entering the activity sequences, duration, resource requirements and schedule constraint into the scheduling tools to generate a schedule with specific start and finalization dates for completing project activities.
Controlling	- Schedule Control: is the process of monitoring and reviewing the status of the project schedule throughout the project as work progress and manage changes to the schedule baseline. In doing that the schedule baseline is compared with the performance of the actual schedule; so changes into the current baseline are added if needed.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.4 Project Cost Management

Cost management approach for the supply chain projects comprises the process required to do an effective cost management of the project so that, the project can be completed within the approved budget. The processes in this knowledge area outlines in the table 9 below.

Table 9: Overview of project cost management processes

Knowledge Area / Process Group	**PMBOK Management Processes**
Planning	- Cost Estimating: the process to estimate the monetary resources required to accomplish the whole activities of the project. It converts unit cost and duration into project cost. Risk should be evaluated for each cost component. - Cost Budgeting: this process encompasses the creation of the cost baseline necessary to monitor project costs.
Controlling	- Cost Control: is the process of monitoring and reviewing the status of the project to update the project budgeting and managing changes to the cost baseline. It also produces an estimated cost at completion of the project, allowing to alert managers about the probability of the final actual costs.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.5 Project Quality Management

Project Quality Management approaches comprises the processes that determine quality policies, objectives and responsibilities in order to guarantee that the project will satisfy the stakeholders' requirements for which it was initiated (see table 10).

Table 10: Overview of project quality management processes

Knowledge Area / Process Group	**PMBOK Management Processes**
Planning	- Quality Planning: identify quality requirements, and/or standards that the project define, plans for, and execute for quality. It enable the project team to ensure quality throughout the life of the project
Executing	- Quality Assurance: this process incorporates the execution of the quality plan and the realization of periodic audits to measure the quality of the solution being developed. It ensures that the plan is appropriate and is being implemented.
Controlling	- Quality Control: is the process of monitoring, examining and recording results of executing quality activities to assess project performance and recommend necessary changes. It also includes outcomes, like cost and schedule performance.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.6 Project Human Resource Management

Project Human Resource Management approaches comprises the processes required to make an effective use of the human resources assigned to the project (see table 11). Many supply chain projects involve cross-functional and multicompany teams which can include different stakeholders, customer, partners, and individual contributors, performing organization, project leader and team members. Usually these project members are having different mind-sets and/or cultural backgrounds, so integrate these bodies into effective teams, can be a highly challenging endeavour. To overcome these difficulties sustainable collaborative practices need to be addressed in order to overcome these difficulties.

Table 11: Overview of project human resource management processes

Knowledge Area / Process Group	**PMBOK Management Processes**
Planning	- Organizational Planning: is the process of identifying, documenting and assigning project roles, responsibilities, and required skills, an organization structure and creating staffing management plan for the project. Usually this plan is flexible, depending on the needs of the project. - Staff Acquisition: this process using the outputs of the responsibility assignment matrix (RAM) is concerned with getting the staff necessary to complete project activities, ensuring that these resources meet project requirements.
Executing	- Team Development: this process is concerned with the developing individual and group competences, team member interaction and overall team environment to enhance project performance.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.7 Project Communication Management

Project Communication Management comprises the processes required to guarantee timely and appropriate communication both internally (at all organizational levels) or external to the organization (supply chain partners) between diverse stakeholders involved in a project. It included creation, gathering, distribution, storage, retrieval, and ultimate disposition of project information (see table 12). As many supply chain projects involve multicompany teams, this factor increase the complexity of these processes. In addition some levels of trust and mutuality between supply chain partners need to be created.

Table 12: Overview of project communication management processes

Knowledge Area / Process Group	PMBOK Management Processes
Planning	- Communication Planning: process of transform Stakeholders communication requirements into a communication management plan. It covers information stakeholders need in terms of contents, forms of delivery, frequency and IT support systems.
Executing	- Information Distribution: process of guide the execution of the communications plan.
Controlling	- Performance Reporting: it is the process of monitoring and controlling communication in the project. It includes both current status and predictions of future performance based on actual results.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.8 Project Risk Management

Project Risk Management processes according to PMBOK search to maximize the likelihood and impact of positive events and decrease the likelihood and impact of negative events in the project (see table 13). The risk impact of supply chain project comes mainly from four situations: strategic goal for the project, multicompany team participation, the need for paradigm changes and ambiguous deliverables.

Table 13: Overview of project risk management processes

Knowledge Area / Process Group	PMBOK Management Processes
Planning	- Risk Management Planning: this process defines how to conduct risk management activities for the project. - Risk Identification: is the process of identifying and documenting which risks may affect the project. - Qualitative Risk Analysis: process of prioritizing risks for further analysis, based on their impact and the probability of occurrence. - Quantitative Risk Analysis: process that analyzes the numerical effect of those prioritized risks events on overall project objectives. - Risk Response Analysis: process of developing options and determining actions to enhance opportunities and reduce threats to projects objectives.
Controlling	- Risk Monitoring and Controlling: it is the process of identifying, analysing, and planning for newly arising risk, keeping track of the identified risks, monitoring trigger condition for contingency plans, monitoring residual risks, and reviewing the execution of risk response while evaluating their effectiveness.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.2.9 Project Procurement Management

Project Procurement Management processes according to PMBOK includes the processes needed to manage effectively the acquisition of products, services, or results from outside the project team. Selecting partners or being selected as a partner is a frequent activity in SCMPs. Because supply chain efforts usually involve many companies along the supply chain working in partnership, new an efficient ways of doing procurement processes are required. In this context, tie collaboration with supplier, shared responsibilities and joint decision-making in supplier selection are means to manage supply chain projects successfully (see table 14).

Table 14: Overview of project procurement management processes

Knowledge Area / Process Group	PMBOK Management Processes
Planning	- Procurement Planning: this process defines and document how to conduct project purchasing decisions, including decisions about the type of contract needed, and identifying potential providers for the project. - Solicitation Planning: this process includes the development of procurement documents and evaluation criteria.
Executing	- Solicitation: includes gathering providers' responses, usually through bidders' conferences and advertising. - Source Selection: processes of review supplier responses and the adjudication of the contract to the selected supplier who is going to produce the goods and services. - Contract Administration: this process is concerned with the administration of the procurement relationships, review of the contract performance and managing changes as needed.
Controlling	- Contract Closeout: this process guide a formal close to the project procurement.

Source: Adapted from PMBOK® Guide (2008) and Ayers (2004)

2.4.3 SCM Project Drivers

A project according to the PMBOK Guide terminology can produces a physical product, a service or a result. Most projects in organizations are addressed at departmental level. However as the maturity level of an organization is increased, the need to carry out portfolio business and supply chain projects will be increased too. In the context of SCMP the source of the projects can come from company strategic planning as well as from supply chain trading partners' requirements or even from the market itself (see table 15).

Table 15: Supply chain management project drivers

Drivers	Description
Market demand	Correspond to the necessity for all companies to understand the forces that will drive consumers to buy a product or pay for a service and then put business endeavours in translate those ideas into reality. For instance, a demand for a new product introduction either on a one-time or on-going basis; another example could be the need to improve the market share of an existing product. In first example, market demand for a new product, it might involve a supply design to support the introduction of the new product in a remote area. In the second example, might need the support of the supply chain at different stages in a product's evolution.
Business need	Business drivers are the collection of people, information and conditions that initiate and support project activities oriented to help an organization to achieve its mission. For instance, many companies seek to apply continuous improvement programs on an on-going basis as mean to increase revenues and profits, improve performance or reduce costs. SCM may have its own continuous improvement programs.
Customer requests	Correspond to a significant driver for SCMPs. Strategies like design-to–order or make-to-order in addition to the more classical make–to-stock model must be supported by the Supply chain design. For instance, an upgrade of an existing warehouse solution with concerns to the supply and installation of new commissioning system operated by Pick to Light technology.
Technology advances	Typically, the concern is that old technology is no longer part of the mainstream and is poorly supported. Sometime the hardware provider has gone out of the market. Sometime the cost of continuing operating with an old technology is too high. And sometime the software technology is archaic, and no longer compatible with other systems. So all of these issues are driving the need for upgraded or new product technologies, new processes for manufacturing or distribution, or advances in supply chain software tools. For instance, Software upgrade of the database and operating system of the existing Warehouse Control system under virtual basis.
Legal requirements	Regulatory changes tend to affect design, production and distribution of supply chain products. For example: legislation encouraging the development of energy efficient and renewable energy products.
Social needs	Correspond to projects focused on meet social needs like civil infrastructure or fund raising.

Source: Adapted from PMBOK® Guide (2008)

In addition, a supply chain effort can be a project or a program. Thus, a project if the supply chain effort is to be a temporary endeavour undertaken to create a unique product, service or result; or a program if the supply chain initiative which is undertaken to create a product, service or result, include in addition, elements of on-going activities. So results of the supply chain efforts can be classified into four categories: SCM Service-based Projects, SCM Result-based Projects, SCM Product-based Projects, SCM Mixed Delivery Projects and SCM Programs (see table 16).

Table 16: Supply chain management projects classified by result types[75]

Project / Program results	Description
Service-based SCM Projects	Correspond to a project with creates something unique in the form of a service. Usually, these projects do not have defined a precise end. Thus, the exact handover date of the deliveries of the project to the final user is not well arranged. So, these kinds of projects can continue for a couple of years after initiation, evolving from "set-up" into an "on-going" mode. An example of a Service-based SCM Project is offering IT services for a specific customer, or offering maintenance services for a warehouse installation.
Result-based SCM Projects	Such kinds of projects are also characterized by not having a precise defined end. Thus they can continue for many years until the project will be setting up into an on-going mode. An example of a SCM Result-based Project is a company facing a partnership with a local distributor to increase the market sharing in an existing market.
Product-based SCM Projects	Correspond to supply chain efforts linked to a new product introduction or focused to improve the market share of an existing product. In this kind of projects the buyer (customer) own the project and its deliverables after the project is completed while the seller (e.g., designers, suppliers, project manager, and contractor) achieve the hand-over of the project and its deliverables over the owner. An example of a SCM project is the development of a new product.
Mixed Delivery SCM Projects	Correspond to a supply chain effort, where the results may produce all three project result types: products, results and services. An example of a mixed delivery is a new customized warehouse solution in a greenfield location, regarding to the supply, delivery and installation of a logistics system for pharmaceutical products.
SCM Programs	Correspond to a group of projects within a program, where the results can involve operations once the solution begins to operate. Thus, a program is an endeavour that in addition to project unique non-repetitive activities has components of continuous, on-going operations. A supply chain improvement program is an example of a program result.

2.4.4 Distributed Project Management (DPM)

During 1980s and 1990s, it was widely accepted by practitioners and academics that a best practice in product development project management involved co-locates cross functional team using a combination of digital project development tools and conventional paper-processes. It allows to speeds up communication, reduce coordination, and enable cooperation across functional departments within an organization.[76] Reducing the spatial distance between cross-functional team members, improves inter-personal communication, enables integration, and creates opportunities for continuous collaboration between project team members; and finally is associated with better product development performance.[77]

[75] Adapted from Ayers (2004)
[76] Anacona and Cadwell (1992); Mckelvey *et al.* (2003); Eppinger and Chitkara (2009)
[77] Bardhan *et al.* (2012)

In more recent years, with the globalization pressures and the rise of information technologies a new paradigm has emerged whereby companies are utilizing skilled team members dispersed around the world to manage global distributed projects in a collaborative manner.

The term distributed project teams appears to have coined in the earlies 2000s. Early definitions looked for the contracts between dispersed and face-to-face teams and therefore focused on physical dispersion and IT-based interaction.[78] In fact, the foundation of first definitions includes the notion that dispersed teams are teams in which members rely on technology-based communication to interact each other across geographic borders.[79] However this concept has evolved as concepts like temporal and organizational dispersion have been added to the initial definition. Indeed, members of a distributed team are not constrained to one physical location, on the contrary can be located throughout the world.[80] Likely are dispersed across temporal borders due the team member's locations in different time zones,[81] and due the adoption of asynchronous communication tools (such e-mails), that constraints the real-time interaction between team members.[82] Finally, members of a distributed team are often served from different organization working across organizational boundaries.[83] Another aspect that has been evolving in the definition of a distributed team is the degree of interaction with electronic media. Maznevski and Chudoba, state that some face-to-face interactions should be allowed in a distributed team as long the majority of interaction occurs in a virtual way.[84] Martins *et al.* drawing on prior and newer definitions have defined distributed or virtual project teams as teams in which members use technology to interact which each other across multiple organizations geographically dispersed, to accomplish mutually dependent tasks.[85]

In this new scenario, ICTs are playing a role as a supporting mechanism of communication to bridge the spatial distance between team members when they are separated by distance and time[86]. By the same token Bardhan *et al.*[87] suggest that the use of new ICTs can reduce the negative effects of physical team dispersion in the project performance by enabling information exchange and close collaboration among project team members. With recent improvements in bandwidth communication and computer technology, several companies are offering virtual meeting technologies, in which high-definition sound and video are used to give their teams members the sense that they are sitting and working together in the same room and practically can touch one another, even if they are distant several thousand of kilometres and dozen time zones away.[88]

According to Bala *et al.*[89] projects in which team members from more than one geographic location contribute to the different phases of a project, is a growing practice in many organizations and industrial sectors. The increase in outsourcing, moving of various

[78] Bouas and Arrow (1996)
[79] Lurey and Raisinghani (2001); Bell and Kozlowski (2002)
[80] Montoya *et al.* (2001)
[81] Kayworth and Leidner (2000)
[82] Bell and Kozlowski (2002)
[83] Maznevski and Chudoba (2000); Zigurs (2003)
[84] Maznevski and Chudoba (2000)
[85] Martins *et al.* (2004)
[86] Amaral *et al.* (2011)
[87] Bardhan *et al.* (2012)
[88] *Ibid.*
[89] Bala *et al.* (2010)

operations of a company to another country and alliance building has resulted in project efforts that require the orchestration of different companies with different cultural backgrounds, separated by geographic and legal boundaries.[90]

In the last decade, researchers have often studied different factors that affect the performance of geographically distributed projects. A summary of the influence factors that have been investigated is shown in table 17.

Table 17: Enabler for geographically distributed project

Enablers	Main characteristics
Re-evaluating processes and procedures	- The use of formal processes and communication infrastructures as a mean to reduce the potentially negative impact of the physical separation of the project team members (Duarte and Snyder, 2001; Fink, 2007). - Nidiffer and Dolan (2005) tackled previous concepts and state that organizations should be open to rethink processes, and use new methods and tools to successfully manage geographical distributed projects.
Tools and Communication technologies	- The role of recent development in ICTs as contributory enabler for distributed project management (Pick *et al.* 2008; Yu *et al.* 2009; Amaral *et al.* 2011; Bardhan *et al.* 2012). - Software providers have released collaborative tools such as web-enable versions of project management tools enabling the distribution of information to multiple sites and multiple users. Likewise many organizations are using project web-based sites and work spaces, for smart sharing and storing of project information. It's clear that these tools and technologies are available to support DPM needs (Nidiffer and Dolan 2005). - Schweitzer (2005) reinforces that providing effective tools (e.g., personal computers, cell phones, high-speed internet access, software) as well as providing trainings in how working effectively with these tools can have a positive impact on distributed team effectiveness.
Human dimension of teamwork	According to De Dreu and Weingart 2003, individual and interpersonal relationships have been strongly correlated with distributed team performance and member satisfaction. New human interaction skills are required in distributed teams. For instance, project managers should develop new skills as orchestrators of project team relationships. In addition, negotiations shall be a core competence for project managers who must balance the needs of the increasing set of stakeholders (Nidiffer and Dolan, 2005).
Organiza-tional Support	Top managers should support distributed teams, in terms of coordination and communication support, human resource support, resource allocation, and team empowerment: - Coordination and communication support relationships between team and functional departments (Denison *et al.* 1996) and assistance to the team to access the necessary information to complete the assigned tasks (West 2004) should be provided.

[90] Nambisan and Sawhney (2007); Jaruzelski and Dehoff (2008)

	- Human resource support in terms of proper staffing, training and professional development is positively related to teamwork effectiveness in distributed teams (West, 2004; Drouin and Bourgault, 2013). - Resource allocation refers to knowledge, skills and competences need to be allocated to support the team to achieve project goals (West 2004). - Team empowerment is recognized by Bourgault *et al.* (2008) as a significant enabler of teamwork effectiveness in distributed teams. This support may positively impact team formation, management and teamwork effectiveness in distributed teams (Bourgault *et al.* 2008; Zwikael, 2008; Drouin *et al.* 2010a)
Performance Support	Drouin and Bourgault (2013) state that top management monitoring support the team's progress in achieving objectives and for that it is positively related to team performance.
Creation of a collaborative culture	Eppinger and Chitkara (2009), argues that the transition from co-located to distributed teams should be supported by the creation of a collaborative culture. They also affirm that many organizations have been successfully in creating a collaborative culture by sending a manager from a Headquarters location to a new subsidiary office during a couple of years. This practice allows training the local team on the Headquarters' processes and procedures and reinforces communication links with Headquarters offices.

To the extent business has become increasingly global, project management practices have become globalized as well. It seems that best practices in SCMPs must involucrate the drivers discussed above and extent his borders from cross-functional collaboration to a mode of global collaboration in which distributed project teams can coordinate their work in an effective manner. This transition must be supported, by new ICTs as well as by new forms and ways to collaborate among supply chain partners across geographic, temporal, and organizational borders together with well-defined strategies to overcome languages and cultural differences. Meaning, geographically distributed SCMPs require a more unified approach to infrastructure, technologies, shared information systems and entirely digital set of unified processes and standards. This approach should ensure that project team members can access, synchronize and exchange appropriate information and communication across organizations while at the same time should support the creation of a collaborative culture among project team members.

2.5 Understanding the Collaborative Relationships in Organizations

In the search for performance improvements several approaches have been investigated to enhance collaborative relationships within organizations and among supply chain as a catalyst for the evolution of a variety of collaborative planning initiatives. Judging by the "soft" issues which were above referred, two different collaborations initiatives can be selected: Firstly, supply chain collaboration efforts such as Efficient Consumer Response (ECR), Continuous Replenishment (CR) and Collaborative Planning Forecasting and Replenishment (CPFR) which have been proposed as strategies to manage a greater process integration, visibility and collaboration. More specifically, these initiatives aims for the driving need to develop an on-going and long-term trust-based relationship from suppliers' supplier to customers' customer, with the sharing of strategic information and process integration in order to fulfil consumer wishes, better, faster and bring mutual benefits to all supply chain partners in the form of reduced inventory and cost[91]. Secondly, maturity models which have been proposed as an attempt to address the extent to which enterprise or supply chain business process for recurring collaboration practices are designed, measured, improved and managed, with the objective of creating sustained collaboration practices[92]. In this way, processes are now viewed as assets that must be developed until them reach an advanced maturity level and maturity models as a means that can be used to help facilitate enhanced process maturity.

2.5.1 Supply Chain Collaboration Efforts

An early origin of term logistics has its roots in the military domains. Indeed, logistics received much attention during both world wars. In that period of time, was needed greater movement of troops and supply than any other period in the history. Over the time, logistics has moved into the business area and in this context was envisioned to have responsibilities for managing all inbound and outbound activities associated with product flow from the points of origin to the end customer[93].
Logistics Management is defined by the Council of SCM Professionals[94] as that part of SCM involves planning, implementing and controlling efficient, effective upstream and downstream flow and storage of products, services and related information between the point of origin and the point of consumption in order to comply with the customer requirements. Logistics is generally seems as managing the flow of material, services and related information as within one firm, although it manages flows between a company and its suppliers and customers.

Among the activities included in the logistics function are: demand forecasting, purchasing, material management, warehousing, material handling, packaging, inventory management, distribution planning, production planning, order processing, transportation, and handling of related information flow bout raw materials, work in process and finished products[95]. In a wide sense, logistics can be understood as an integrated management concentrated in four main fields: Supply Logistics, Production Logistics, Distribution Logistics and Inverse Logistics[96].

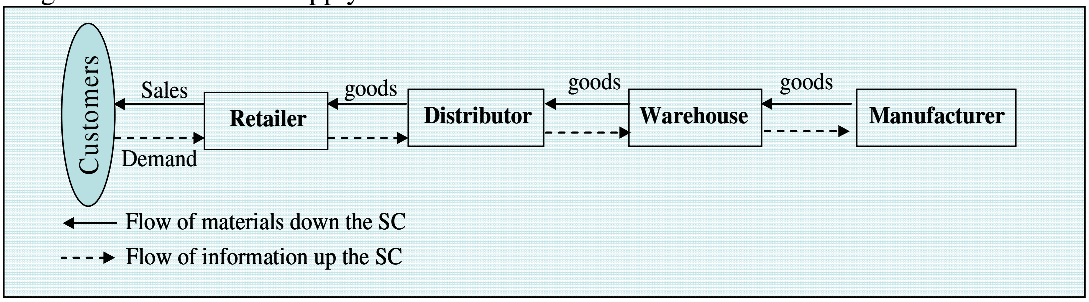
From this early vision was not always clear how the term "logistics" differs from the concept of SCM. Under this traditional concept the SCM was generally based on the coordination of activities within the procurement, production and distribution functions. Moreover, as activities such as transportation and inventory control were in cost-conflict, they were considered as a part of logistics[97]. So each member of the supply chain based his production orders solely on replenishment orders placed by immediate downstream member, on his

[91] Cited in Barratt and Oliveira (2001); Saha (2003)
[92] Lockamy and McCormack (2004)
[93] Lummus *et al*. (2001)
[94] Lummus *et al*. (2001); Council of SCM Professionals (2015)
[95] Ballou (2007)
[96] Lambert *et al.* (1998)
[97] Ballou (2007)

inventory levels and on his work in process goals. Moreover each member strove to develop local strategies for optimizing his own organization without considering the impact of his decisions on the performance of the other members. Owing to that, each echelon in the supply chain only has information about what their immediate downstream level wants and not on what the end customer needs.

The traditional supply chain was characterized by a feed-forward flow of materials and the upstream feedback flow of information with a lack of visibility of the whole supply chain and a little coordination both across the functional departments within a company and between firms along the supply chain[98] (see figure 15).

Figure 15: Traditional supply chain structure



Source: Adapted from Sari (2008)

2.5.1.1 Vendor-Managed Inventory (VMI)

The pace of change and the uncertainty about the evolution of the markets coupled with revolutionary advances in communication and information technology has led to new and more competitive, unstable and complex environments. In today's fast-paced business scenario there is greater pressure that ever before to control and reduce costs, while maximizing customer satisfaction. To survive in this environment, companies have to be aware of the supply chain they participate and to understand the roles that they play.

It is a common view that under this new scenario in which organizations must operate demand a new approach as a strategy for competing. In this context, several authors have recognized that improved exchange of information and well establish collaborative strategy appear to be facilitating the creation of new competitive advantages for the entire supply chain[99]. Put in another way, organizations are extending outside their boundaries as a way to compete forming networks of companies, therefore their strategies should be not only based on minimize time, enhance technology and squeezing more asset productivity but also should be based on the development of long-term relationships strategies among the partners in a supply chain. It is the business models and collaboration network that compete.

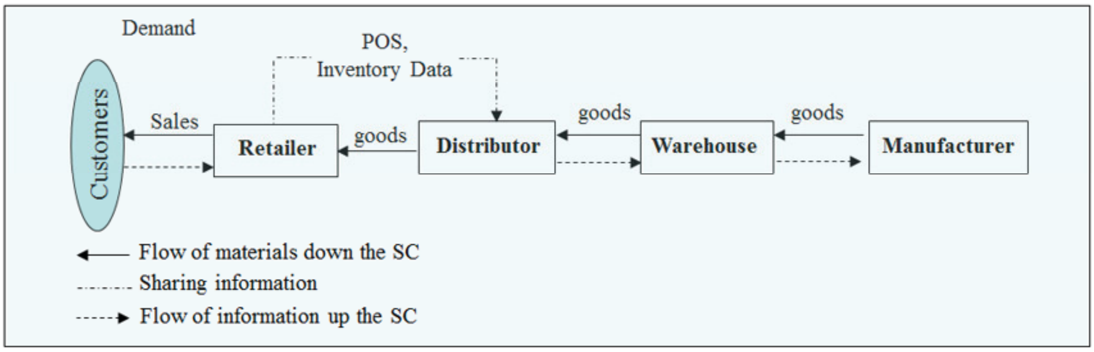
Owing to this new business scenario, process management within a company and along the supply chain are now evolving from an extremely traditional and vertical functional management system, to a matrix arrangement of highly integrated processes[100]. This new arrangement is looking to promote greater integration, visibility and collaboration both across

[98] Disney and Towill (2003)
[99] Yao, *et al.* (2007); Lockamy and McCormack (2004); Loeser (1999)
[100] Hammer and Stanton (1999)

functional departments within an organization and between multiple trading partners along the supply chain. In fact, this new structure is looking to engage companies along the supply chain into an on-going and long-term relationship allowing them to bring mutual benefits to all collaborating partners involved as well as an increasing customer service level.

In reacting to this scenario, Vendor-Managed Inventory (VMI) as a supply chain strategy was developed in the mid-80s, whereby the retailer shifts the ownership of inventories and leaves the sole responsibility of managing the customer's inventory, including the replenishment process, to its immediate upstream member (supplier or manufacturer) and the upstream member allows him to access the real-time demand information in return[101] (see figure 16). VMI may be seen as the first dyadic relationship between suppliers and customers.

Figure 16: Supply chain structure under VMI



Source: Adapted from Sari (2008)

VMI offers a competitive advantage for both. For retailers, because it results in higher product availability, more effective inventory management and less uncertainty regarding inventory turnover and customer service levels. For suppliers, on the other hand, because it results in reduced bullwhip effect, better utilization of manufacturing capacity, as well as better synchronization of replenishment planning[102].

However, it possesses numerous challenges and problems in practice that may reduce the benefits expected. For instance, retailers are not satisfied with the lack of collaboration with their suppliers, suppliers' inability to deal with products promotions, as well as with the forecasting ability of their suppliers[103]. On the other hand, suppliers are not satisfied because the benefits from inventory reductions are not equally distributed between retailers and suppliers[104].

The major weakness of VMI often lies in the insufficient in visibility of the whole supply chain. That means that the point-of-sale (POS) historical data and inventory levels are disregarded while the replenishment process relies on the immediate upstream link. Due to the weakness listed above, the grocery sector has to a large extent abandoned VMI and has led the search for alternative techniques[105].

---

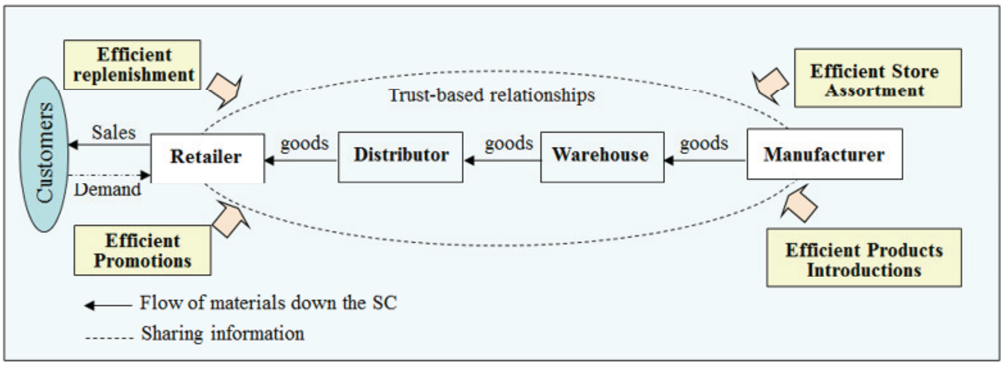
[101] Yu H. *et al.* (2009)
[102] Achabal *et al.* (2000); Sari (2008)
[103] Sari (2008)
[104] Yao, *et al.* (2007)
[105] Sheffi (2002)

2.5.1.2 Efficient Consumer Response (ECR)

In 1985, a study developed by Kurt Salmon Associated showed than the delivery time in the apparel industry was excessively long due the time spent in warehouses or in transit. As a result of this study the Quick Response (QR) Program was developed. As a result of this new strategy retailers and suppliers were allowed to work together with the objective to respond more quickly to consumer needs by sharing on-line information of sale data while at the same time increase the profitability of inventory by supplying the inventory when and where they are needed[106].

Later, in the early 90s the Grocery industry in the USA was struggling with stagnation of revenues, rising cost, and scarcely increasing of productivity. This situation developed a driving need to develop a trust-based relationship between manufactures and retailers among key trading partners across the grocery supply chain**.** As Kurt Salmon Associates states, a business philosophy similar in concept to QR named Efficient Consumer Response (ECR) was created as an attempt of sharing accurate information through a paperless system in order to fulfil consumer wishes, better, faster and take out of the supply chain cost which do not add consumer value[107]. ECR focuses is develop a supply chain in which information and product flow quickly and reliable to where they are needed[108]. Benefits could be achieved by excelling in four core strategies: efficient promotions, efficient store assortment, efficient new products introductions, and efficient replenishment[109]. Despite not reaching its full potential in terms of delivered benefits, ECR is becoming increasingly popular in many international markets, because it is viewed as a means of transforming the grocery supply chain from a "push system" to a "pull system", calls for the creation of a timely, accurate and paperless flow of information, as through Electronic Data Interchange (EDI) [110] (see figure 17).

Figure 17: Supply chain structure under ECR



Source: Based on Kurt Salmon Associates (1993)

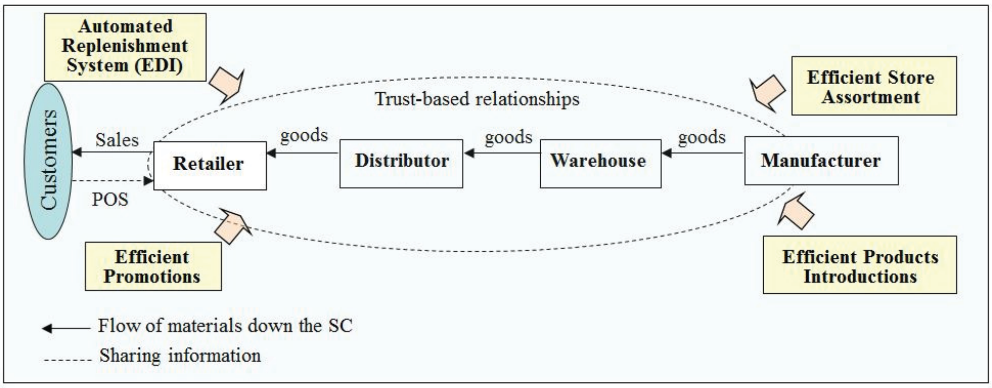
[106] Fiorito *et al.* (1995)
[107] Cited in Barratt and Oliveira (2001)
[108] Kurt Salmon Associates (1993)
[109] Cited in Svensson (2002)
[110] Svensson (2002); Harris *et al.* (1999); Lohtia *et al.* (2004)

2.5.1.3 Continuous Replenishment (CR)

A further development from VMI and ECR, in the mid-90s, Continuous Replenishment (CR) emerged to address and improve ECR´s four core strategies. As a part of its evolution, CR moves one step ahead from pushing products from inventory to pulling products based for the first time on POS and inventory information in real-time to generate a sales forecast and address some of the VMI weaknesses by requiring supply chain trading partners to share more data and information through an automated replenishment system[111]. The idea of this model is to replenish the inventory constantly by working closely with suppliers and distributors. However, if the replenishment process involves many shipments, the cost could be too high, causing the supply chain to collapse. Therefore, both tight integration and Electronic Data Interchange (EDI) ability are required in order to make the ECR promise a reality.

Although CR has provided a better approach to replenishment and product assortment processes, its untimely and inefficient processing of EDI, has limited its ability to use the retailer's information to synchronize productions plans to customers' requirements[112]. So, CR programs still shows a clear gap between ECR promises and CR practices, especially in relation to the process of creating the sales pattern and then predicting future events as well as, to the promotion and new product introduction process[113] (see figure 18).

Figure 18: Supply chain structure under CR



Source: Based on Barratt and Oliveira (2001)

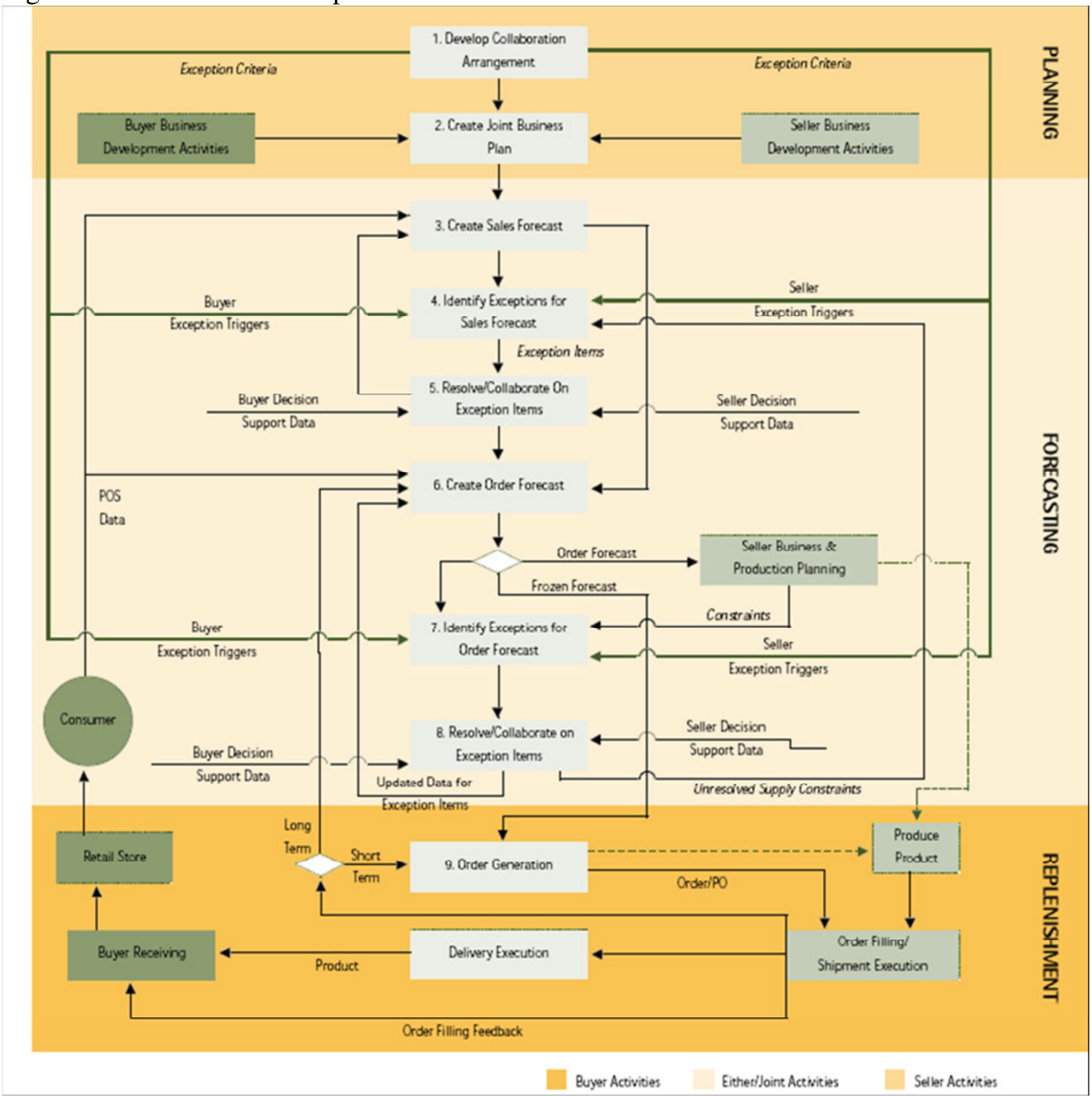
2.5.1.4 Collaborative Planning Forecasting and Replenishment (CPFR)

In the mid-90s, Warner-Lambert and Wal-Mart supported by SAP, Manugistics and Benchmarking Partners (now Surgency), started the first Collaborative Forecasting and Replenishment project. Initially it was referred to as CFAR which intended to reduce inventories across the supply chain by means of comparing sales and orders forecasts with each trading partner and making visible any forecast differences early enough for the partners to resolve them[114]. In 1997, the "planning" element was incorporated to create Collaborative Planning Forecasting and Replenishment model (CPFR). In addition a sub-committee of the American Voluntary Inter-industry Commerce Standards (VICS) organisation one year later issued the first guideline of CPFR[115], referred to as a nine-step joint business planning process

[111] Sabath *et al.* (2001)
[112] Andraski (1994)
[113] Barratt and Oliveira (2001)
[114] Seifer (2003)
[115] GC1 (2002)

that aims to enhance supply chain visibility to improve planning, forecasting and replenishment through information shared between suppliers and retailers. The detailed steps of this first CPFR are shown in figure 19.

Figure 19: CPFR Process steps – from VICS – CPFR Model



Source: Min and Yu (2008)

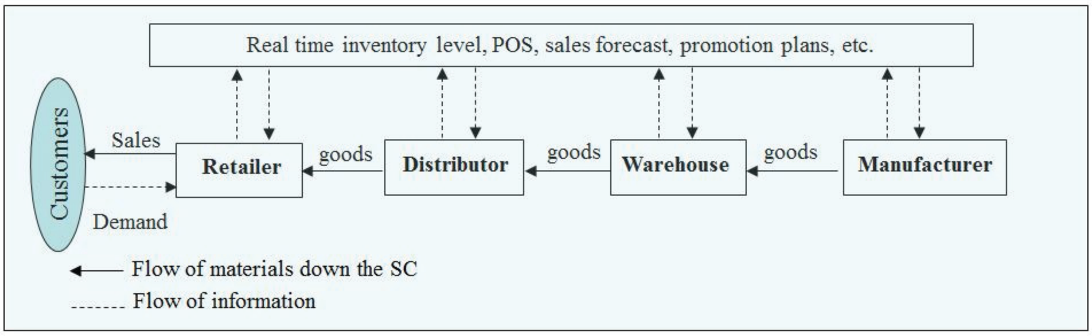
In 1999, the VICS published the VICS CPFR Roadmap providing a comprehensive and detailed plan for the companies to begin a CPFR relationship[116]. After that, in 2002 under the auspices of the Global Commerce Initiative (GCI), a joint committee of VICS and the ECR organization updated the original VICS CPFR guidelines to incorporate global requirements. This group reviewed and incorporated contributions in the areas of promotions planning, exception resolution, multi-tier collaboration, and synchronization[117]. Finally, the VICS

[116] VICS CPFR (1999)
[117] GC1 (2002)

CPFR committee in 2004 developed the major revision of the original CPFR model, aimed to overcoming shortcomings highlighted in the original process[118].

CPFR is a SCM strategy that engages the trading partners into exchanging information in an on-going and long-term relationship for achieving strategic goals that add value to all collaborating partners in the form of reduced inventory and increased customers service level[119]. With CPFR, inventory levels, POS data, promotions plans, sales forecast and all other information that may be influential on the market demand are shared between collaborating partners[120] (see figure 20).

Figure 20: Supply chain structures under CPFR



Source: Adapted from Sari (2008)

According to the latest version of the CPFR guidelines[121], the CPFR planning process structures an interactive cycle of four main activities, so called Collaboration Activities: Strategy and Planning, Demand & Supply Management, Execution and Analysis. Figure 21 shows the crucial role of the consumer by placing it in the centre of the model, as the focus of collaborate efforts. Likewise, it shows the manufacturer (seller) and the retailer (buyer) as trading partners, working together in a close relationship at any step of the main eight specific collaboration activities shown in the model through the arrows.

The initiative of CPFR was to cover the gaps left by the traditional collaborative practices listed above[122]. Principally it differs from the others in that it brings mutual benefits to all the supply chain partners involved by using intensively the most modern information and communication technologies to support the exchange of complex quantities of data and requires all members of supply chain to develop demand forecasts, productions and purchasing plans, and inventory replenishments. Furthermore, for the first time issues related to the visibility of POS data and all inventory in the downstream part of the supply chain are more fully addressed[123] (see figure 22).

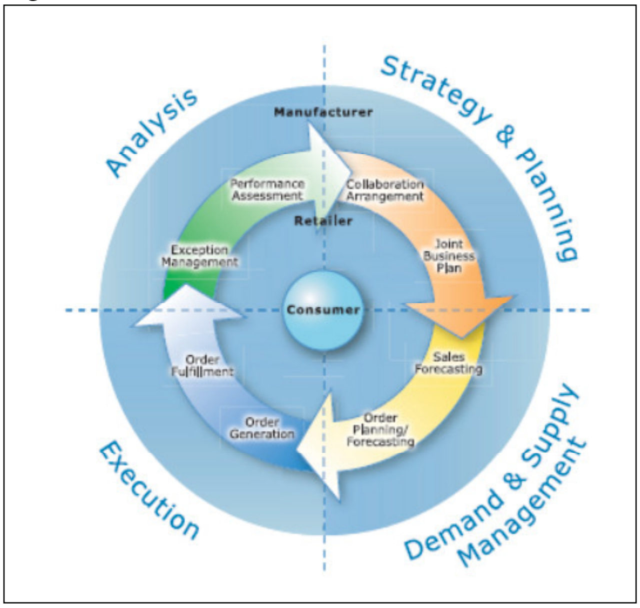
So, for the next years, in order to attain the benefits offered by CPFR in a larger scale than is prevalent now, high levels of internal and external cooperation (expand collaborative planning initiatives from suppliers' supplier to customers' customer) are required. CPFR requires an earlier and freer exchange of information among functional departments within an

---

[118] VICS CPFR (2004)
[119] Saha (2003)
[120] Sari (2008)
[121] VICS CPFR (2004)
[122] Cited in Barratt and Oliveira (2001)
[123] Barrat (2003)

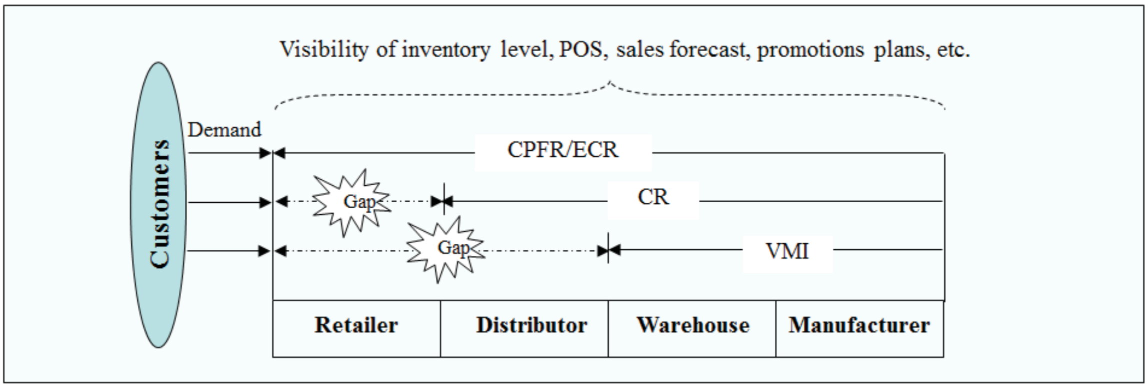
organization given needing forecast information for planning purposes. Specifically, internal issues need to be synchronized firstly. Then collaboration among trading partners would be pursued.

Figure 21: CPFR model



Source: VICS CPFR (2004)

Figure 22: Gaps in supply chain visibility



Source: Adapted from Barrat (2003)

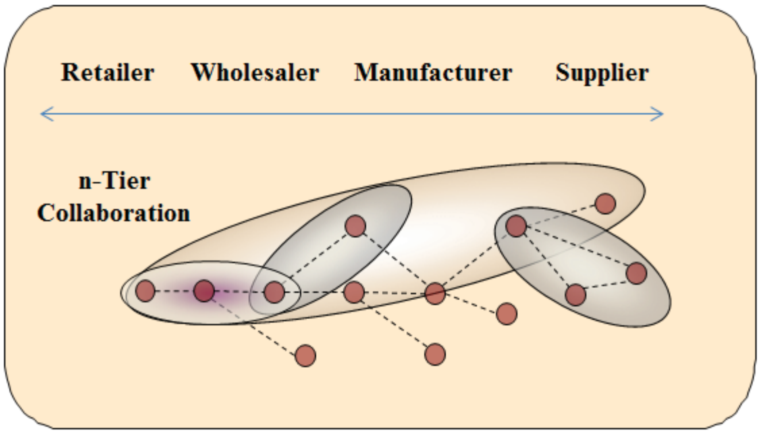
Put differently, the scope of the inter-organizational integration should be rolled out to include multiple tiers to the model where all the trading partners can exchange information and collaborate with each other at the same time in order to achieve network effect[124]. By sharing certain of information as close to real-time as possible between multiple trading partners, the impact of change will be minimized and performance of each nodes and the supply chain as a whole would be improved.[125] It is important to highlight that mutual benefit for the trading partners increase disproportionally as the number of nodes or tiers doing collaboration is

[124] Toiviainen and Hansen (2011)
[125] GCI (2002)

increased. Thus, the mutual benefit offered by the "end-to-end collaboration" for the trading partners is greater than the sum of multiple trading partners (see figure 23).

Certainly, widespread sharing and leveraging of existing information across functional departments within an organization and between supply chain partners would be able to enhance real integration up and down-stream in the supply chain.

Figure 23: n-tier CPFR modelled on the network effect



Source: GCI (2002)

Under that modern business scenario in which the concept of SCM has been evolved, several practitioners and academics have recognized the strategic importance of collaboration in the supply chain. Those breakthroughs in SCM allow understanding that companies no longer compete as stand-alone units, but rather as supply chains and those that can provide management's abilities and leadership to integrate the company's intricate network of business relationships, will be the strongest competitors.[126] The age of a collaborative supply chain is clearly beginning, signalling the demise of the age of confrontation.

2.5.2 Maturity Models

It has to be emphasized that if an organization must maintaining alignment with end customers, it will be nearly impossible without some level of structure to manage development processes. So it is necessary that managers provide organizations with processes that concurrently support long-term and short-term value generation. Therefore, this section of the literature review is devoted to point out some of the most commons maturity models developed and used to address the extent to which processes at organizational or supply chain level are managed with the objective of creating sustainable collaborative practices. Furthermore, as a clear understanding of what is meant by "Collaboration Maturity in a supply chain", this work has incorporated models and experiences from other domains such as Software Development Process (SDP) and Business Process Management (BMP).

First of all, some definitions about the topics "maturity" and "maturity model" given by academics and practitioners are presented. Then, some examples in different domains and areas where those maturity models have been applied are presented.

[126] Monezka and Morgan (1997); Christopher (1992)

In general, Simpson and Weiner define the notion of maturity as a way to evaluate "the state of being complete, perfect or ready". [127] By the same token, Gonzales *et al.* understand project maturity as the state where the project is in a perfect situation to achieve his objectives. They suggest assessing it by the progress of the different processes and activities required to achieve the project phases.[128] Following this concept, Mettler[129] has stated that maturity "implies an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired end stage". Furthermore, Mettler[130] state that the term "maturity" in the literature has been understood in four different dimensions: (1) Process-focused, thus focusing on the extent to which a specific process is clearly structured, managed, measured, and controlled (e.g., Paulk *et al.* 1993; Fraser and Vaishnavi 1997), (2) object-focused, in terms for instance to which extent a product, service or result enhance a predetermined level of sophistication (e.g., Gericke *et al.* 2006), (3) people-focused, thus oriented on to which extent workers are capable to create knowledge and enhance their competences (e.g., Nonaka 1994), and (4) A combination of factors in which the focus is centred at the level of sophistication on more than one maturity level at the same time (e.g., collaborative process, groupware functionalities, and knowledge workers capabilities).

Previous works sustain that a maturity model is an approach to the design and deployment of recurring collaboration processes and for assessing and improving the maturity of these recurring collaboration processes, aiming at creating sustained collaboration practices that offer an organization a large competitive advantage. The scope of these models can include processes within an organization or across organizational boundaries.

Maturity models have been used in different domains as enhancers of the capability of organizations to move from their current as-is to their desired maturity stage. Among others, these models addresses issues such as the maturity of business/IT alignment, process management, project portfolio management, innovation management, and cooperation strategy.[131] For instance, in SDP domains, maturity models have been proposed as an issue capable to systematize the set of practices of this area and design a framework in which organizations assess and improve the collaboration processes.[132] Another area of application is the BMP domains, where this issue has been proposed to assess collaboration maturity of the business process and to enhance the following steps to reach an advanced maturity level.[133] The SCM domain is one of the most recent areas of application.

2.5.2.1 Capability Maturity Model (CMM)

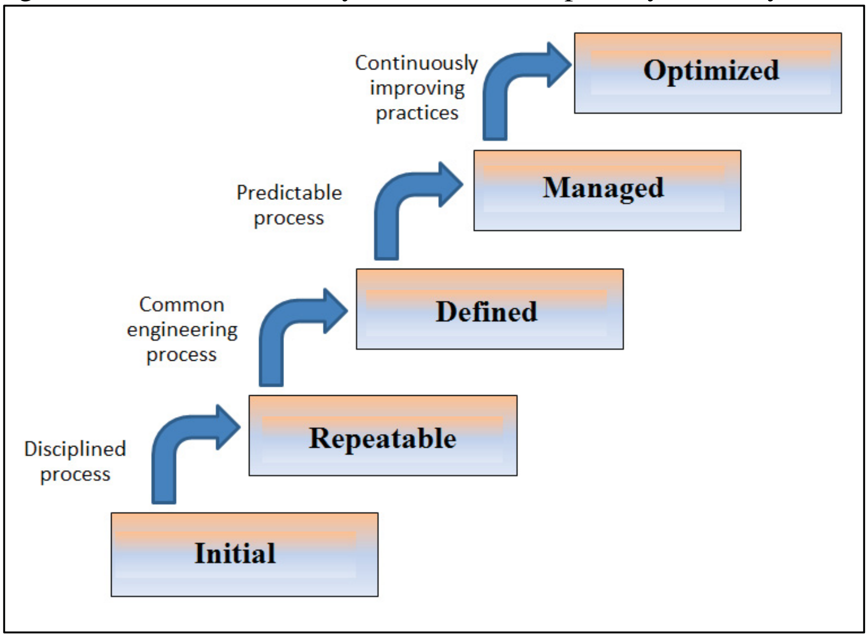
Although, maturity models have been inspired by the principles of quality management and more specifically by Crosby's *Quality Management Maturity Grid (QMMG)*;[134] maturity

[127] Cited in Mettler (2009)
[128] Gonzales *et al.* (2007)
[129] Mettler (2009)
[130] Cited in Mettler (2009)
[131] Fitterer and Rohner (2009)
[132] Magalhães *et al.* (2007); Santanen *et al.* (2006)
[133] Rosemann and de Bruin (2005)
[134] Crosby (1979)

models has become popular since the introduction of the Capability Maturity Model (CMM) in the late 1980's by the Software Engineering Institute (SEI) at Carnegie Mellon University.

In the context of SDP, the CMM is recognised as one of the most widely accepted set of guidelines for assist organizations in performing assessments of their software processes. This unidimensional model can be used to assess an organization against a scale of five process maturity levels. Each level comprises a set of process goals that, when achieved, result in an improvement in the process capability of the organization.[135] During the five maturity level evolution process the software development practices are transformed from an ad hoc, undisciplined state into more disciplined processes supported by continuous process improvement, capable of predict final results or outputs of the software development practices (See figure 24).

Figure 24: The five maturity levels of the Capability Maturity Model



Source: Paulk *et al.*, (1993)

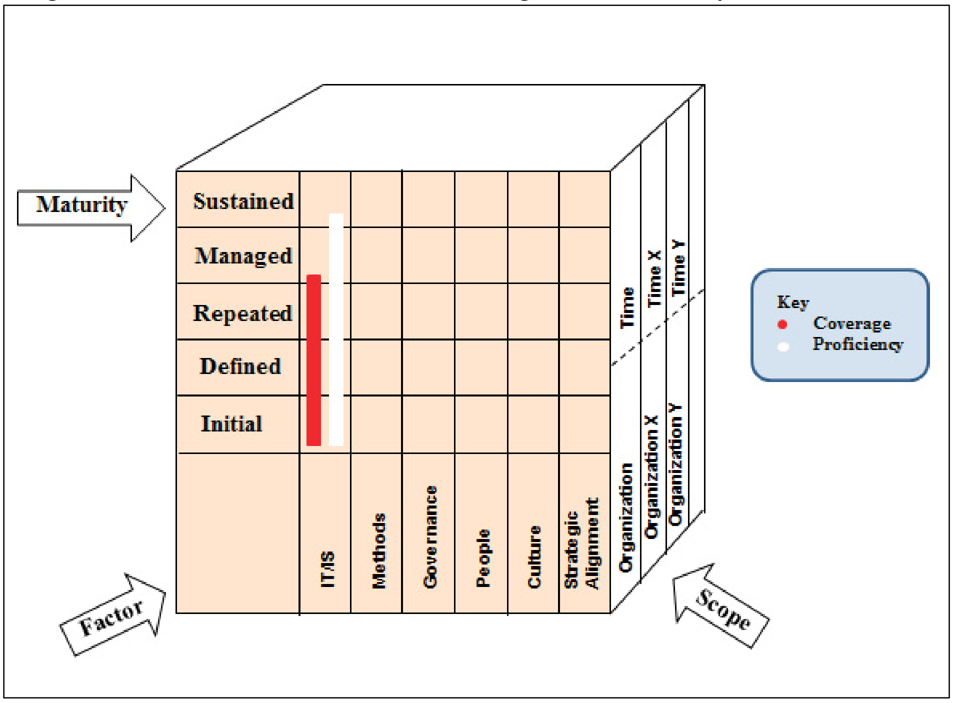
2.5.2.2 Process Management Maturity Models

Another potential area for development and deployment of maturity models is the context of BMP. In this domain models like Business Process Management Maturity Model (BPMMM)[136], Business Process Maturity Model (BPMM)[137] and Process and Enterprise Maturity model (PEMM),[138] are the most representative. As the models proposed by Curtis and Alden, and Hammer are very similar to the BPMMM, only this last model is pointed out in more detail in the next paragraph.

[135] Paulk *et al.*, (1993)
[136] Rosemann and de Bruin (2005)
[137] Curtis and Alden (2007)
[138] Hammer (2007)

Although the model presented by Rosemman and de Bruin keeps the stage names consistent with those adopted by the CMM in the dimension of maturity (Initial, Defined, Repeated, Managed and Sustained), maturity in the BPMMM Model is conceived as a combination of "Coverage" and "Proficiency". Coverage refers to "how far" within the organization BPM practices are extended, whereas Proficiency refers to "how well" BPM practices are managed. Aside from the maturity dimension, this model introduces two additional dimensions: Factors, and Organizational Scope and Time. The x-axis represents five major factors, identified as a critical factor for successful implementation of BPM, and the z-axis represents the organizational scope and the point in time in which the model is applied.[139] So, this framework depicts a three-dimensional maturity model which enables organizations to analyse maturity factors, with maturity levels simultaneously throughout 25 cubes or stages of maturity. This allows measuring the maturity level for each of the 5 factors. The assessment of the 25 cubes enables organizations to identify and understand their as-is position. Likewise, this model can be applied over time and at different organizational scopes (see figure 25).

Figure 25: The Business Process Management Maturity Model



Source: Rosemann and de Bruin (2005)

2.5.2.3 Project Management Maturity Models

In the last two decades the project management community has directed great attention on methodologies developed to measure and improve project maturity. In this context various project management maturity models have been developed to improve organization's project management effectiveness, many of them have appeared in the mid-1990s. According to the attention devoted in the literature, this research has chosen the following models as the most representative in this domain:

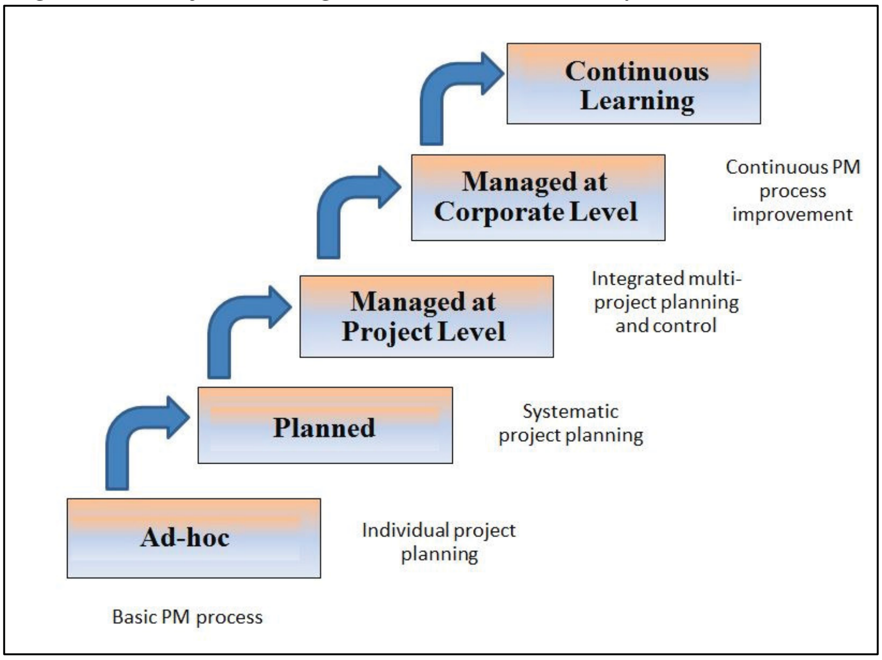
- CMM Model (already described in section 2.6.2.1)

[139] Rosemann and de Bruin (2005)

- Berkeley Project Management Process Maturity Model (PM)²
- PM Solutions Project Management Maturity Model
- Organizational Project Management Maturity Model (OPM3)
- Portfolio, Programme and Project Management Maturity Model (P3M3)

Kwak and Ibss[140] based on benchmarking of different project management maturity models introduced the (PM)². This model introduced a systematic and incremental approach combining the Project Management Institute's (PMI's) nine PMBOk knowledge areas and the five project management phases (Initiate, Plan, Execute, Control and Close-out), as an intent to evaluate an organization's current project management maturity level. They found that higher levels of Project Management Maturity are reflected in improved project performance.[141] Each maturity level includes key project management processes, major organizational characteristics and key focus areas. The results of the assessment allow organizations to identify strengths and weaknesses of project management practices as well as to focus on the identified weaknesses to achieve improved project management maturity levels. Figure 26 illustrates the 5-level (PM)² Model.

Figure 26: Project Management Process Maturity (PM)² Model



Source: Kwak and Ibbs (2002)

In the same vein, the Project Management Institute (PMI) introduced the PM Solutions Project Management Maturity Model which is fully aligned with the SEI CMM, featuring five maturity dimensions (Initial Process, Structured Processes and Standards, Organizational Standards and Institutional Process, Managed Process and Optimizing Process) and combining them with the PMI's PMBOK knowledge areas to provide a conceptual framework for assessing project management maturity.[142] This model gives an organization an overview

[140] Kwak and Ibbs (2000)
[141] Kwak and Ibbs (2002)
[142] Crawford (2002)

about their strengths and weakness areas as well as provides a roadmap outlining the necessary steps to be followed in order to accomplish higher and more sophisticated project management maturity levels and performance improvements (see figure 27).

Figure 27: PM Solutions' Project Management Maturity Model

Project Management Maturity Model	Level 1 Initial Process	Level 2 Structures Process and Standards	Level 3 Organizational Standards and Institutionalized Process	Level 4 Managed Process	Level 5 Optimizing Process
Project Integration Management					
Scope Management					
Time Management					
Cost Management					
Quality Management					
Project Human Resource Management					
Communication Management					
Risk Management					
Procurement Management					

SEI Maturity Levels

PMI Knowledge Areas

Source: Crawford (2015)

In 2003 the PMI introduced the Organizational Project Management Maturity Model (OPM3) as a PMI standard that provides requirements for assessing and developing capabilities in portfolio, program and project management, helping organizations to understand and measure their maturity levels and bridge the gap between organizational strategy and successful projects.[143] This framework has three concatenating elements: knowledge element, describes the context of the standard; assessment element, provides methods, processes and procedures to assess the maturity; and Improvement element, setting the steps to be followed to accomplish higher maturity levels. Within the OPM3 (see figure 28), the five project management processes (Initiating, Planning, Executing, Controlling and Closing) are associated with each of the three domains (Project, Program and Portfolio) and through the four stages of processes improvement they are progressing toward higher levels of maturity.

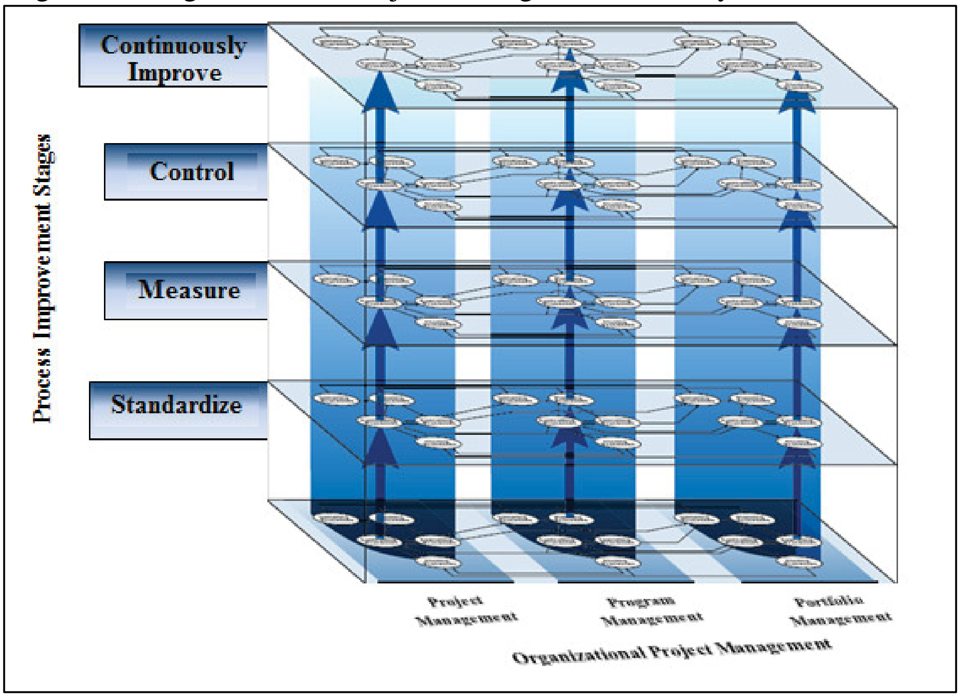
It is worthwhile to realize how the tree domains in the context of OPM3 are understood. The first domain is the Project management domain which involves the five processes defined in the PMBO Guide.

The second domain, Program management, refers to a group of related projects managed in a centralized way to achieve program's strategic objective and benefits not possible to obtain if they were managed individually. The third domain, Portfolio management, refers to a

[143] Project Management Institute (2003)

collection of projects and/or programs and other on-going related work (not necessarily interdependent or directly related) grouped together with the objective to facilitate effective management as well as the achievement of company's strategic objectives.[144]

Figure 28: Organizational Project Management Maturity Model OPM3

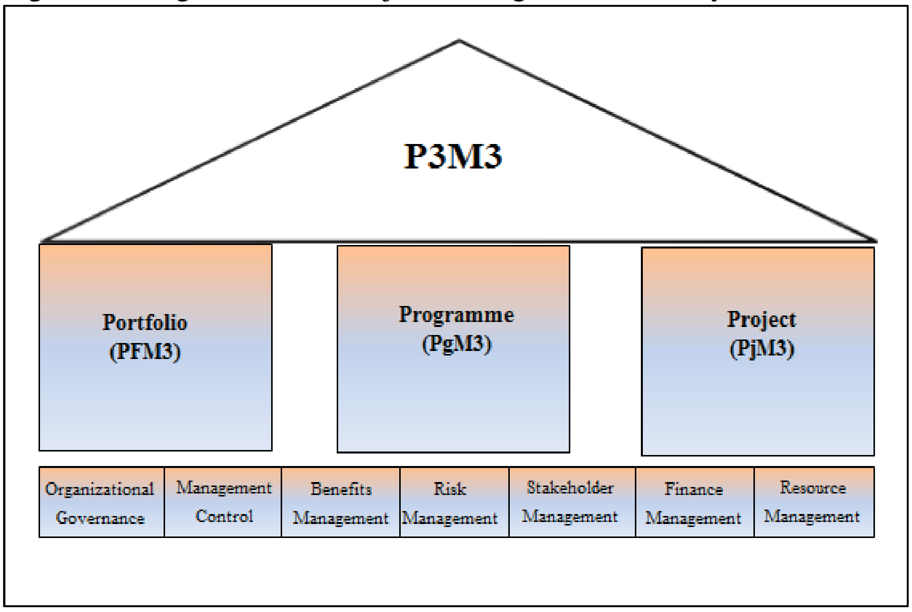


Source: Project Management Institute (2003)

Later in 2006, the Office of Government Commerce (OGC), a department within the UK government, dedicated to help public sectors organizations, introduced the Portfolio, Program and Project Management Maturity Model (P3M3). An updated version (P3M3 version 2.1) was released in 2013.[145] This framework provides three maturity models for organizations to assess and benchmark the current level of maturity for their Portfolio, Program and Project-related activities as well as effectively develop plans for improvement (see figure 29). Outputs of the periodic assessments of the Portfolio, Program and Project management maturity allow an organization to assess it actual capabilities and compare them to its target capabilities. Put differently, it allows an organization to evaluate the impact of its strategies and improvements put in place. The five Maturity levels (Awareness of Process, Repeatable Process, Defined Process, Managed Process and Optimized Process) defined by the P3M3 are combined with seven process perspectives (Management Control, Benefits Management, Financial Management, Risk Management, Stakeholders Engagement, Organizational Governance and Resource Management) to provide the assessment of the model. It is worthwhile to realize that if an organization wishes to have its Portfolio Management Maturity (P3M3) assessed it can only do so by having its Program Management Maturity P2M2 and its Project Management Maturity P1M1 assessed at the same time.

[144] *Ibid.*
[145] Office of Government Commerce (2013)

Figure 29: Organizational Project Management Maturity Model P3M3



Source: Office of Government Commerce (2013)

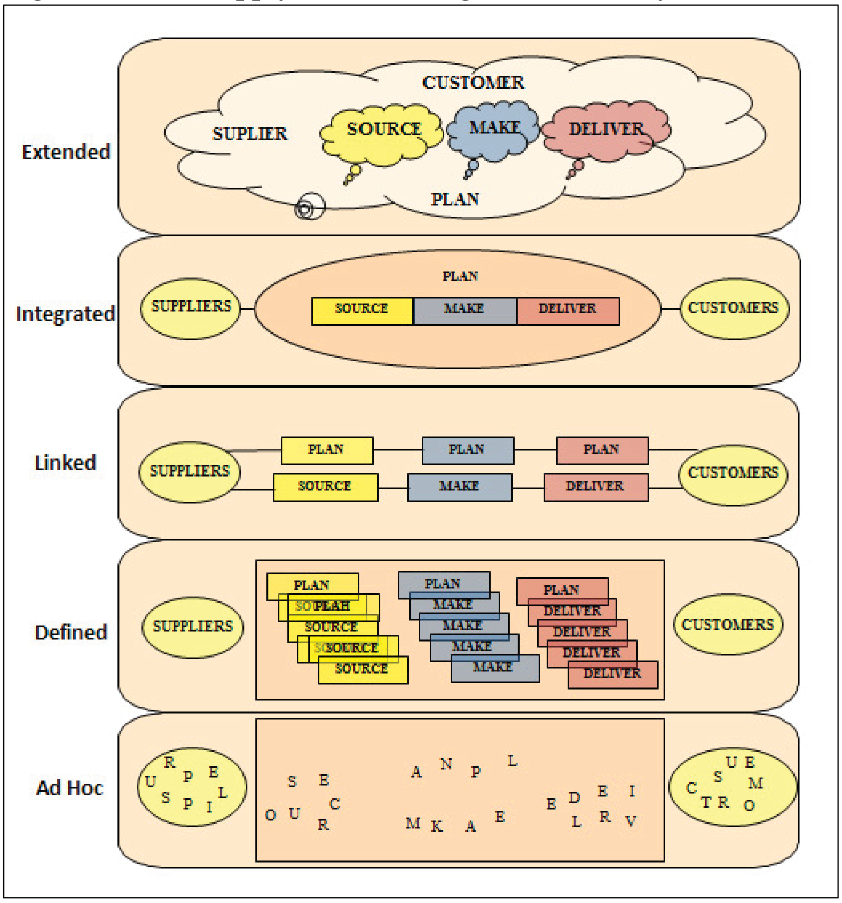
2.5.2.4 Supply Chain Management Maturity Models

In examining the maturity models relative to SCM, the SCM Maturity model developed by Lockamy and McCormack is one of the most representatives (see figure 30). This maturity model was developed based on the concept of Business Process Orientation (BPO) and the CMM. Although this issue has adopted the same five dimension of maturity, the different levels of maturity were conceptualized using the Supply Chain Operations Reference (SCOR) model. The SCM maturity levels defined were: Ad hoc, Defined, Linked, Integrated and Extended and it has been used to assess the level of maturity across several organizations along a supply chain. Each stage of maturity is including characteristics such as predictability, capability, control, effectiveness and efficiency which supported by a continuous process improvement, are serving as an engine that maintains and improves process maturity to next maturity level. Furthermore, Lockamy and McCormack stated, that organizations which are focused on creating an infrastructure and culture that support BPO practices reach greater levels of performance as well as report higher levels of collaboration and less conflicts.[146]

McCormack *et al.* [147] argue that the SCM maturity model helps organizations to identify the SCM activities that could improve the overall performance of the supply chain as a whole.

146 Lockamy and McCormack (2004)
147 McCormack *et al.* (2008)

Figure 30: The Supply Chain Management Maturity Model



Source: Lockamy and McCormack (2004)

Maturity models have been used during the last three decades as mechanisms to achieve improvements either for on-going operations or for project activities. The aim of these models could be summarized as guidelines to help organizations inside their company borders or across the supply chain to assess the current maturity levels, give an overview of their strengths and weaknesses areas and outline the necessary improvements to be followed in order to achieve higher maturity level in a specific domain.

On the SCM domain, these models can be used in helping organizations to identify the supply chain activities that should be improved in order to achieve better performance of the supply chain as a whole. Besides that, they can be used to help organizations to identify recurrent collaboration practices, to baseline their current collaboration maturity stage, and to support achieving of to-be desired stage. Specifically they could: 1) assist organizations across the supply chain to identify which processes should be managed in a collaborative way, 2) enable organizations across the supply chain to assess their current collaboration maturity stage, 3) enable organizations to determine their desired collaboration maturity stage; and 4) assist organizations to reach an advanced collaboration maturity level by means of developing of a process road-map to move from as-is to their desired position.

2.6 Social Network Analysis for Business Applications

Social Network Analysis (SNA) is a well-known methodology used for examining the interaction patterns and information flows that take place among people and groups in an organization, as well as among business partners and customers. It has emerged as an interdisciplinary methodology developed in the 1960s and 1970s in the domain of Sociology. Further development in collaboration with Mathematics, Statistics, and Computing during the last three decades, has allowed it to have an exponential growing trends (e.g., to extent its application to other disciplines such as: Sociology, Anthropology, Economics, Organizational Studies, Business Management, Public Health, Human Resource Management, Information Science, Biology, Complexity, and Chaos Theory).[148] SNA software such as UCINET, Pajek, Netminer, Gephi, the Statnet suite of packages for R, muxViz, SNAP package among others have been experiencing a similar proliferation. However, Gartner's February release predicted that "*Through 2015, only 25 per cent of enterprises will routinely utilize social network analysis to improve performance and productivity*" and addressing the "why": *"when surveys are used for data collection, users may be reluctant to provide accurate responses. When automated tools perform the analysis, users may resent knowing that software is analysing their behaviour. For these reasons, social network analysis will remain an untapped source of insight in most organizations"*.[149]

Relationships among partners can be modelled as social networks in which the nodes of the network represent people and the links of the network represent some kind of relationships (e.g., supervisor/subordinate, information sharing, interactive cooperation or collaboration). Indeed, "Collaborative Networks" can be defined as a special case of social networks in which the links represent "who is collaborating with whom".

In the domain of Project Development Programs for instance, Kratzer *et al.* applied SNA to investigate how some structural aspects of two project team networks in the space industry stimulate or discourage the project team creativity.[150] They argue that creativity arises from coordinated integration among teams. The nodes of the networks represent the product decomposition into sub-components, with each component assigned to one team, and the interactions among actors depict problem-solving-related information such as technical specifications, tests results, technical problems etc. In this study, three network structures were evaluated: 1) Network range, as the ratio to which a team is linked to other teams in the network; 2) Tie strength as the frequency of contacts among the teams; and 3) Network efficiency as the proportion of non-redundant relationships between the teams that allow them accessing different information sources. Main outputs of this research indicate that team's network range is positively linked to creativity. Thus, teams with higher ratios of relationships with other teams are better able to produce creative outputs. Likewise, the tie strength attribute was linked to the creativity by fitting a quadratic regression analysis. Finally, network efficiency has negative influence on creativity suggesting that direct contacts have greater influence on creativity than open and efficient networks.

[148] Knoke and Yang (2008)
[149] Gartner (2010)
[150] Kratzer *et al.* (2009)

The subject of innovation networks has been another area of interest for socio-technical network analysis. Since middle 1990s it has been showing a rapid increase in the number of empirical studies; most of them looking at the structure of the relationships between actors in the network and at the impact of network structure on performance. For example, Arranz and Arroyabe pointed out that many organizations have been working together with other parties or institutions like companies, research centres, and universities; designing organized innovation networks, for the purpose of developing technological projects efficiently as well as enhancing the competitiveness of the firms involved positively. [151] These actors have also pointed out that an innovation network may increase its performance and efficiency through the suitable design of (1) technological distributed processes, (2) organizational structures and (3) network governance structures, while the multidimensional effects among these variables have a complementary or synergistic effect.[152]

In addition, Gartner's December 2009 Press Release describes potential applications of SNA in business that can help CEO Managers to realize a pattern-based strategy. Gartner has identified three applications of SNA: organizational network, value network and influence analysis; that can be used to understand the relationship ties, information flows and value exchanges among individual, or nodes, in the network in order to figure out how to capitalize on business opportunities or avoid disruptions.[153]

In the Knowledge Management domain, Hossain and Wigand suggest that in the design of a knowledge sharing system the lack of understanding of the social context for which this system is developed may lead to the failure of cross-functional knowledge sharing in most organizations. They conclude that for the improvement of cross-functional knowledge sharing is required: (1) Understanding of both legitimate organization chart and shadow network structure and 2) the use of ICTs that can support both strong and weak ties among the individual working in the network.[154]

In the SC context, Borgatti and Li state that SNA can be applied to both hard and soft aspects of a SCM. Thus, to the soft side of SCM helping to understand how patterns of interpersonal relationships can be capitalized on business opportunities or translated to competitive advantage; and to the hard side, helping to understand the movement of materials and financial flows. Indeed, they conclude that SNA applied to these both aspects are essentials to understand the structural characteristics of a SCN.[155] By the same token, Bellamy and Basole argue that traditional modelling approaches are not well suited to shape complex structural characteristics and behavioural aspects of SCNs and due to that they propose the use of an integrative SNA framework based on three different but interdependent perspectives: SCN structure, SCN behaviour and SCN strategy. The application of this framework allow companies to: understand, design and manage the risk and complexity of a supply chain system; understand interdependencies patterns among actors in a supply chain; help to assess

[151] Arranz and Arroyabe (2006)
[152] Arranz and Arroyabe (2012)
[153] Gartner (2009)
[154] Hossain and Wigand (2012)
[155] Borgatti and Li (2009)

the impact of the system architecture on the performance of the SCN; and help to determine management mechanisms oriented to reduce systemic risks.[156]

In the Team-building context, Park *et al*, suggest the use of SNA as a tool to study the relationships and the relationship's network structure in a team, in order to understand team processes such as friendship, communication, cooperation and collaboration among team members. In addition, the need for team building interventions, could be assessed, planned, developed, and implemented in order to increase team effectiveness.[157]

In the Human resources context, Ehrlich and Carboni suggest that SNA can help organizations to gain understanding about the effects of workforce diversity on hiring, retention and leadership development.[158] By the same token, Lazer and Katz report the recent surge of interest in research of topics related to "Social Capital" (i.e., how does the configuration of a set of ties at the individual or collective level affects the productivity either of an individual or of a collective).[159]

Finally, in the Sales and Marketing context, Wang applies SNA to a huge online group games network (over 10 million people) to improve marketing performance of a specific client. He concludes that applications of quantitative (computational analysis) and qualitative methods (visual analysis) would help organizations to uncover the network structure of actors in a network and their transaction behaviours. As results of this empirical study, some insights about customer purchase behaviours and the social network structures behind it were discovered. Based on this information several marketing promotions strategies were recommended to be applied.[160]

According to Innosupport guide, SNA becomes an important tool that can assist organizations to reveal and analyse their social network structures, in order to find if they meet the business needs of the group. Some of the potential benefits of using SNA include: awareness of social network; allow the building of knowledge maps; retention of people with vital knowledge; increased innovation, higher productivity and responsiveness; smarter decisions on formal organizational structure; support decisions such as leader selection, taskforce selection, and mergers and acquisitions.[161]

SNA is an interdisciplinary methodology that has been gaining a growing recognition by the academics of a great number of fields including supply chain. Beside the significant benefits that SNA have provided to contexts like Economics and Social Psychology, it is an innovative methodology that has been applied to a wide range of business problems such as: Knowledge Management and Collaboration, Team-Building, Human Resources, Sales and Marketing, Pattern-based Strategy, and SCM among others. Indeed, SNA can provide important insight into how to understand, design and manage complex systems by helping organizations to: understand interactions between actors; identify interdependencies pattern among actors;

[156] Bellamy and Basole (2012)
[157] Park *et al.* (2013)
[158] Ehrlich and Carboni (2005)
[159] Lazer and Katz (2003)
[160] Wang (2012)
[161] InnoSupport Guide (2009)

assess the impact of the relationship's network structure on processes such as friendship, communication, cooperation, and collaborations as well as on the performance of the network as a whole; and determine management mechanisms oriented to reduce system risks and capitalize business opportunities.

3 Building the Collaboration Characterization Project Management Model (CCPM Model)

Numerous articles both in the academic literature and in SCM practice provide a basic rationale to identify collaborative initiatives along the supply chain as an essential success factor. It involves the issues of how to build relationships both across functional departments within an organization and between multiple supply chain trading partners.

The term collaboration in the supply chain context has been defined as a way of working that encompasses all supply chain partners, coordinating specific activities, exchanging appropriate information and leveraging participant's resources seeking the benefit of all parties concerned. Collaboration brings the possibility of addressing others' hard and soft issues (resources, knowledge, relationships) and using each party's resources for mutual benefit.[162] It requires an environment of trust, reciprocity, flexibility, interdependence and commitment.[163]

This section presents a literature review regarding the contributory factors that enable supply chain collaboration. Finally as an attempt to gain understanding about the collaborative relationships among PTRs in SCDPs, this contribution proposes a conceptual framework, the CCPM Model, which can be used to assess the positive links between contributory factors to enable collaboration and the Intensity of Collaboration among PTRs.

3.1 Contributory Factors to Enable Collaborative Relationships

Recognition of collaborative relationships as a core element of new efficient and optimized business practices has prompted research on the factors that enable the development of effective partner relationships; That is, on the factors that make a collaborative relationship successful. More in-depth, there are interesting findings regarding both the characteristics of the interaction among the channel partners, and the conditions and trade-offs that may exist among the members of the supply chain network

In this context, Aryee and Naim[164] stated that the contributory factors to enable inter-organizational relationships can be split in two dimensions: "hard" issues, such as technology, and "soft" issues, such as collaborative initiatives. These issues allow companies and even a network of organizations to enhance process coordination and collaboration both across functional departments within an organization and between multiple partners along the supply chain. Kanter[165] categorizes five levels of integration that influence successful collaborative relationships among trading partners. Strategic integration, through continuing interaction among the top leaders, defines how broad goals and changes in each company are achieved. In tactical integration, there are middle managers working together on specific projects or joint activities, with the aim of better linking the companies or to enable knowledge flow

[162] Shuman and Twombly (2010)
[163] Vieira *et al*. (2009)
[164] Aryee and Naim (2008)
[165] Kanter (1994)

among the partners in collaboration. Interpersonal integration is a means to develop synergies born on paper. Thus, relationships between companies are more than the integration of functional areas in pursuit of common goals. People in a collaborative relationship play a strong role; that is, they need to know each other before they are willing to work together. Operational integration refers to the rules that allow people to carry out the day-to-day work. Finally, cultural integration allows both sides to establish cultural awareness.

Building on the work of Kanter[166] and Vieira *et al.*[167], the attributes that enable collaborative relationships among PTRs in this endeavour were categorized into three types of factors: strategic, tactical, and interpersonal (see figure 31). Although many of the characteristics mirror those of other business collaborations, collaborative relationships in SCDPs differ because of the PM context. A stream of literature supports the value of the attributes mentioned below. Indeed, their presence strengthens the probability of success of a collaborative relationship, and their absence in many cases increases the chance of failure.

3.1.1 Strategic Relationships

The Strategic Relationships perspective is an integral part of the goals of the firms in an inter-organizational relationship. Firms that are unwilling to articulate their strategies would probably be unable to build a closer relationship. This factor includes the following attributes: Team Formation and Projectized Organizational Structure; Relationship History; and Top Management Involvement.

3.1.1.1 Team Formation and Projectized Organizational Structure

This attribute refers to the idea that teams need to be clearly defined. Thus, the team should have a clear identity, create a statement of purpose, have clearly defined goals, possess access to resources, enjoy a supportive environment and have sufficient connections with those outside the team who can provide resources and support. It also requires careful selection of team members who can work together in a virtual environment.

In addition, this attribute reflects the degree to which the organizational structure of the firm is adapted to support the project environment, including the resources to help people connect to other team members and to the extended virtual team. The better aligned the goals and objectives of the trading partners are, the greater their willingness to build a closer relationship and the higher the chance of collaborative relationship success will be.[168]

3.1.1.2 Relationship History

There is support for relationship history as a strategic relationship driver in the literature; it has been assumed that both good prior relationship experience[169] and the age of the relationship may lead enterprises to establish close relationships.[170] According to Graton and

[166] *Ibid.*
[167] Vieira *et al.* (2009)
[168] Lambert *et al.*(1996); Golicic and Mentzer (2005)
[169] Lambert and Knemeyer (2004)
[170] Golicic and Mentzer (2005)

Erickson,[171] forming teams that capitalize on pre-existing relationships increases the chances of collaboration among the PTRs. Thus, newly-formed teams need more time and effort to build trusting relationships than those with established relationships.[172]This attribute can be measured by the extent of prior formal associations between two organizations, ranging from a few collaborative efforts to many such relationships.

3.1.1.3 Top Management Involvement

Drawing on the conceptualization of top management involvement as an attribute on the strategic relationship level, Kanter[173] emphasizes that it is essential that top management gets involved in collaborative agreements, since stakeholders will set business rules to enable compatibility between the partners in collaboration. Furthermore, top management support plays an essential role by supporting activities inside their own organization, like getting approval from their own organization for changes to business practice, as well as by deploying necessary resources in order to facilitate the development of strategic relationships with key supply chain partners while completing project tasks in accordance with requirements and schedules.[174] They also need to negotiate internally with the collaborative project teams to ensure their organization's interests are protected.[175]

A team's success or failure in collaborating reflects the willingness of the top management to build and maintain social relationships, demonstrate collaborative behaviour themselves and create signature relationship practices throughout the organization.[176] For example, top management can encourage collaborative behaviour by making highly visible investments in infrastructure designed to give employees the opportunity to build relationships, by changing executives' roles frequently, and by making investment in face-to-face interaction to create opportunities for people across the company to see executives in action.

3.1.2 Tactical Relationships

The tactical relationship perspective is concerned with bringing managers together to align individual goals with joint goals, to foster more efficient connections and to lead to better knowledge exchange between partner business processes.[177] This factor includes: Joint Actions, and Communications and Information Sharing Structures.

3.1.2.1 Joint Actions

This element outlines the degree to which supply chain partners work together to pursue individual or collective common goals;[178] that is, the extent to which channel partners undertake activities jointly rather than unilaterally.[179] Min *et al.* found that joint efforts such

[171] Graton and Erickson (2007)
[172] Rolfes (2001)
[173] Kanter (1994)
[174] Mentzer *et al.* (2000)
[175] Cameron (2005)
[176] Graton and Erickson (2007)
[177] Kanter (1994)
[178] Frazier and Rody (1991)
[179] Heide and John (1990)

as planning, goal-setting, performance measurements, and problem-solving are essential for successful collaborative relationships.[180] According to Vanpoucke and Vereecke, the creation of cross-functional supply chain teams to carry out focused activities helps companies work together in a more structured and formal fashion that builds and sustains the partnership.[181]

Project team members collaborate because they are pursuing individual or collective common goals. To achieve the purpose that brought the organizations together, some kind of administrative structure must exist that moves from governance to action.[182] Key administrative functions such as coordination, clarity of roles and responsibilities, and monitoring mechanisms are also addressed in building collaborative relationships, but they take on a new meaning because of the more symmetrical and horizontal relationship found in collaboration.[183] Sagawa and Segal[184] suggest that coordination of efforts needs to be enhanced by "relationship managers" whose specific task is to manage and build intra- and inter-organizational relationships. William[185] reinforces that, highlighting the importance of having boundary spanners or individuals who have the skill to develop and enhance social relationships; put differently, individuals with the skill to build and manage interpersonal relationships. Furthermore, several studies argue that joint coordination efforts enable partners in interaction to co-align their operations and processes, which enhances the relationship by building trust and commitment.[186] SCDPs still require a central position for coordinating communication, organizing and disseminating information, and keeping project team members aware of the common goals and rules that built and sustain the relationship. This role would mostly be fulfilled by the project team leaders.

3.1.2.2 Communication and Information Sharing Structure

This attribute, Communication and Information Sharing Structure, is defined as the reliability, completeness, exactness, timeliness and appropriateness to which critical, often proprietary, information of relevance is communicated between partners in collaboration through media such as face-to-face meetings, file sharing, e-mail and audio and video conferences.[187]

Effective communication and information sharing on a frequent, bidirectional, informal and non-coercive basis is essential to guarantee coordinated actions, and moreover is a critical factor for partners to realize benefits of collaborative relationships.[188] According to Rolfes,[189] the phrase "collaborative teams" implies that communication is taking place. He also states that communication builds trust.[190] Communication links should be within all levels of the organizations as well as across the team members.

---

180 Min *et al.* (2005)
181 Vanpoucke and Vereecke (2007)
182 Thomson and Perry (2006)
183 Ring and Van de Ven (1994)
184 Sagawa and Segal (2000)
185 William (2002)
186 Min *et al.* (2005); Jap and Ganesan (2000); Subramani and Venkatraman (2003)
187 Vanpoucke and Vereecke (2007)
188 Min *et al.* (2005); Mohr and Spekman (1994); Mohr *et al.* (1996); Vieira *et al.* (2009)
189 Rolfes (2001)
190 *Ibid.*

The advent of new communication technologies allows distributed teams to keep in touch, collaborate, and be more effective as a team. Tools such as face-to-face meetings, phone, fax, e-mail, file sharing, audio and video-conferencing, shared electronic white-boards, and additional applications using internet and intranet have given organizations opportunities to overcome the barrier of distance and time, allowing them to bring their distributed workforce together despite physical distance.[191] Indeed, state-of-the-art information and communication technologies are at the heart of the operating environment of these dispersed SCDPs. An important feature of these teams is that many conversations are asynchronous (e.g. e-mail, voice mail, and shared files) and are only sometimes synchronous (e.g. audio/video conferencing). These teams in the literature are commonly denominated virtual teams.

Finally communication can be broken down into its data capacity and the quality or richness[192] of information transmitted. New communication technologies have led to an increase not only in the quantity of information conveyed, but also in the richness of that information, compared to what was available a decade ago.[193] Likewise, Eggert examines the effect of different types of communication mechanisms on the level and the stability of the cooperation. He concludes that the success of collaborative efforts is not only determined by the content of linguistic codes exchanged, but also by the communication technology used to convey this information itself.[194]

3.1.3 Interpersonal Relationships

Interpersonal relationships are necessary to put the synergies conceived at the strategic level into practice. Relationships not only involve the integration of functional areas in seeking to achieve common objectives, but also involve the employees that work for the firms, including their own personalities, their emotions and their willingness to change.[195] People are not willing to exchange information, technology or participate on joint teams until they know one another personally. The attributes from the literature that are directly related to this factor are: Trust; Cultural Diversity and Background; and Mutuality.

3.1.3.1 Trust

Trust as a form of building social capital is conceptualized as the willingness to believe that the partner can be relied on to fulfil obligations, behaves in a predictable manner and is honest and ethical in its behaviour even when the possibility for opportunism exists.[196] Partners have to trust that others are doing their work, and are doing it at a high quality. Geyskens *et al.*[197] argue that the greater a firm’s trust in its partners, the higher its motivation to continue the collaborative relationship. Indeed, trust is presented as the cornerstone of inter-organizational cooperation, because relationships characterized by trust will enhance the parties’ desire to

---

[191] Chutnik and Grzesik (2009)
[192] Richness is a property of the communication mechanism used to convey information, which includes the medium’s ability to provide on-line feedback, use multiple cues and channels, and allow personalization and language variety.
[193] Bain and Bowen (2000)
[194] Eggert (2001)
[195] Golicic and Mentzer (2005)
[196] Zaheer *et al.* (1998)
[197] Geyskens *et al.* (1996)

commit themselves to such relationships,[198] but building trust takes an inordinate amount of time and nurturing.[199] Successful collaborative relationships are built on trustful relationships.[200] For some authors in the literature, trust encompasses three essential elements: trust in the partner's benevolence, honesty and credibility.[201] Likewise, Ganesan has suggested that partners who trust each other will be more satisfied with the relationship and will be more willing to put additional effort into ensuring its continuity.[202] Additionally, those trusting partners will commit resources to the relationships, because the relationship is perceived as a long-term investment.

In a face-to-face project, trust is built through frequent interaction. Members of the project team who are located at the same site, have the advantage of previous integration with their colleagues, can see one another working on the project and of course may have the opportunity to get to know each other and build a relationship with daily interaction. Distributed project teams, however, may have none of these advantages.[203] Furthermore Gibson and Cohen, and Henttonen and Blomqvist add that in dispersed teams, trust is harder to identify and develop. They describe the role of trust as the most critical component of team development and effectiveness.[204]

In a SCDP, it is possible to build trust by the number of interactions (Frequency of Contact) between PTRs in the network during the project life cycle. The hypothesis to test is: The greater the frequency of contact between two PTRs, the higher the trust among those PTRs and the higher the probability of those PTRs to exhibit collaborative behaviours.

3.1.3.2 Cultural Diversity and Background

Spencer-Oatey defines culture as a variable set of attitudes, beliefs, behavioural norms, and basic assumptions and values that are shared by a group of people, and that influence each member's behaviour and their interpretation of the behaviour of others.[205] One of the implications of this postulate has to do with mismatches in the interpretation of one culture's behavioural norms by other cultural groups, which may result in misunderstanding, miscommunication, conflicts, and mistrust. Thus, cultural differences affect the relationships among the team members and ultimately degrade team performance.

Due to physical team dispersion, possible thanks to new communication and information technologies, more organizations are forming teams that connect participants from different countries and organizations. As space and distance are no longer a limitation, teams transcend national borders and members can come from many countries around the world. This situation naturally encompasses the possibility of seeing cultural diversity in team membership. Thus, there is a high probability that team members have to deal with this cultural diversity and consequently will be confronted with mistrust, miscommunication, unknown expectations and

198 Hrebiniak (1990)
199 Huxham and Vangen's (2005)
200 Sandhoff (2000); Nyaga *et al.* (2008); Cai *et al.* (2010)
201 Moorman *et al.* (1992); Morgan and Hunt (1994)
202 Ganesan (1994)
203 Rolfes (2001)
204 Gibson and Cohen (2003); Henttonen and Blomqvist (2005)
205 Spencer-Oatey (2000)

different dynamics. Indeed, behavioural norms of regional, national, and even organizational cultures need to be understood.[206] Likewise, Bal and Foster argue that organizations are not required to have all the best collaboration technologies to support the work of dispersed teams, but attention should be paid to cross-cultural differences between the project team members in order to help communicate more effectively.[207]

Differences that inhibit collaboration include not only cultural differences but also nationality, age, educational level, and even occupation. Gratton and Erickson argue that the greater the cultural and background diversity, the less likely the team members are to exhibit collaborative behaviours.[208]

3.1.3.3 Mutuality

Mutual dependency measures the level to which trading partners work together to obtain mutual benefits, since each partner is relatively equally dependent upon the other's knowledge.[209] Thus, information sharing is necessary for collaboration, but not sufficient for maintenance of a thriving collaborative relationship. A collaborative relationship has to bring mutual benefit for the trading partners.[210] In fact, mutuality is seen as a win-win problem-solving tool that, based on complementarities of the partners in collaboration, can address the conflicts inherent in differing interests by forming mutually beneficial interdependencies. The more consensus partners can make out of differences based on each other's needs, the greater the likelihood they will be able to collaborate.[211]

Holmlund and Törnroos[212] characterize mutuality by four core features: the degree of mutuality that dominates the relationship; the multitude of different kind of bonds (i.e., technical, economic, social, knowledge, and legal) between the partners in relationship; the symmetrical nature of the relationship (e.g., the importance of each partner to the other's success, relative size, market share, financial strength, productivity, brand image, company reputation and level of technological sophistication); and the balance achieved in the long run. These characteristics bring sustainability to the relationship even in situations with low mutuality. Deep one-sided asymmetry in the relationship may cause a loss of interest from the other partner in maintaining and developing collaborative relationships.[213] Duffy found empirical evidence that supports mutual dependency as an essential attribute in distinguishing partnerships from other kind of relationships, the type of partnering strategy employed and the extent of collaboration achieved.[214]

According to Morgan and Hunt,[215] if a committed partner believes the relationship is worth working for, then the desire to maintain valued collaborative relationships persists indefinitely

[206] Jarvenpaa and Shaw (1998); Hsieh *et al.* (2008)
[207] Bal and Foster (2000)
[208] Gratton and Erickson (2007)
[209] Mohr and Spekman (1994)
[210] Ellram and Edis (1996); Thomson and Perry (2006)
[211] Thomson and Perry (2006)
[212] Holmlund and Törnroos (1997)
[213] Häkansson and Snehota (1995)
[214] Duffy (2008)
[215] Morgan and Hunt (1994)

and he will be willing to make an effort on behalf of the relationship. Krause *et al.*[216] found that performance improvements are often made possible when partners commit to long-term relationships. It should be noted that commitment is unlikely without the presence of trust and reciprocity throughout the relationship.[217]

In a SCDP, it is possible to measure mutuality by the balance of the project team members' relationship in the medium term. Thus, reciprocity or mutuality among project team members is given when two actors report the same value of communication frequency or degree of task interdependency with each other during the project life cycle. (E.g., if a project team member establishes a tie with another team member, the second team member is more likely to share a tie back to the original actor).

3.2 Dependent Variable

Gruat La Forme *et al*. (2007) have identified two main dimensions that are commonly considered in many different studies concerning the collaborative relationships among trading partners.[218] On one hand, identify the intensity/depth of the relationship, as the degree or measure of closeness or strength of the relationship among partners in collaboration, from single information sharing to real partnership.[219] On the other hand, deal with the extent of the collaboration, as the perimeter to which collaboration activities are spread throughout the network. As the main objective of this research is focused on characterize and measure collaborative relationships among partners in collaboration, this contribution based on the works of Gruat La Forme *et al*. proposes the Intensity of Collaboration dimension as a Dependent variable.

The Intensity of Collaboration therefore is understood in this research as an assessment of direct and depth collaboration between the PTRs. It describes the current relationship between the PTRs and is defined by the degree to which activities are coordinated, from single information sharing to the sharing of vital information, quality and timeliness is shared, participant's resources are leveraged, and partners are working together to solve a specific problem or to achieve a common goal.

3.3 Collaboration Characterization Project Management (CCPM) Model

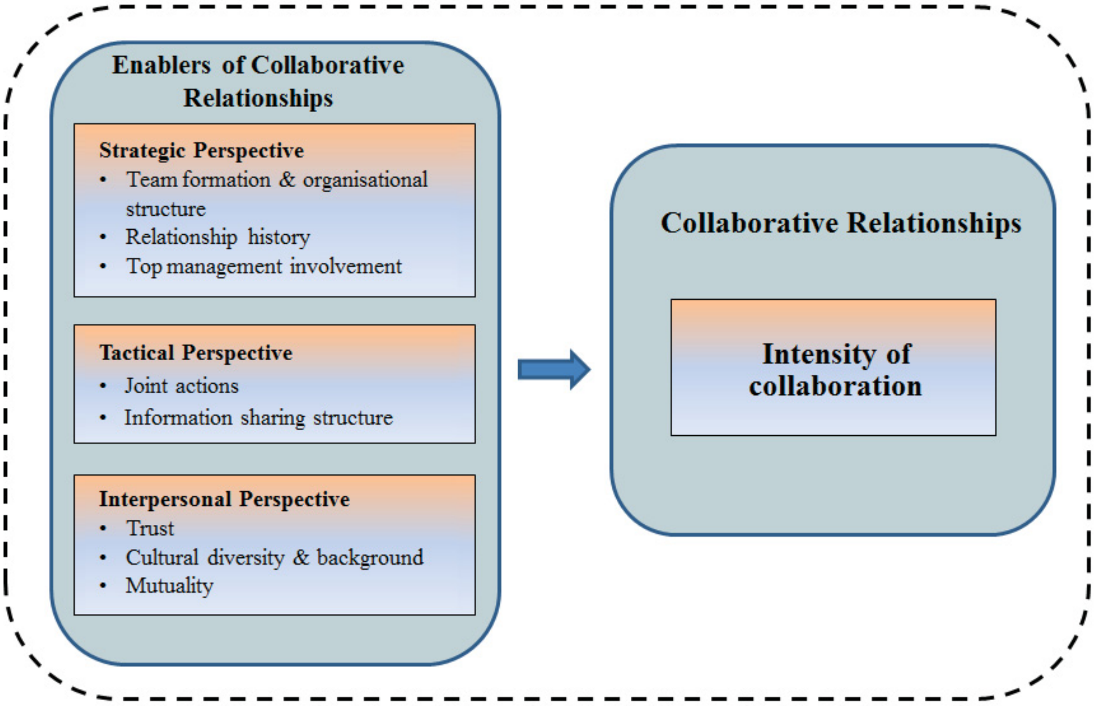
Concerned with understanding the partnership relationships between the PTRs and features of the associated ties between them in SCDPs, this contribution proposes the CCPM Model to evaluate the positive link between contributory factors to enable collaboration and the Intensity of Collaboration among PTRs (see figure 31). This model constitutes a practical tool that can be used to assess the ability of a project network to build collaborative relationships during a project's life and to appraise the impact of the intrinsic and extrinsic contributory factors on the dimensions of collaboration.

---

216 Krause *et al.* (2007)
217 Thomson and Perry (2006)
218 Gruat La Forme *et al.* (2007)
219 Golicic, *et al.* (2003)

Hence the following hypothesis will be tested: *Higher levels in the attributes to enable supply chain collaboration increase the Intensity of Collaboration among PTRs in SCDPs.*

Figure 31: Structure of the CCPM model



Source: Adapted from Meisel-Donoso and Zsifkovits (2013)

4 Empirical Research

The empirical research was carried out using a case study methodology. Three case studies were performed to:

(1) describe the structure of the project network (i.e., centrality measures, density, reciprocity, distance between PTRs and attribute analysis) in order to identify the characteristics of these networks, the key actors in the networks, and who is collaborating with whom, and to give a line of graphical evidence of the effects of the above-identified attributes in the Collaboration Intensity Network formed by the PTRs;

(2) assess the influence of local structural dependencies (endogenous factors) and nodal attributes (exogenous factors) in the overall structure of the observed network (Collaboration Intensity Network formed by the PTRs). That is: to establish what explains collaboration between PTRs.

The case study research was applied using SNA to assess whether the CCPM model proposed in this endeavour works in the real world; thus, to evaluate if it is a realistic simulation of the attributes that enable collaborative relationships among the PTRs in SCDPs. An important characteristic of the Collaboration Intensity Networks studied in this research is that some of its members were no longer sitting together in close proximity.

The three researched cases correspond to a select group out of all the projects carried out by an international company. This company is working as a provider of customized warehouse logistics systems. Each case study represents a special type of project, categorized by the standard ABC Classification. The ABC classification of the projects was applied using the criteria defined by the company analysed (subsidiary company) and an example showing how a project was categorized is shown in table 18. Additional information about the project categorization for the other two case studies used in this research is available in appendix 8.1.

Table 18: Project categorization according to ABC classification
Case study A - Large-Scale Project

Project Categorization								
Customer:	001*			***Start Date:***			11.06.12	
Project's Name:	Project A			***Finalization Date***			04.02.15	
Project's Number:	0001			***Project Manager:***			Node (150)	
Country	Brazil			***Language:***			English	
Short description:	New customized warehouse solution in a greenfield location in the north of Brazil. It concerns to the supply and installation of a new Shuttle Solution with Pick to Light stations and sorter technologies at the dispatch ramps as described in the commercial offer and approved Layout.							
Categorization	**68**			**A - Project (Large-Scale Project)**				**up 60**
				B - Project (Standard Project)				**35 - 60**
				C - Project (Small Project)				**15 - 34**
Evaluation Criteria	**3 Points**		**2 Points**		**1 Point**		**Weights**	**Sums**
- Order Size	> 2,5 Mio €	x	1 Mio € - 2,5 Mio €		0,25 Mio€ -1 Mio €		5	15
- Estimated profit	<5%		<10%	x	>10%		1	2
- New Development / New product	substantial/ significant	x	negligible		none		3	9
- Estimated proportion of integration (with third party suppliers)	> 20%		5% bis 20%	x	< 5%		2	4
- Country / Industry risk	high		medium	x	low		2	4
- Credit / Currency / Payment risk	yes		no		none	x	1	1
- Critical project workflow	yes		no		none	x	2	2
- Deadline pressure / operational urgency	high		medium	x	low		2	4
- Mann hours	>10.000	x	< 10.000		<3000		2	6
- Strategic Importance	high		medium	x	low		1	2
- General Contractor	yes				no	x	3	3
- Complexity	Many parts and many processes		Many parts or many processes	x	Few parts and few processes		3	6
- Strategic customer	yes	x	no		no		2	6
- Reference for new products	yes		no		no	x	2	2
- Industry/Market Development	yes		no	x	no		1	2

Source: Original research

4.1 Research Design

4.1.1 Data Collection

This study's empirical data consists of email relationships and calendaring and scheduling information (on-line and face-to face meetings) data stored in the database module of a Lotus Notes application.[220] The Lotus database information offers the necessary social network data about the PTRs and their relationship/interactions with other PTRs during the project life of a specific supply chain project. For the practical purposes of this research, this information was exported from Lotus note to a Flat File (.dat). Then, using the software Mathematica[221] and its manipulation functions, the key information data regarding the number of nodes (PTRs in each network) and their relationship biased in one direction or another among PTRs[222] was extracted and two files were built. One contained the total amount of nodes (nodes file) and

---

[220] An application suite used by this subsidiary company that includes the following components: e-mail, calendaring and scheduling, address book, database, web server and programing.

[221] Mathematica is a computational software program used in many scientific and research fields. It was conceived by Stephan Wolfram and uses the Wolfram language as a programming language. Website: www.wolfram.com/mathematica/. In this research it is used to debug some key information stored in a flat file.

[222] Project team members associated with a specific functional role within the project (e.g., Subsidiary's Project Manager, Logistics Operation Manager, Overseas Branch Office's Project Manager)

the other contained the links among nodes belonging to this network and their corresponding weights (edges file with weights ranged from 1 to 5). See the Pseudo-code used below.

Pseudo-Code

i. *Identify the structure or symbol that separates the emails between project team members and replace with "++++".*
ii. *The symbol @ is replaced by "xxxxx" because this symbol can cause problems in the code in Mathematica.*
iii. *Use Excel to import flat file (.dat) separating with ":" and ",". Then save the file as a .csv file.*
iv. *Using Mathematica:*
    a. *Import[data.csv]*
    b. *Delete the empty places in the imported matrix.*
    c. *Split the imported matrix with "++++".*
    d. *Delete the integer and real values in the matrix.*
    e. *Build a vector that identifies the position of the emails that contain a word related to an attached file. The words used: angehangten, attached, Attached, adjunto, enclosed, anexo, Anexo .pdf, .JPG, .jpg, .docx, .doc, and .xlsx. Build a vector for each word.*
    f. *Develop a function that builds the relationship network and intensity network.*

Do [

If [email is not a meeting (to identify a meeting we used the word "RequiredAttendees"),

Build a vector with the structure {From, SendTo (all emails), CopyTo (all emails)} name listdirect[i] for each email sent i.

Listdirect[i] = {From, emails related to SendTo, emails related to CopyTo}

Build a vector that contains the weight of the edges in the abovementioned network using the vectors that identify the attached file. The options were: indirect email without attached file = 1; direct email without attached file = 2; indirect email with attached file = 3; direct email with attached file = 4. The vector is named weightdirect[i] and its position is according to the vector listdirect[i] for each email sent i.

If [email has an attached file,
weightdirect[i] = {0, 4 (for each direct email related to SendTo), 3 (for each indirect email related to CopyTo)},

(If not)
weightdirect[i] = {0, 2 (for each direct email related to SendTo), 1 (for each indirect email related to CopyTo)}],

(If not)

Build a vector with the structure {From, RequiredAttendees (all emails)} name listdirect[i] for each email sent i.

Listdirect[i] = {From, emails related to RequiredAttendees}

Build a vector that contains the weight of the edges in the abovementioned network. In this case, there is only the option meeting = 5. The vector is named weightdirect[i] and its position is according to the vector listdirect[i] for each email sent i.

weightdirect[i] = {0, 5 (for each email related to RequiredAttendees)}

]

, { i, Length[data]}]

g. *Get the nodes of the listdirect, delete duplicates and sort them*
   Nodes = Sort[DeleteDuplicates[listdirect]]
h. *Debug the list of the nodes in order to get the complete names of project team members or their emails.*
i. *Review the vector Nodes with the purpose of identifying the names or emails that correspond to the same project team member. Then create a vector that contains the uniform name or email that identifies a specific project team member.*
j. *Replace the names or emails of the project team members in the complete network (listdirect) with the vector of corrected names or emails. The name of this network is listdirect2.*
k. *Get the nodes of the listdirect2, delete duplicates and sort them*
   Nodes2 = Sort[DeleteDuplicates[listdirect2]]
l. *Export the list of nodes to a .csv file*

v. *With this list of depurated nodes, a list of PTRs (group of project team members with the same role in the project) was created in Excel.*

vi. *Using Mathematica*
   a. *With the list of PTRs, replace the names or emails of the project team members with the names of the PTRs in the complete network (listdirect2).*
   b. *Delete the isolated nodes (PTRs).*
   c. *Build the edges matrix. The edges matrix must have the following structure: {source, target, directed, id, " ", weight of the edge between the source and target nodes/areas}. This matrix contains the information of the intensity collaboration matrix.*
   d. *Debug the edges matrix with the purpose of deleting duplicate PTRs that can be in the same sent email.*
   e. *Export edges matrix to a .csv file.*
   f. *Export list of nodes/roles to a .csv file.*

Finally, the software Gephi and Excel were used, and the *Relationship*, *Frequency of Contact* and the *Intensity of Collaboration matrices* were built.

The Relationship Matrix provides information concerning the existence of links between nodes belonging to this network (i.e., this matrix reflects the existence of ties between the

PTRs). The *Frequency of Contact* matrix outlines the number of interactions among PTRs during the project life. Finally, the *Intensity of Collaboration* matrix presents a measure of closeness or strength of the relationship among partners in collaboration.

4.1.2 Measures

4.1.2.1 Measure of Independent Variables (Attributes)

The attributes for evaluating the Collaboration Intensity Network formed by PTRs were classified in two categories: those in which the probability of adding a new tie was dependent on the typical local structures of the network (endogenous factors), and those in which the probability that a tie will be generated was based only on nodal attributes (exogenous factors).

Within the category of endogenous factors, three attributes (structural parameters) were included as predictors into the model in this research: Mutuality, Joint Actions and Information Sharing Structure. Similarly, six attributes were included within the category of exogenous factors as predictors in the model in this research: Organizational Structure, Top Management Involvement, Relationship History, Joint Actions (modularity), Trust and Cultural Diversity and Background.

1) Mutuality (Reciprocity): This attribute is defined as the fraction of reciprocal ties between two PTRs. Thus, if a project team role sends a tie to another team role, that team role is more likely to send a tie back to the original actor. In fact, in a logistic project it is expected that the PTRs act with reciprocity toward each other during the project life.

2) Joint Actions: This attribute was operationalized using two parametric forms of the ERGM—Geometrically Weighted Edgewise Shared Partner (GWESP) and Geometrically Weighted Dyad-wise Shared Partner distribution (GWDSP)—as well as using a community detection algorithm.[223] These statistics are parameters included in this research to understand and characterize local clustering structures that are shaping the Collaboration Intensity Network; thus, to describe both how PTRs in a network work together in order to undertake activities jointly rather than unilaterally (a measure of the dyadic or transitivity structure of the network) as well as to determine if PTRs collaborate together in small triads, clusters or communities.

3) Information Sharing Structure: This attribute was operationalized using three parametric forms of the ERGM—GWESP, GWDSP, and Geometrically Weighted Degree Statistic (GWDegree, available also in the ERGM). These statistics are included in this research to describe how relationships in the Collaboration Intensity Network is being shared from only a pair of high-degree nodes sharing ties, through more organized structures, like, dyadic, triadic, small groups, or large clusters.

4) Organizational Structure: It was found that all project network analysed have a clear and well-defined organizational structure. Thus, all the actors in these networks have a

[223] Modularity analysis detects PTRs that can be easily grouped into potential set of node densely connected internally.

clear and well-identified hierarchical structure, which means that they have a defined purpose and goals to achieve for the project, and also have access to resources, enjoy a supportive environment and have enough connections with those outside the project network to provide resources and support in case of need. Likewise, project team members in each project were selected by the departmental managers, according to the specificities and requirements of the specific project. An example of the operationalization of this attribute is shown in table 19. All the nodes belonging to a specific network (Case A, B or C) were classified according to the Organization, Division or Area (project team role) each one belonged to.

5) Top Management Involvement: PTRs identified in each project network were categorized in terms of the attribute “Level of Management.” This attribute was split into its four common levels: Administrative or Top Level of Management, Executive or Middle Level of Management, Supervisory or Lower Level of Management, and Non-managerial Level.

   Team role titles for Top Manager in this research include: General Manager, Chief Executive Officer (C.E.O.), Chief Financial Officer (C.F.O.), Chief Operating Officer, Executive Vice President of Sales (EVP Sales) and Division Directors. It includes a group of crucial roles essential to leading and directing the efforts of other team roles involved in this SCDP. Likewise, team role titles of Middle Managers include: Departmental Head, Project Manager, Technical Project Manager, On-site Manager and Senior Supervisor. People in this group are responsible for executing the plans and policies made by the top level as well as being responsible for providing guidance to lower-level management and inspiring them to perform better. Finally, this research considered the following team role titles to be the lower level of management: On-site Supervisors and Group Leaders. Managers of this group should carry out the work or pass on instructions to Non-Managerial workers according to the plans of top and middle level management and give reports to the middle management on workers’ performance, difficulties, feelings, demands, etc.

   This parameter fits well with the definition used below in section 3.1 for Top Management Involvement, as an attribute on the Strategic Relationship level to measure if the top management level gets involved with, supports and facilitates the development of strategic collaborative relationships with other PTRs belonging to the same top management level inside their own project network.

Table 19: Example of PTRs categorized by an organizational structure's attribute

Area & Role	Organization	Division
Assistant General Manager	Headquarter	General Management
Controlling	Subsidiary Office	Finance & IT Infrastructure
Customer Care	Subsidiary Office	Customer Service
Customer Care (Medium Manager)	Subsidiary Office	Customer Service
Customer Support & Projects	Subsidiary Office	Customer Service
Human Resources	Subsidiary Office	Human Resources
Information System	Subsidiary Office	Information system
Logistics Operations	Customer	Logistics Operations
Project Development	Subsidiary's Provider	Development
Project Development	Subsidiary Office	Development
Project Management	Customer	Desktop Support
Project Management	Subsidiary Office	Customer Service
Software Engineering	Subsidiary Office	Project Implementation

Source: Original research

6) Relationship History: This variable was operationalized using the attribute "Employee's Seniority Characterized" and ranging, according to years of service in one of the following corporate organizations (Headquarters, Subsidiary and Overseas Branch Office) as follows: less than one year's service (0), from 1 to 2 years' service (1), from 2 to 5 years' service (2), from 5 to 10 years' service (3), and more than 10 years' service (4).

   This parameter adequately fits the definition used below in section 3.1 for Relationship History, as an attribute at the Strategic Relationship level to measure whether prior relationship experiences and the length of time a project team role has been engaged in project management work (years of service in a projectized organization) may guide an actor in a project network to establish close relationships.

7) Trust: Based on the work of Rolfes, which states that trust is built through frequent interactions among the members belonging to a collaborative network,[224] a variable was built to measure trust through the frequency of integration between the members in relationship. This variable outlined the number of interactions among PTRs during a project's life (information obtained from the edges matrix) divided by the duration of the project in days, as shown in the following formula.

$$Trust\ (i,j) = \frac{Contact\ Frequency\ among\ nodes\ i\ and\ j}{Duration\ of\ the\ project\ (in\ days)}, \forall\ i,j$$

   Additionally, the results of these ratios were categorized, for instance for the case of the large-scale project, ranging from:

   - (0) no contact.
   - (1) sporadic—about one contact per year.

224 Rolfes (2001)

- (2) intermittent—no more than a quarterly contact.
- (3) medium—no more than a monthly contact.
- (4) frequent—no more than a weekly contact.
- (5) more frequent—more than one contact per week.

8) Cultural Diversity and Background: Due to the project team members assigned to the project network analysed coming from different countries around the world, an interesting cultural diversity was perceived. As cultural background constitutes the ethnic, religious, racial, gender, linguistic or other individual's upbringing, this variable was operationalized using three attributes: Native Language,[225] Frequent Communication Language,[226] and Ethnic Group.[227] So all the team roles in the project were analysed, focusing on the effects of these attributes on the shaping of the Collaboration Intensity Network formed by the PTRs.

   Hence, the attribute "Native Language" was classified in seven categories: German, Portuguese, Spanish, Dutch, Czech, Russian and Persian. Similarly the attribute "Communication Language" was classified in four categories: English, German, Portuguese and Spanish. Finally the attribute "Ethnic Group" was characterized in six categories: Germanic, Dutch, Latin Europe, Latin America, Russian and Czechs.

4.1.2.2 Measurement of Dependent Variable

With the aim of measuring the intensity of collaboration between PTRs, the dependent variable "Intensity of Collaboration" was built. This variable provides information about the degree or measure of closeness to which PTRs share information of appropriate relevance, leverage resources and work together in the network. That is, it describes the degree to which activities are coordinated, from single information sharing to real collaboration, including the sharing of vital information, leveraging resources and working together to solve a specific problem or to achieve a common goal.

To operationalize the Intensity of Collaboration variable the following procedure was used:

1) Individual relationships among PTRs (edges matrix) were classified according to the following ranges:

   - (0) unlinked—PTRs do not work together at all.
   - (1, 2) networking/coordination—PTRs in relationships share only information, thus they exchange e-mails to each other either when the recipient's e-mail is in the "To" box or in the copy/"Cc" box, and the email not contain an attachment.

[225] Native Language refers to the first language learned at home in childhood.

[226] Frequent Communication Language refers to the most common communication language used by two project team roles during the life of a project.

[227] Ethnic Group pertains to the characteristics of a group sharing a common and distinctive culture, religion, language or the like. For instance: Latin-Europe is the part of Europe in which Romance languages are predominant. Italy, France, Spain and Portugal belong to this group. In the same way, Germans, Austrians, Luxembourgers, south Tiroleans and German-speaking Belgians belong to the Germanic group. The Slavic East group consists of Russians, Ukrainians, and Belarusians among others. Czechs, Poles, Slovaks, and others belong to the Slavic West. Finally the inhabitants of Latin America were grouped in the Latin American group.

- (3, 4 and 5) cooperation/ collaboration—PTRs in relationships share not only information but includes the sharing of vital information. Thus they have exchanged either direct or indirect e-mails to each other (recipient's e-mail is on "To" box or on the copy/"Cc" box), and the email contain an attachment, and/or when PTRs had been maintaining contact during the project life through audio/video conferences as well as face-to-face meetings, thus PTRs were working together as a formal team to solve a specific problem or to achieve common goals.

2) The edges matrix containing the weight of the edges (individual weighted relationship) was introduced as a .CSV file into the software Gephi, in order to calculate the total weighted relationship for a pair of nodes during the project life. For instance, if two nodes had five relationships during the project life and those relationships were weighted (1, 2, 2, 3, and 4); that means, the total weighted relationship for these two nodes during the project life will be: 1+2(2)+3+4 = 12.

3) A total weighted relationship matrix was calculated for all pairs of nodes interacting in the project.

4) Then an average weighted relationship for each pair of nodes was calculated using the following formula, and then the resulting ratios were categorized using the range defined in (1) for the edges matrix.

$$Intensity\ of\ collaboration(i,j) = \frac{Total\ weighted\ relationship\ among\ nodes\ i\ and\ j}{Contact\ Frequency\ among\ nodes\ i\ and\ j}, \quad \forall\, i,j$$

5) As the ERGM package for R only allows working with binary data (ERGM uses logit regression), Edges and non-edges in the Collaboration Intensity were dichotomized as follows:

- Collaboration Intensity = 0, when PTRs either did not work together at all (unlinked), or when PTRs in relationships had only been sharing information (networking/coordination).
- Collaboration Intensity = 1, when there was cooperation or collaboration between PTRs in addition to networking and coordination. Thus, when PTRs had been sharing direct or indirect contact to each other and the email contain an attachment, and/or when PTRs had been maintaining contact during the project life through audio/video conferences as well as face-to-face meetings.

4.1.3 Analysis

Many fundamental characteristics of social networks can be analysed through the use of the mathematical approach of graph theory. This approach is a result of the direct manipulation of matrices – the transposing, adding and multiplying of matrices all return information about the structure and parameter of the network analysed—and therefore is a useful tool for organizations. However, specialized computer programs,[228] by keeping as much of the mathematics as possible hidden from the user, allow an easier, more direct approach as well as the use of a wide variety of analytical procedures. Thus, data in a matrix form can be read by these programs, and suitable graph theory concepts can be explored without the researcher needing to know anything at all about the mechanics of the theory or of matrix algebra. Nevertheless, an understanding of basic graph theory concepts can improve the sophistication of the researcher's analysis.[229]

The analysis in this research followed two approaches: first, a visual and descriptive analysis, and second, a stochastic network method using an exponential random graph model. Analysis was conducted using Gephi and R software.

4.1.3.1 Visual and Descriptive Analysis

This research used visual analysis as an exploratory way to get a preliminary understanding of the properties of a network's data set. Network visualization and description were performed to: 1) identify how the PTRs were linked within a SCDP "X"; 2) identify the nodes that were perceived as being leaders in the SCDP "X"; and 3) recognize subgroups of PTRs working together. The size of the node represents the number of relationship ties: the larger the node, the higher the number of relationship ties.

The analysis focused on networks and individual properties. The measurements calculated for the sociometric relationships of the network were: density (total number of connections divides by total possible connections); reciprocity (the percentage of correspondence of links in the network); in-degree (the number of links that a project team role receives from others in the network); out-degree (the number of links that a project team role has to others in the network); betweenness (the extent to which a project team role acted as a bridge between other PTRs that are not directly connected); and closeness (how close a project team role was to all the other project team roles in the network). [230]

In addition, a community detection algorithm was used to detect subgroups of nodes working together in the network.[231]

4.1.3.2 Exponential Random Graph Models (ERGMs)

Network analysis methods can be categorized into descriptive and inferential statistics. Descriptive methods are designed to account for the effect of covariates on outcomes, and have reached statistical maturity and general acceptance with academics and practitioners in recent years. However, descriptive methods cannot be used to estimate the influence of the outcomes on each other; therefore the validity of regression results breaks down when such network dependencies go un-modelled. In this vein, in their work Maoz *et al*. recognize the

[228] The most popular examples being: UCINet, Pajek, Gradap, Gephi, the Statnet suit of packages in R, and GUESS.
[229] Scott (2000)
[230] Wasserman and Faust (1994), Freeman (2005)
[231] Blondel *et al.* (2008)

importance of endogenous network structures to network outcomes, by computing exogenous structural equivalent scores for each dyad.[232]

In network analysis, it is common for the relational tie between a given pair of actors to depend on one or more of the other ties in the network. This dependence among relationships in network data cannot be represented as a covariate when the classic descriptive methods are being used, without violating the regression assumption of conditional independence of observations. Methods for statistical inference with network data can be used to test hypotheses about the creation and evolution of a network, allowing the effects of exogenous covariates on the ties in a network to be estimated, while simultaneously can be used to represent the complex dependence processes that can exist in relational data.[233]

The ERGM has evolved out of a series of efforts by academics to address the failure of the descriptive models to recognize dependences among the covariates. Certainly, researchers can use ERGMs to build hypotheses to evaluate both the effects of exogenous covariates on outcomes, and structural effects that are endogenous to the network.[234]

The theoretical foundations for the ERGM originated in the work of Besag. He proved that there exists a class of plausible probability distributions that are consistent with a Markovian approach. That is, the spatial position of any location is dependent only on the special stochastics interactions with its adjacent neighbours.[235] Building on Besag's work, Holland and Leinhardt derived the exponential family of distributions for networks[236] and Fienberg, Meyer and Wasserman adapted log-linear models to the exponential-family of distributions for networks for the analysis of multivariate social networks.[237] Then, under the assumption that two possible edges are dependent only if they share a common node, Frank and Strauss[238] proved the characterization for the probability distribution of undirected Markov graphs and proposed a pseudo-likelihood parameter estimation method. It was not until Wasserman and Pattison,[239] however, that the current formulation of the ERGM (also referred to as the p* class of models) was first derived, as a generalization of the Markov graphs of Frank and Strauss. An important characteristic of these probability models for networks is that they allow generalizations beyond the classical restrictive dyadic independence of the earlier model class introduced by Holland and Leinhardt[240]. Recent developments in model specifications and estimation techniques for ERGMs introduced by Wasserman and Robins,[241] and Snijders *et al.*,[242] offer substantial improvements that not only expand the class of models, but have important conceptual implications.

Due the reasons explained above, ERGMs were used in this research to estimate the implications of structural parameters (endogenous effects) and node level effects (exogenous

232 Maoz *et al.* (2006)
233 Cranmer and Desmarais (2011)
234 Cranmer and Desmarais (2011)
235 Besag (1975)
236 Holland and Leinhardt (1981)
237 Fienberg *et al.* (1985)
238 Frank and Strauss (1986)
239 Wasserman and Pattison (1996)
240 Robins *et al.* (2007B)
241 Wasserman and Robins (2005)
242 Snijders *et al.* (2006)

effects) in the Collaboration Intensity Network formed by the PTRs in the SCDPs analysed. More precisely, the aim of the ERGM is to estimate the parameters for an ERGM in a way that the observed network has the highest probability of being replicated by the fitted ERGM model when this model is used to simulate a network.[243]

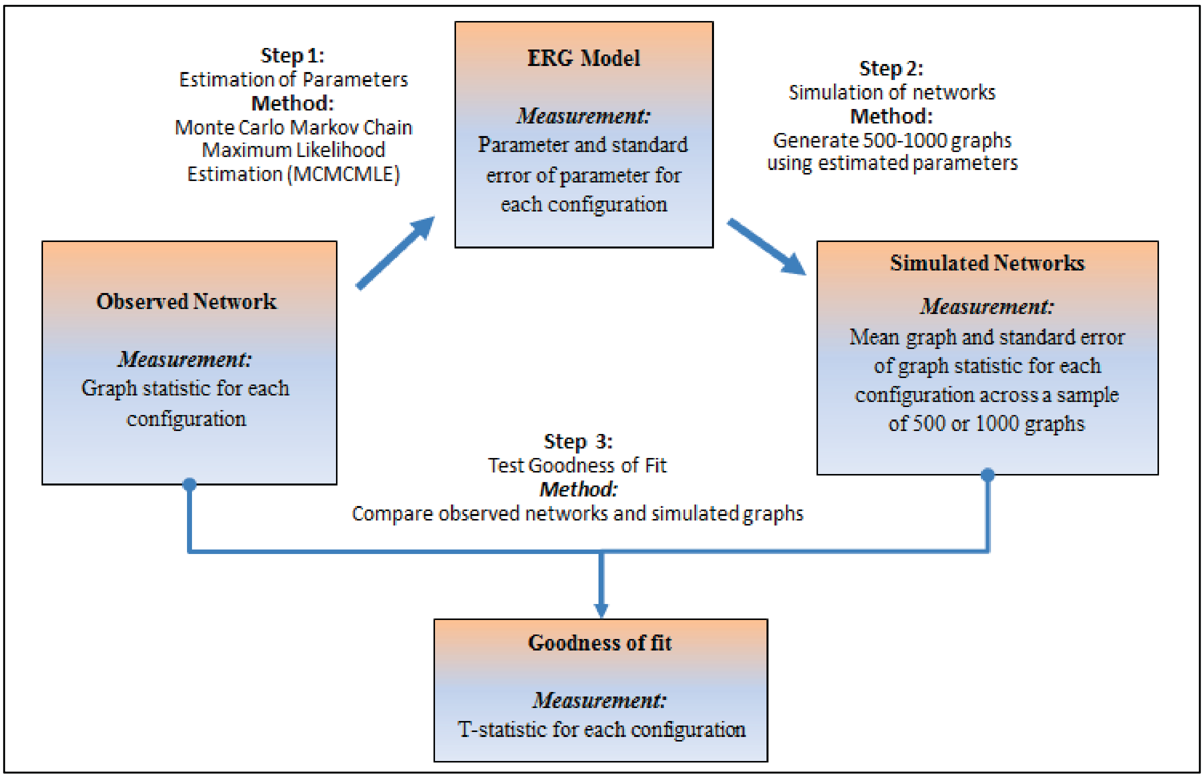
There are two carefully constructed packages that are available for the statistical analysis of network data: Statnet[244] and SIENA[245]. These packages are powered by the use of Markov Chain Monte Carlo (MCMC) algorithms for estimating the parameters in ERGMs. The ERGM package[246] for R, which is part of the Statnet suite packages,[247] was used in this work. It contains a wide range of functionalities for the statistical analysis of social networks that can be used to fit approximate maximum likelihood estimates (MLEs), simulate random networks from the specified ERGM, and evaluate the goodness of fit of an ERGM to the data.[248] This package provides tools for modelling networks based on a well-studied class of models called exponential-family random graph models (ERGMs) or p-star models.[249] An example of the R code used in this research is available in appendix 8.2.

In particular, the package, allows users to: estimate ERGM using a technique called Markov-Chain Monte Carlo Maximum Likelihood Estimation (MCMCMLE) in which a stochastic approximation to the likelihood function is built and then maximized;[250] simulate random networks from the specified ERGM using Metropolis-Hasting MCMC algorithms;[251] and finally, through the use of the gof function in the ERGM package, certain sets of statistics are used to compare features of the observed network with the same features of the simulated networks, which allows the user to perform graphical goodness of fit checks. The process of estimating, simulating and testing an ERGM from a set of observed data is shown in figure 32.

The purpose of using ERGM in this research was to assess to what extent local structural dependencies (endogenous factors) and nodal attribute (exogenous factors) shaped the overall structure of the observed network (i.e., Collaboration Intensity Network formed by the PTRs).The observed network is considered as a single realization from a stochastics process where many other realizations of the network with similar important characteristics are possible. Ties among nodes of this network are assumed to be random variables, and assumptions about dependencies among these random tie variables help to shape the form of the ERGMs.[252]

Figure 32: Estimating and testing the goodness-of- fit of an ERG Model

[243] Robins *et al.* (2007A); Robins *et al.* (2007B)
[244] A package written for the R statistical environment described at http://csde.washington.edu/statnet/
[245] Simulation Investigation for Empirical Network Analysis package available at http://www.stats.ox.ac.uk/~snijders/siena/
[246] Handcock *et al.* (2015)
[247] Goodreau *et al.* (2011)
[248] Hunter *et al.* (2008); Goodreau *et al.* (2008); Jasny and Acton (2012)
[249] Wasserman and Pattison (1996); Robins *et al.* (2007B); Morris and Goodreau (2014)
[250] Geyer and Thompson (1992)
[251] Snijders (2002)
[252] Robins *et al.* (2007B)



Source: Harrigan (2009)

As mentioned previously, the attributes for evaluating the Collaboration Intensity Network formed by PTRs were classified in two categories: those in which the probability of adding a new tie is dependent on the typical local structures of the network (endogenous factors), and those in which the probability that a tie will generate is based only on nodal attributes (exogenous factors).
In the category of endogenous factors, five structural parameters are included as predictors in the ERGM: Edges, Mutuality, and three geometrically weighted terms (GWESP, GWDegree, and GWDSP).

1) Edges: A parameter equal to the number of links in the network. As the network is directed, two parameters have to be added: one based on the number of relationship ties that a project team role has to other actors in the network (ostar1) and the second based on the number of relationship ties a project team role has from others in the network (istar).

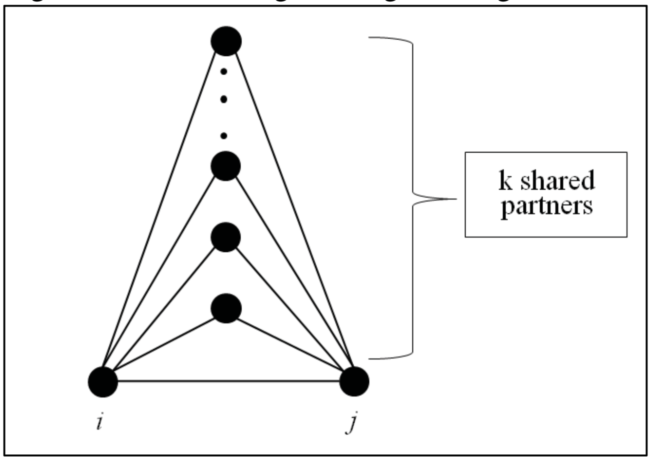
2) Mutuality (Reciprocity): This parameter models the tendency of correspondence of links in the network between two PTRs. That is, this term is calculated by equalling the number of pair actors i and j for which relationship tie $(i \to j)$ and $(j \to i)$ both exist[253].

3) Geometrically Weighted Edgewise Shared Partner Distribution (GWESP): This statistic is a measurement of the transitivity structure of the network. It captures the tendency of PTRs that share a tie to form complete triangles with other PTRs in the

[253] Morris *et al.* (2008)

network.[254] Thus, a k-triangle transitive relationship occurs when 2 actors *i* and *j*, connected by an edge (the base of the k-triangle), are also connected to k other nodes, outlined as shared partners. A k-triangle configuration is shown in figure 33.

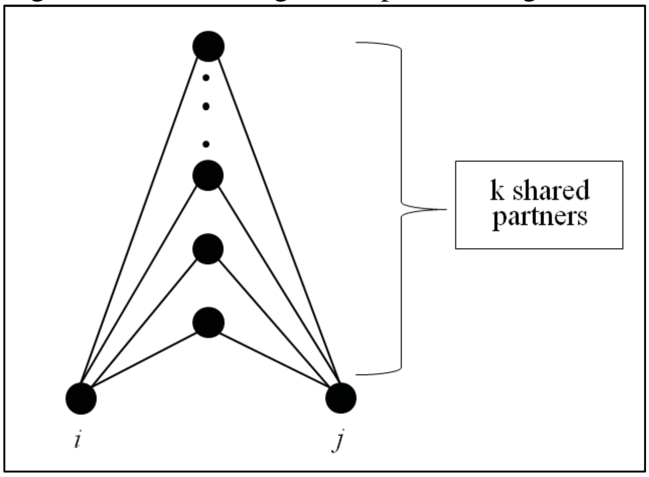
Figure 33: Alternating k-triangle configuration



Source: Robins *et al.* (2006)

4) Geometrically Weighted Dyad-wise Shared Partner Distribution (GWDSP): A measurement of the network's structural equivalence. It captures the tendency of a pair of PTRs to share identical ties with the same sets of partners in the network.[255] A diagram of this k-two parts distribution is shown in figure 34. In this configuration there is no requirement for an edge at the base of the k-triangle and as such it can be seen as a precursor of the transitivity configuration.

Figure 34: Alternating k-two paths configuration



Source: Robins *et al.* (2006)

5) Geometrically Weighted Degree Distribution (GWDegree): This statistic captures the tendency of PTRs with higher in-degree or out-degree to form Collaborative Relationship Ties with one another.[256]

---

254 Hunter *et al.* (2008); Van Duijn, Gile and Handcock (2009)
255 Hunter *et al.* (2008)
256 Goodreau (2007); Van Duijn, Gile and Handcock (2009)

The three geometrically weighted terms (GWTs) were included in this research due to their dual function. First they reveal important aspects of local network structures and secondly overcome the problem of model degeneracy; that is, they give some guarantee that the fitted model can render the observed data (network structures) in a practical sense.[257]

Similarly, within the category of endogenous factors two terms to assess the nodal attribute effects are included in the ERGM as predictors: nodecov (main effect of a covariate) and homophily (interaction effects).

6) Nodecov effect: This parameter models the tendency for nodes with a particular attribute to send or receive ties to other nodes (whether or not that other node has the attribute). This term adds a single network statistic to the model equalling the sum of the values for a specific attribute of PTRs (*i*) and (*j*) for all edges (*i; j*) in the network. In this case, nodeicov and nodeocov term were used.[258] One item assessed nodecov effects: Frequency of Contact during the project life.

7) Homophily effect: This statistic models the tendency of nodes with a particular attribute to have a tie between them (with homophily shown by a positive significant estimate for the interaction effect or a negative significant estimate for the difference effect).[259] In short, homophily is a metric studied in the field of SNA that supports the idea that, "Contact between similar people occurs at a higher rate than among dissimilar people."[260]
   Two kinds of homophily effects were examined in the literature: the uniform homophily effect, which models the tendency of two PTRs to have the same level of the attribute; and the differential homophily effect, which includes a set of statistics, one for each level of the attribute and measures the tendency of two PTRs to have a specific attribute level. The differential homophily effect was used in this study with: Organization Structure, Level of Management, Native Language, Ethnic Group, Frequent Communication Language, Employee Seniority Characterized, and Modularity.

The structural parameters, as well as the nodal attributes used to explain and understand the structures observed in the Collaboration Intensity Network, are shown in the table 20. The model building was developed in three stages (see for instance tables 21 and 22). First a null model was built (model 1). This model (Bernoulli and Erdös-Rényi model) uses edges parameters (ostar1 and istar1) to capture the total number of edges in a network. Second, an additional structural process (Mutuality) and some nodal attributes were added to the model (model 2). Finally, three geometrical weighted terms (GWDegree, GWESP, and GWDSP) were included in the model (model 3).

Table 20: Structural parameters and nodal attributes used in the ERGM

[257] Goodreau (2007); Hunter *et al*. (2006); Hunter *et al.* (2008); Van Duijn, Gile and Handcock (2009)
[258] Morris *et al.* (2008)
[259] De la Haye *et al.* (2010); Lusher, Koskinen, and Robins (2013)
[260] McPherson, Smith-Lovin, and Cook, (2001)

Perspective	Enabler (name in the CCPM Model)	Parameter (in the ERGM)	Type	Category
N.A.	N.A	Ostar1	Basic terms (edges)	Local Structural Dependencies Endogenous Processes
		Istar1		
Strategic Perspective	Organizational structure	Organization	Homophily (interaction effects)	Nodal Attribute Exogenous Processes
	Top management involvement	Level of Management		
	Relationship history	Employee Seniority characterized		
Tactical Perspective	Join Actions	GWESP	Parametric forms	Local Structural Dependencies Endogenous Processes
		GWDSP		
		Modularity	Homophily (interaction effects)	Nodal Attribute Exogenous Processes
	Information sharing structure	GWESP	Parametric forms	Local Structural Dependencies Endogenous Processes
		GWDSP		
		GWIndegree		
		GWOutdegree		
Interpersonal Perspective	Mutuality	Mutuallity	Basis terms	Local Structural Dependencies Endogenous Processes
	Trust	nodeicov: frequency of contact	Nodecov (main effects)	Nodal Attribute Exogenous Processes
		nodeocov: frequency of contact		
	Cultural diversity & Background	Native Language	Homophily (interaction effects)	
		Frequent communication language		
		Ethnic group		

Source: Original research

The network's ERGMs fit was assessed using the Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the goodness-of-fit statistics for common network distributions.[261] For the graphical tests of goodness-of-fit, as proposed by Hunter and Goodreau, four sets of statistics are considered: degree distribution (distribution of lines incident with each node in the graph); distribution of edge-wise shared partners (number of edges in which two partners have k partners in common for each value of k); geodesic distribution (number of pairs for which the shortest path between partners is of length k); and triad census distribution (counts of different groups of three nodes that arise in the network).[262] These sets of network statistics were used to compare the observed network with a network simulated from the fitted model in order to estimate to what degree the structural features of the observed data were predicted by the fitted model.

4.1.3.3 ERGM Model Specification

A generic random network was represented by the matrix Y, an *n x n* symmetric matrix where *n* is the number of PTRs (nodes). Each entry of the Y_{ij} could equal zero or one, with $Y_{ij} = 1$ indicating the presence of an edge between *i* and *j* (strong relation of collaboration) and zero indicating the absence of such an edge (weak relation of collaboration). The possibility of self-edges ($Y_{ij} = 0$) for all *i* is disallowed. The distribution Intensity of Collaboration Y could be parameterized in a canonical exponential family as follows:[263]

$$P_{\emptyset}(Y = y|X) = \frac{\exp\{\theta^T g(y, X)\}}{K}$$

Where:

[261] Hunter *et al.* (2006); Hunter *et al.* (2008)
[262] Hunter *et al.* (2006); Goodreau (2007)
[263] Hunter *et al.* (2006)

Y, is the (random) set of relations (edges and non-edges) in the Network of Collaboration Intensity. This matrix is termed the *adjacency matrix*.

y, is a particular given set of relations, the matrix of observed ties, or the *observed network*.

X, is a matrix of attributes for the vertices in that network. This matrix is termed the *nodal covariate matrix*. Some such attributes in this matrix—like Organization, Level of Management, Native Language, Ethnic Group, Communication Language, Employee Seniority Characterized, Frequency of Contact, and Community—are not influenced by local structures in the network in any way; these are termed *exogenous covariates*. Other covariates may exhibit endogeneity; those are termed *endogenous covariates*.

θ represents the coefficients of the network statistics; their value returns the change in the conditional log-odds of a tie for each unit increase in $g(y, X)$ that the tie would create.

K represents the normalizing constant, the sum of $\sum_{w} \exp\{(\theta^{t} g(w, X)\}$ over all possible networks with w actors.

$g(y, X)$ represents any possible network statistic (structural parameters and nodal attributes). It symbolizes a vector of network statistics which can include exogenous effects and effect that are endogenous to the network. In the tables below, the constituent terms that appear in any of the models evaluated in this research, either as structural parameters and nodal attributes, are described.

Table 21: Structural parameters for the ERGM

Structural Parameter	Description / Formulation	Constituent terms
Edges statistics	This term adds one network statistic equal to the number of edges (i.e. nonzero values) in the network.	ostar(1) : counts the number of distinct k[i]-outstars in the network, where a k-outstar is defined to be a node N and a set of k different nodes \{O_1, ..., O_k\} such that the ties (N,O_j) exist for j=1, ..., k. istar(1): counts the number of distinct k[i]-instars in the network, where a k-instar is defined to be a node N and a set of k different nodes \{O_1, ..., O_k\} such that the ties (O_j, N) exist for j=1, ..., k.
Mutuality	Mutuality: as the number of reciprocated dyads in the graph	number of pairs of actors (project team members) *i* and *j* for which (*i => j) and (j => i)* both exits.
GWESP	$u(y;\phi_t) = e^{\phi_t} \sum_{i=1}^{n-2} \left\{ 1 - \left(1 - e^{-\phi_t}\right)^i \right\} EP_i(y)$	where EP*i* (y) is the number of edges in y between two nodes that share exactly *i* neighbors (project team members) in common, i.e., the number of edges that serve as the common base for exactly i distinct triangles.
GWDSP	$v(y;\phi_t) = e^{\phi_t} \sum_{i=1}^{n-2} \left\{ 1 - \left(1 - e^{-\phi_t}\right)^i \right\} DP_i(y)$	The GWDSP statistic is similar to GWDSP, except EP_i (y) is replaced by DP_i (y), which is the number of pairs (*i; j*) such that *i* and *j* share exactly *i* neighbors in common, whether or not y*ij* = 1.
GWD	$w(y;\phi_s) = e^{\phi_s} \sum_{i=1}^{n-2} \left\{ 1 - \left(1 - e^{-\phi_s}\right)^i \right\} D_i(y), \quad (1)$ $k(\theta) = \sum_w \exp\{\theta^T g(w, X)\}, \quad (2)$	- w(y; Φs) is a scalar for a fixed network y and parameter Φs, obtained by a linear combination of the degree statistics Di(y) that depends on the tuning parameter Φs. - k(θ) is the normalizing factor that ensures that Equation 1 is a legitimate probability distribution. The sum (2) is taken over the whole sample space of allowable networks w. - θ is the vector of coefficients,

Source: based on Hunter *et al*. (2006)

Table 22: Nodal attributes for ERGMs

Nodal Attribute	Description	Constituent terms
Nodemath	This parameter is used to assess the differential homophily effect to:	-Number of edges between PTRs with the same Organization level.
		-Number of edges between PTRs with the same level of Management.
		Number of edges between PTRs with the same Native Language level.
		Number of edges between PTRs belonging to the same Ethnic group.
		Number of edges between PTRs using same communication language.
		Number of edges between PTRs with the same Employee Seniority Characterized level.
		Number of edges between PTRs belonging to the same Community (cluster identified using the weighted degree).
Nodecov	This parameter was used to assess the main effect of a covariate. This term include a single statistic that equaling the sum of attribute (i) and attribute (j) for all edges (i, j). We used nodeicov and condeocov.	Frequency of Contact.

Source: Original research

4.2 Case Study A: Large-Scale Project

4.2.1 Data Collection

For case study A, 211 different nodes/PTRs associated with a specific team role within an organization were identified. These nodes belonged to 9 different organizations. These organizations were: Headquarters, Headquarters' Provider, Subsidiary Office, Subsidiary's Provider, Overseas Branch Office, Overseas Branch Offices' Provider, Customer, Customer's Provider and Government Institution.

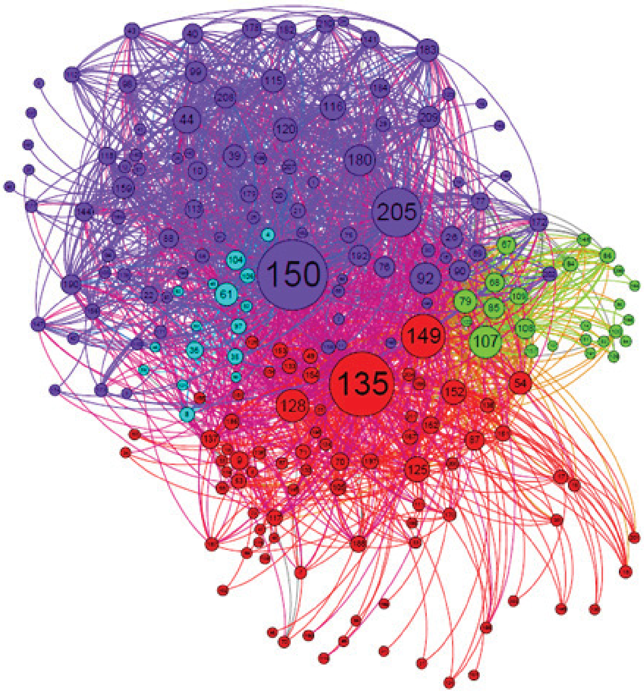
4.2.2 Descriptive and Visual Analysis

One of the primary uses of a Descriptive and Visual analysis in SNA is the identification of the "most important" actor in a social network. There are various techniques whereby a social network may be analysed. The following centrality measures have been deemed appropriate to the scope of this project and have been applied to the project network to get a holistic view of the respective networks, as well as to identify the prominent actors.

4.2.2.1 Degree Centrality

The size of the network was 211 nodes (PTRs). The density of the directed network was 0.05, indicating that approximately one-twentieth of the possible ties are present. The average path length (average geodesic distance) to get from one node to another node in the network is 2.19. The degree measurement for the relationship network showed that four roles (Subsidiary's Project Manager, Headquarters' Project Manager, Subsidiary's Technical Project Manager and Overseas Branch Office's Project Manager) were the most central actors with the highest degree centrality index in the network. As Wasserman and Faust stated, these are the most prominent and visible actors involved in relationships with other actors in the network.[264] It is worth noting that all these actors have project management roles as a team role in this network (see figure 35).

Figure 35: Network of PTRs organized by degree centrality



Id	Label	In-degree	Out-degree	Degree	Weighted Degree	Weighted In-Degree	Weighted Out-Degree
Subsidiary's Project Manager	150	131	112	243	22392	13459	8933
Headquarter's Project Manager	135	96	125	221	14826	6470	8356
Subsidiary's Technical Project Manager	205	79	81	160	7012	3701	3311
Overseas Branch's Project Manager	149	57	79	136	6581	3543	3038

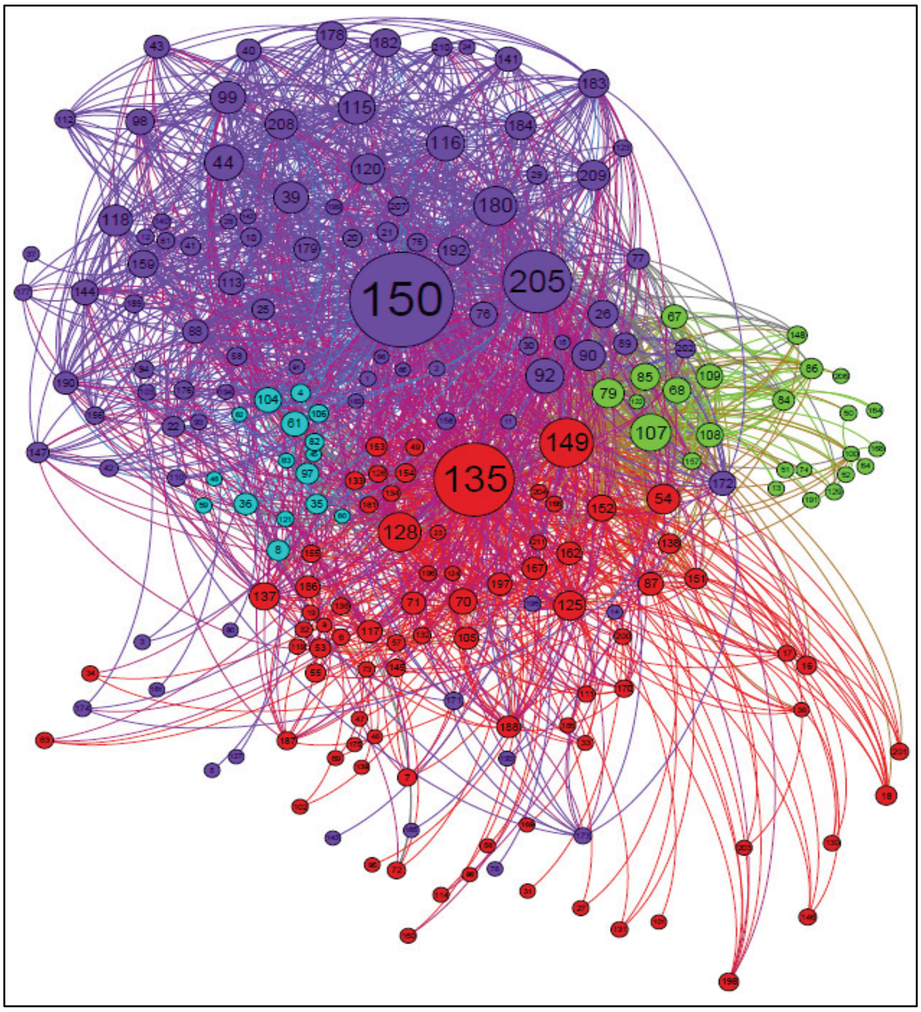
Note: Node size based on degree centrality measurements
Source: Original research

The in-degree measurement for the relationship network[265] shows that the nodes with the most relationship ties from other in the network were four: Subsidiary's Project Manager (node 150), Headquarters' Project Manager (node 135), Subsidiary's Technical Project Manager (node 205) and Overseas Branch's Project Manager (node 149) (see figure 36). That

[264] Wasserman and Faust (1994)
[265] In-degree or through in-links means the links each PTR receives from other PTRs

is, focused on the actors as recipients, those are the most prestigious nodes in the network due the fact that those nodes become the object of many relationship ties.
It should be emphasized that the node with the highest in-degree is the Subsidiary's Project Manager (node 150); thus, it is the most prestigious actor in this network.

Figure 36: Network of PTRs organized by in-degree centrality

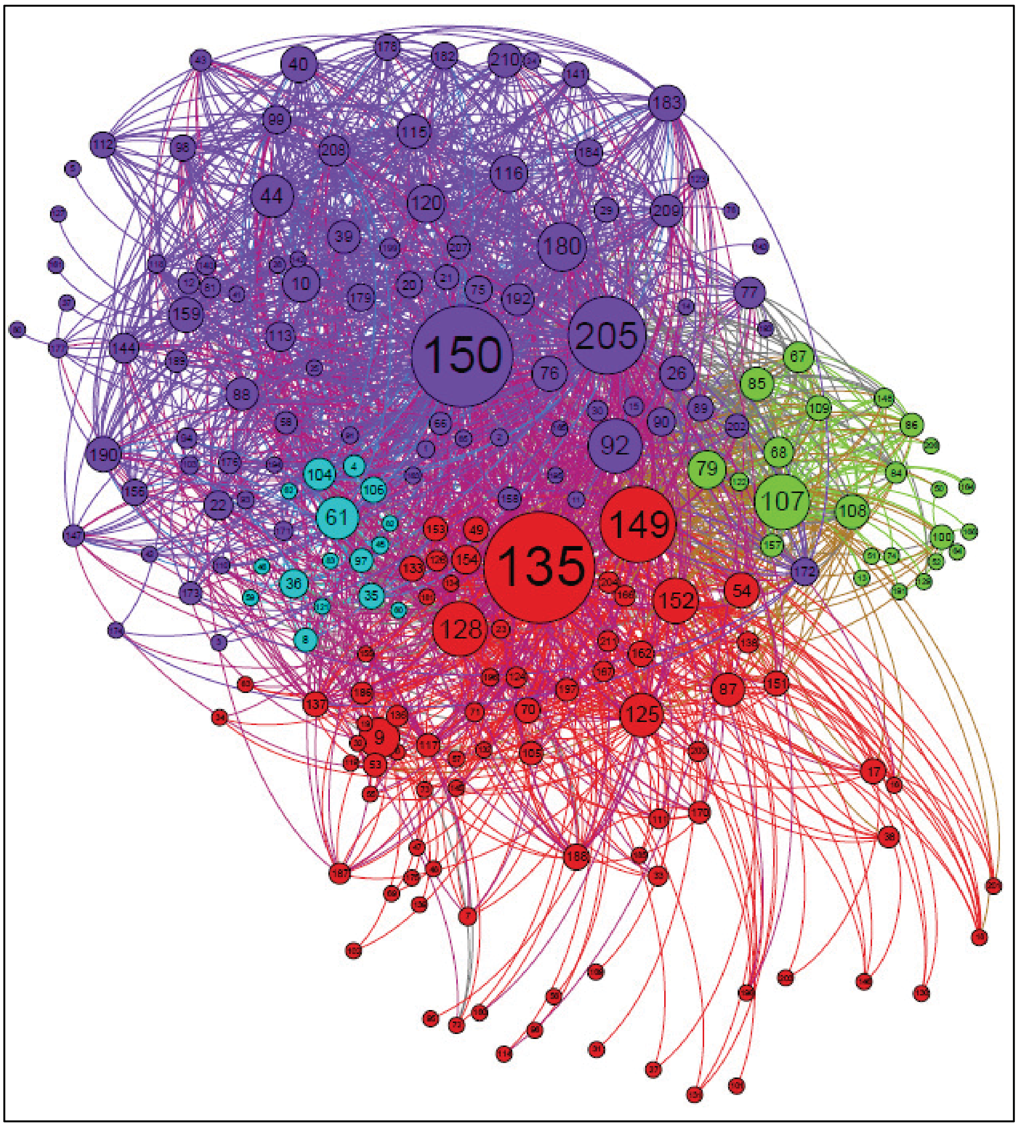


Note: Node size based on in-degree centrality measurements
Source: Original research

The out-degree measurement[266] shows that the nodes with highest out-degree (number of ties or relationship leading out of the node) were the four team roles mentioned above. Thus, these nodes were the most central actors in spreading information and influencing other nodes in the network. It is important to highlight that the node with the highest out-degree was the Headquarters' Project Manager (node 135); this result is unsurprising, given the role of the Company Headquarters in this project as a general contractor. Special mention should be made of another 3 nodes that can also be identified as important nodes distributing information throughout the network. Those are: Customers' Manager Logistics Operations (node 107), Subsidiary's On-site Manager (node 128) and Overseas Branch's Manager Customer Service (node 92) (see figure 37).

[266] Out-degree or out-links means links that connect a PTR to other PTRs

Figure 37: Network of PTRs organized by out-degree centrality

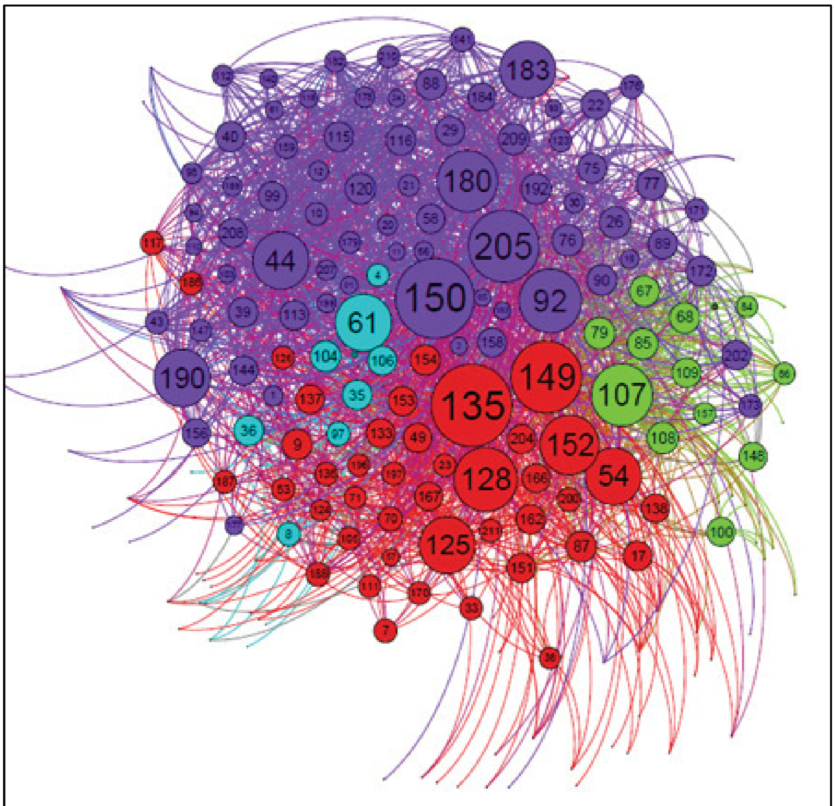


Note: Node size based on out-degree centrality measurements
Source: Original research

4.2.2.2 Closeness Centrality

The closeness centrality index measures how close an actor is to all other actors in the network. Thus, this index calculates the average length of all shortest possible paths from a node to all other nodes in the network. The results show that nodes 135, 150, 149 and 205 had the highest closeness centrality values. That is, they were the PTRs nearest to all other PTRs, and therefore the ones with the greatest influence in speeding communication and/or exchange of information over the entire network (see figure 38).

Figure 38: Network of PTRs organized by closeness centrality



Id	Label	Closeness Centrality
Headquarter's Project Manager	135	1,442
Subsidiary's Project Manager	150	1,490
Overseas Branch's Project Manager	149	1,663
Subsidiary's Technical Project Manager	205	1,663

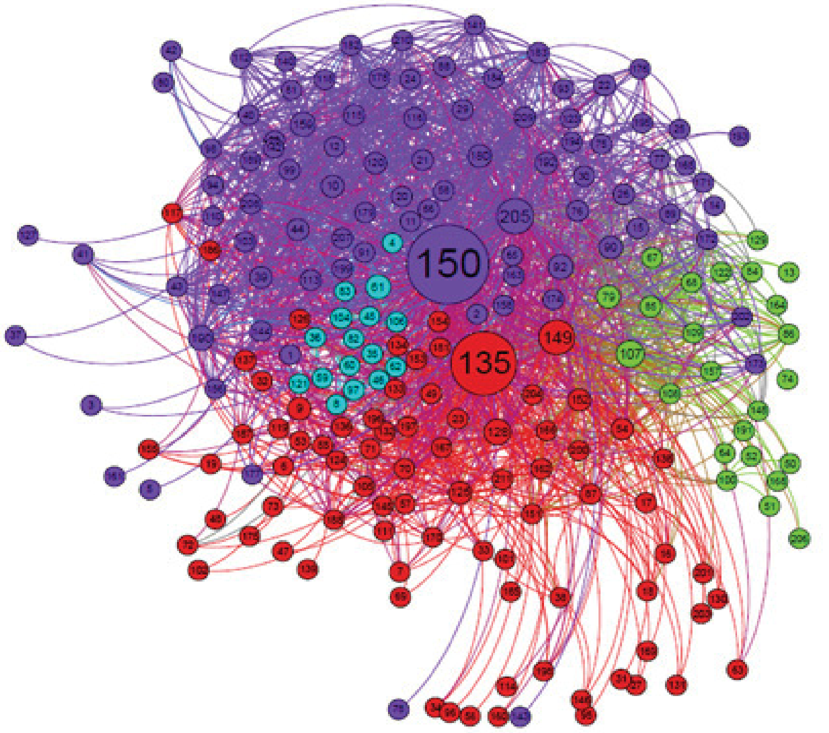
Note: Node size based on closeness centrality measurements[267]
Source: Original research

4.2.2.3 Betweenness Centrality

Betweenness centrality shows which nodes were most likely to be communication paths between other nodes. The results of this analysis clearly show that the actor Subsidiary's Project Manager (node 150) and the actor Headquarters' Project Manager (node 135) had the highest betweenness centrality values, and therefore were acting as bridges between other roles in the network that were not directly connected. As stated by Smith *et al.*,[268] they had a capacity to facilitate or limit relationships between the nodes they linked (see figure 39).

[267] how close a PTR is to all other PTRs in the network
[268] Smith *et al.* (2009)

Figure 39: Network of PTRs organized by betweenness centrality



Id	Label	Betweenness Centrality
Subsidiary's Project Manager	150	9297,8
Headquarter's Project Manager	135	6874,1
Subsidiary's Technical Project Manager	205	2412,6
Overseas Branch's Project Manager	149	2313,3

Note: Node size based on betweenness centrality measurement.[269]
Source: Original research

4.2.2.4 Community Detection

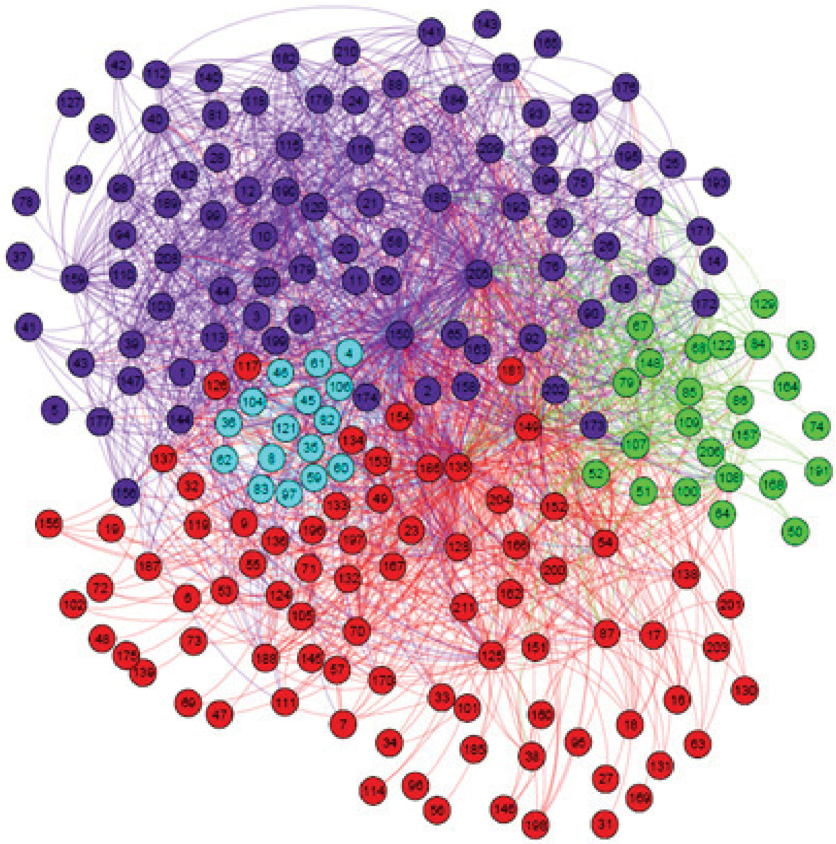
The community detection analysis allows for the discovery of groups of PTRs that can be easily grouped into potential sets of nodes that are densely connected internally. Using the degree relationship and weighted degree relationship matrices, different groups of nodes working together in close cooperation were identified.

First, based on the degree relationship matrix, four different groups of nodes working together were identified as follows: Headquarters (red), Customer (green), Subsidiary (blue), and Administration & Human Resources (light blue). The first three communities mentioned above correspond to groups of PTRs that came from the same organization (i.e., Headquarters, Customers, and Subsidiary, respectively). The last community identified a cross-organizational group of interacting PTRs that worked for the same functional area (Human Resource area). They were carrying out supporting tasks for the project (i.e., drawing

[269] Number of times a PTR is acting as a key intermediary between other PTRs that are not directly connected

up cooperation technical agreements, offering assistance on procedures and conditions for applying for work visas, work permits and any additional customer requirements), with the objective of allowing all the technicians assigned to implementation activities for the project to be able to work in a foreign country (see figure 40).

Figure 40: Network of PTRs organized by communities



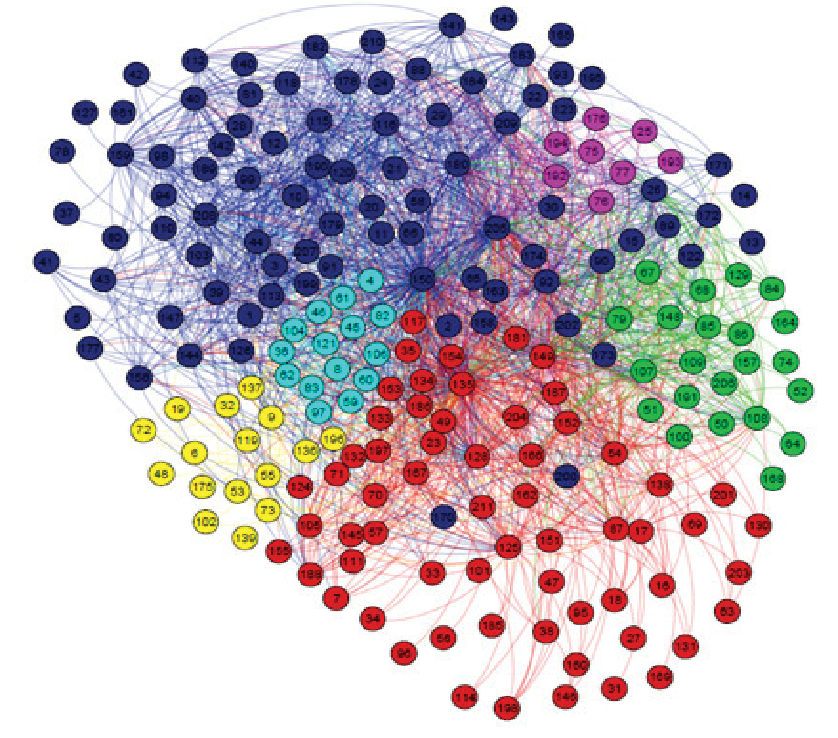
Community	%	Color
Headquarter	37,91	
Admin & Human Resources (Cross-organizational group)	7,58	
Customer	11,37	
Subsidiary	43,13	

Note: Communities based on degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

Second, based on the weighted degree relationship matrix, six groups of nodes (communities) working together in a tight collaboration were identified (see figure 41). Three communities corresponded to groups of PTRs who came from the same organization: Customers (green), Headquarters (red), and Subsidiary (blue). Likewise, three communities of PTRs sharing common supporting activities were identified. Those Communities were: Portfolio Managers (yellow), Administration & Human Resources (light blue), and System Administration (purple).

The Portfolio Managers' team role community was providing support during project implementation (supporting role); undertaking cross-functional support and cross-department coordination in mediating or coaching parties to improve collaboration between stakeholders (coordinating role); and controlling and participating in project steering meetings reflecting senior level support (controlling role). An important characteristic of this community of Managers is that its nodes (actors) are located at the highest executive level in either the Headquarters or Subsidiary organizations. The Administration & Human Resources community undertook the support, guidance and assistance on procedures and conditions for applying for work visas, work permits and any additional customer requirements. The main objective of this community was to allow all the technicians assigned to implementation activities for the project to be able to work in a foreign country. Finally, the PTRs identified in the System Administration community were working together to ensure effective provisioning, installation/configuration, operation, and maintenance of system hardware, operating systems, software systems, and related infrastructure.

Figure 41: Network of PTRs organized by communities



Community	%	Color
Portfolio Managers	7,58	(yellow)
Admin & Human Resources (Cross-organizational group)	7,11	(light blue)
Customer	10,43	(green)
Headquarter	29,38	(red)
Subsidiary	41,71	(dark blue)
System Administration (Cross-organizational group)	3,79	(purple)

Note: Communities based on weighted degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

4.2.2.5 Attribute Analysis

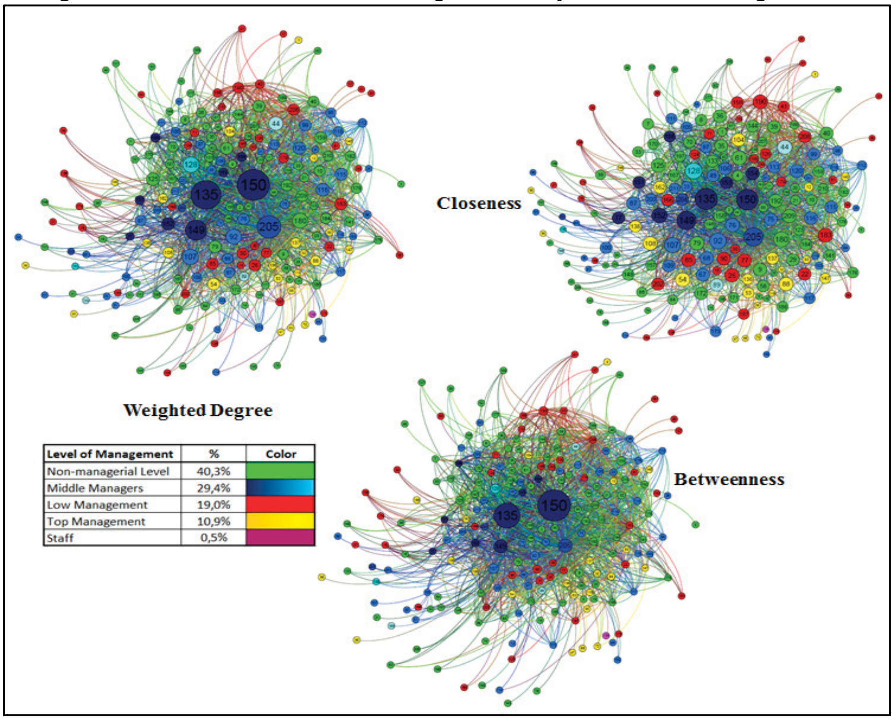
Using the interactive visualization and exploration platform of Gephi, an attribute analysis sought to understand the implications of the different attributes proposed in this research in the Collaboration Intensity Network formed by the PTRs in this SCDP. Thus, to give a line of empirical evidence that the development of effective collaborative relationships among the PTRs participating in this project had been affected by the presence of some of the attributes here identified. This analysis explores four attributes for the development of effective collaborative relationships between team roles in a SCDP: (1) Level of Management; (2) Native Language and Frequent Communication Language; (3) Organization; (4) Employee's Seniority Characterized.

1) Level of Management

As described in section 4.1.2, the attribute "Levels of Management" was categorized in four levels: General or Top Level of Management, Executive or Middle Level of Management, Supervisory or Lower Level of Management, and Non-Managerial Level.

A visual and descriptive analysis for the PTRs classified by this attribute is shown in figure 42 and table 23. Based on the top 10 ranked actors according to weighted degree centrality, it can be inferred that Middle Managers were the most central actors in this network. Thus they were the most prominent/visible and prestigious nodes in the network.

Figure 42: Network of PTRs organized by level of management



Note: Node size based on centrality measurements. PTRs received a colour according to which level of management they were sorted.
Source: Original research

Similarly, four of these team roles (nodes 150, 135, 205 and 149) were found to have the highest scores of betweenness and closeness centrality. Thus, these actors were the key intermediary actors in the network as well as the most likely to be in communication paths between other nodes. That is, it seems that PTRs with project management team roles were those who supported the formation of Collaborative Relationship Ties between other PTRs in the network. Finally, results suggest, that the PTRs were more likely to share Collaborative Relationship Ties with other team roles if they belonged to the same level of management.

Table 23: Top ten ranked PTRs based on centrality measures

Label	Organization	Level_of_Management	Degree	Weighted Degree	Closeness	Betweenness
150	Subsidiary Office	Project Manager	243	22392	1,49	9297,8
135	Headquarter	Project Manager	221	14826	1,44	6874,1
205	Subsidiary Office	Technical Project Manager	160	7012	1,66	2412,6
149	Overseas Brandoffice	Project Manager	136	6581	1,66	2313,3
107	Customer	Departmental Manager	90	4206	1,88	1092,4
92	Overseas Brandoffice	Departmental Manager	84	3757	1,85	695,4
128	Subsidiary Office	On-site Manager	92	2459	1,83	924,5
180	Subsidiary Office	Non-managerial level	84	2416	1,89	434,8
152	Customer	Project Manager	59	2075	1,93	338,2
85	Customer	Low Management	44	2064	2,04	178,8

Source: Original research

2) Native Language and Frequent Communication Language

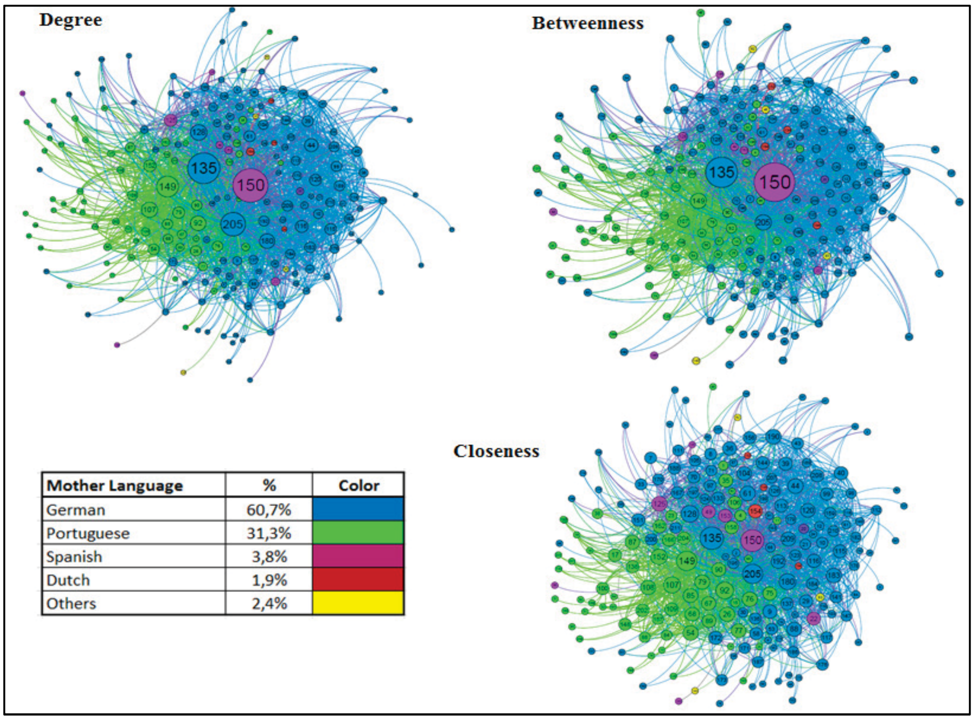
The actors belonging to this network were analysed, focusing on the effects of the attributes "Native Language"[270] and "Frequent Communication Language" on the shaping of collaborative relationships between PTRs. As was explained before, the attribute "Native Language" was classified in five categories: German, Portuguese, Spanish, Dutch and Others. Similarly the attribute "Frequent Communication Language" was classified in four categories: English, German, Portuguese and Spanish.

Because of the physical proximity of some nodes (PTRs) on the depicted networks, it appears that a PTR was more likely to establish Collaborative Relationship Ties with those partners that shared the same native language than with those that didn't. The same occurred with the Communication Language attribute. Thus, it appears, that two PTRs are more likely to share a collaborative tie with those partners with whom they share the same native language than with those with different native language. Similarly, nodes interacting with each other during the project life through the same communication language are more likely to form Collaborative Relationship Ties than other nodes which are using different communication languages (see figures 41 and 42).

Additionally, based on their central position in the network (see figures 41 and 42) and the higher centrality ratios showed by the nodes 150 and 135 (see table 24), it appears that those nodes were the bridge between German and Portuguese communities. In addition, the date collection revealed that the node 150 was one of the actors in this network able to establish communication with other actors in at least three different languages (Spanish, English and German).

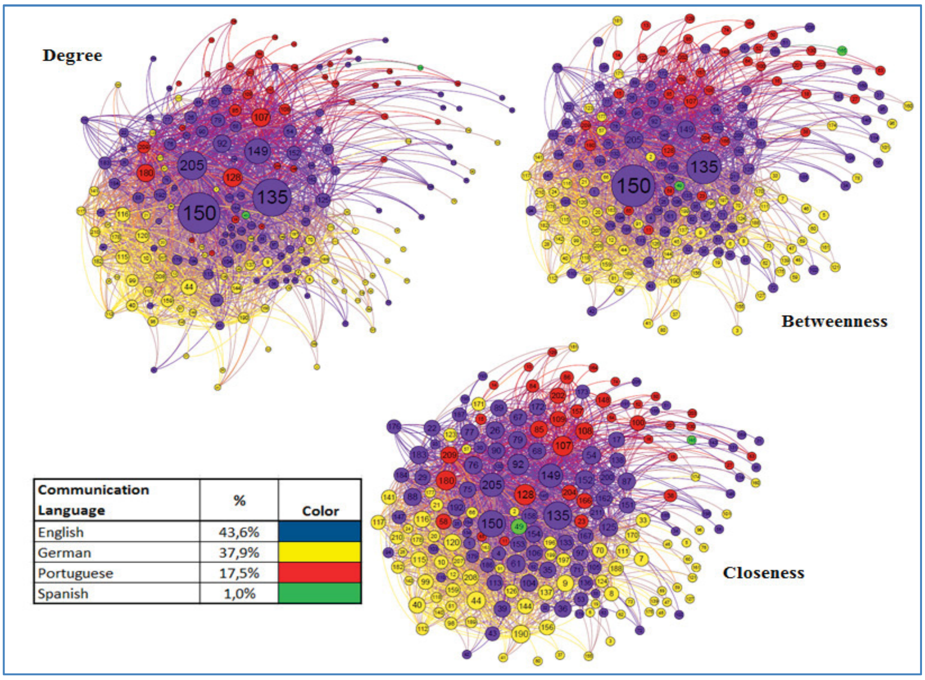
270 Native Language refers to the first language learned at home in childhood.

Figure 43: Network of PTRs organized by native language



Note: Node size based on centrality measurements. PTRs received a colour depending on which native language they were sorted.
Source: Original research

Figure 44: Network of PTRs organized by frequent communication language



Note: Node size based on centrality measurements. PTRs received a colour depending on which communication language they were sorted.
Source: Original research

Table 24: Top ten ranked PTRs based on centrality measures

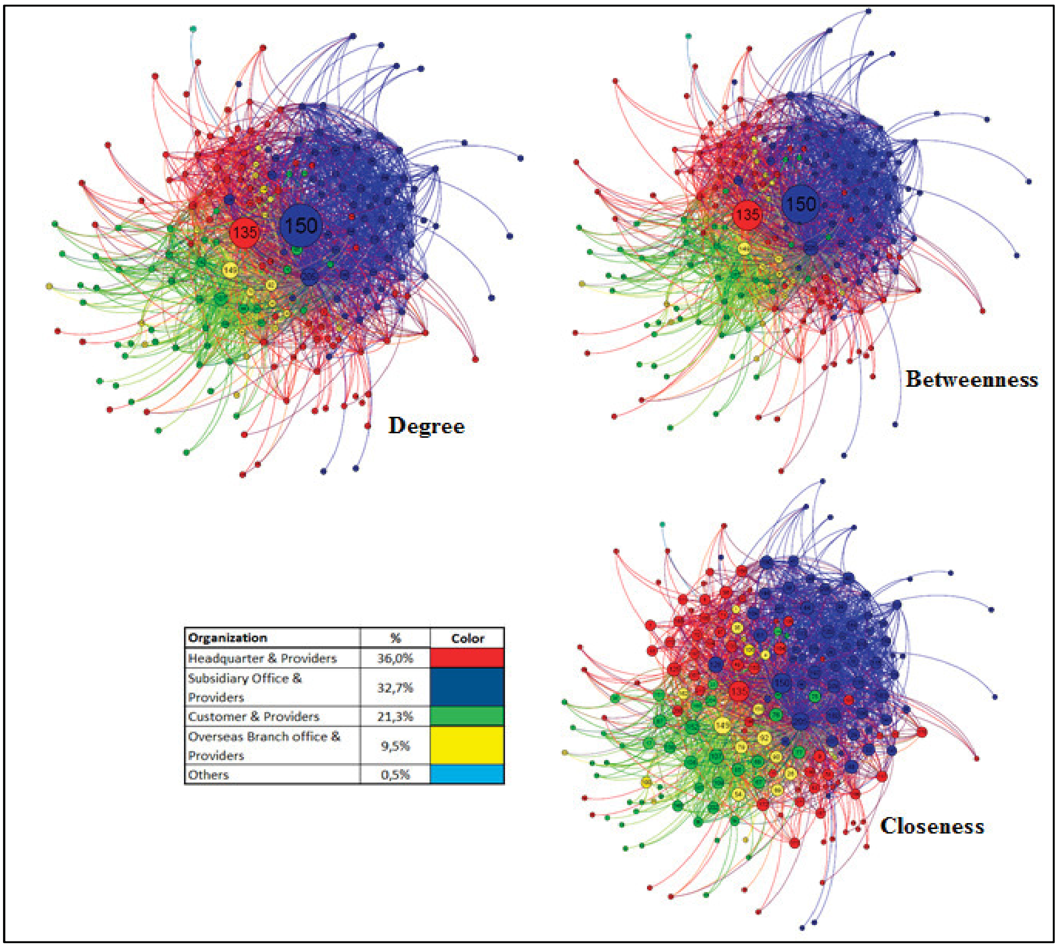
Label	Organization	Level_of_Management	Communication Language	Native Language	Degree	Weighted Degree	Closeness	Betweenness
150	Subsidiary Office	Project Manager	English	Spanish	243	22392	1,49	9297,8
135	Headquarter	Project Manager	English	German	221	14826	1,44	6874,1
205	Subsidiary Office	Technical Project Manager	English	German	160	7012	1,66	2412,6
149	Overseas Brandoffice	Project Manager	English	Portuguese	136	6581	1,66	2313,3
128	Subsidiary Office	On-site Manager	Portuguese	German	92	2459	1,83	924,5
107	Customer	Departmental Manager	Portuguese	Portuguese	90	4206	1,88	1092,4
92	Overseas Brandoffice	Departmental Manager	English	Portuguese	84	3757	1,85	695,4
180	Subsidiary Office	Non-managerial level	Portuguese	German	84	2416	1,89	434,8
44	Subsidiary Office	Senior Supervisor	German	German	70	1338	1,98	255,9
116	Subsidiary Office	Departmental Manager	German	German	62	1387	2,09	158,4

Source: Original research

3) Organization

Results of the Organization attribute reveal the network of PTRs classified by organization type. They were—in order of importance, calculated as ratio of the total number of nodes that each organization has in the network—as follows: Headquarters (36%), Subsidiary Office (32.7%), Customer (21.3%) and Overseas Brand Office (9.5%) (see figure 45).

Figure 45: Network of PTRs classified by organization



Note: Node size based on centrality measurements. PTRs received a colour depending on which organization they were sorted

Source: Original research

Because of the closeness location of some nodes (PTRs) on the depicted networks, it appears that two PTRs tended to share a collaborative tie with those in their own organization than with those from another organization. Worthy of note is the position of the nodes belonging to the Overseas Branch Office. As can be seen in the closeness graph, they were mostly located close to the customer nodes (green) and therefore it can be presumed they were acting as intermediaries between the customer and either the Headquarters or Subsidiary organizations.

Due the size of the relationship network of this case study (Large-Scale Project), the attribute "Organization" was analysed by means of a low-level analysis. Thus, the subnetwork and its key players and idle roles were identified to gain an understanding of which roles are important to which subnetwork. First of all, the main network was split into three subnetworks: (a) Headquarters, (b) Subsidiary, and (c) Overseas Branch Office, Customer and Customer's Providers. Secondly, the following four metrics were deemed appropriate to characterize the key PTRs in the abovementioned subnetworks: Activity, Authority, Reach, and Access.[271]

Activity was defined in terms of how active and collaborative an actor was in the network, and the weighted degree centrality was used to measure that. Authority was measured using the eigenvector centrality measurement. This measure was most concerned with how much control a node had over the flow of information (low = 0, high = 1). Meaning, a measure of the actor's importance in a network, based on how well-connected it was to other nodes, how many groups it bridged, or how long it took to reach the rest of the network. Reach was measured in terms of how much potential influence a node wields. Therefore, betweenness centrality measurement was used for that. Finally, for the metric Access, the closeness centrality measurement was used and indicated how easily an actor can get the resources he needs to be successful in the network.

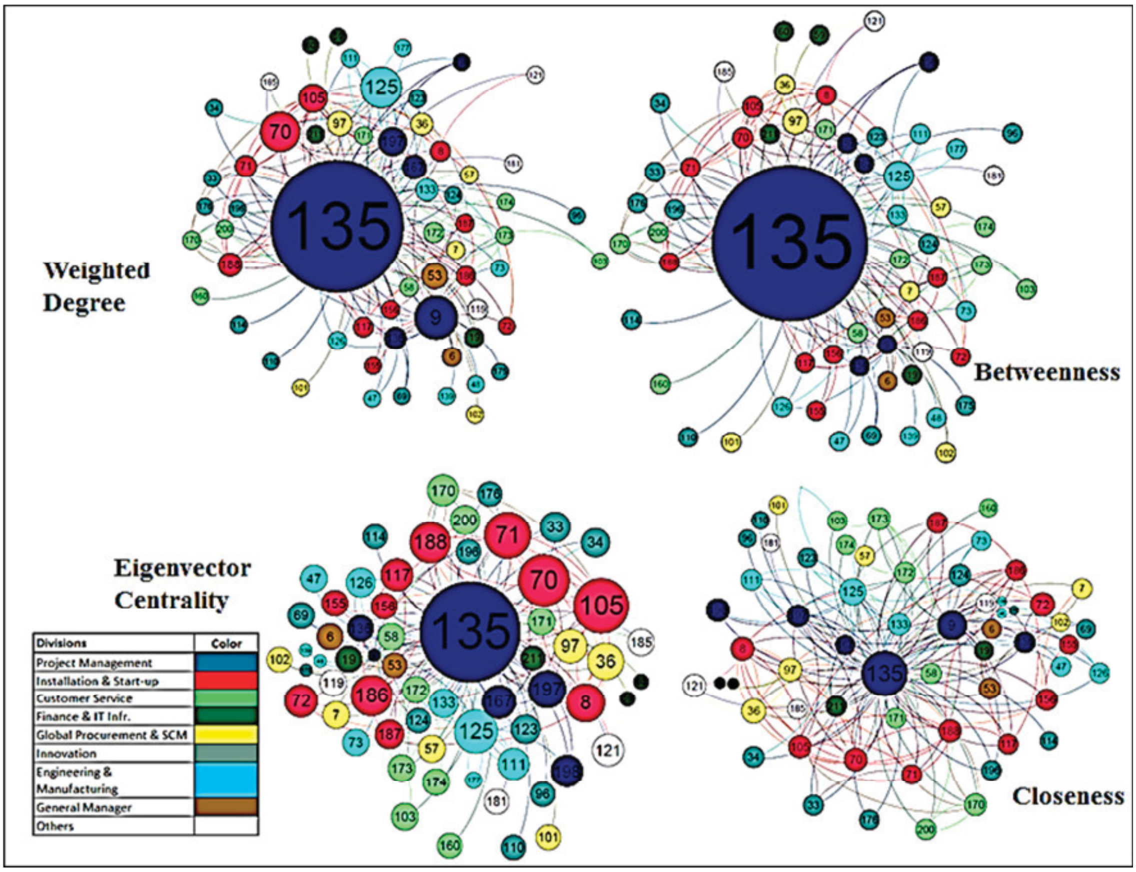
a) Headquarters Subnetwork

This subnetwork had 62 nodes (29.38% visible) and 202 edges (9.2% visible). The density of the directed sub-network was 0.05, indicating that approximately one-twentieth of the possible arcs were present.

The Headquarters Project Manager (node 135) had the highest degree centrality, indicating that it was the most active role in this subnetwork. It is important to note that this node had the maximum value of Eigenvector measurement (1.0), which translates to maximum authority in this subnetwork. Similarly, this role had the highest betweenness and closeness centrality. That means this node was the most intermediate and critical node for connecting other nodes that were not connected in the network, and at the same time the one that could speed up the communication and/or exchange of information, resources and knowledge in this subnetwork (see figure 46).

[271] The Advisory Board Company (1996).

Figure 46: Headquarters' sub-network of PTRs organized by divisions



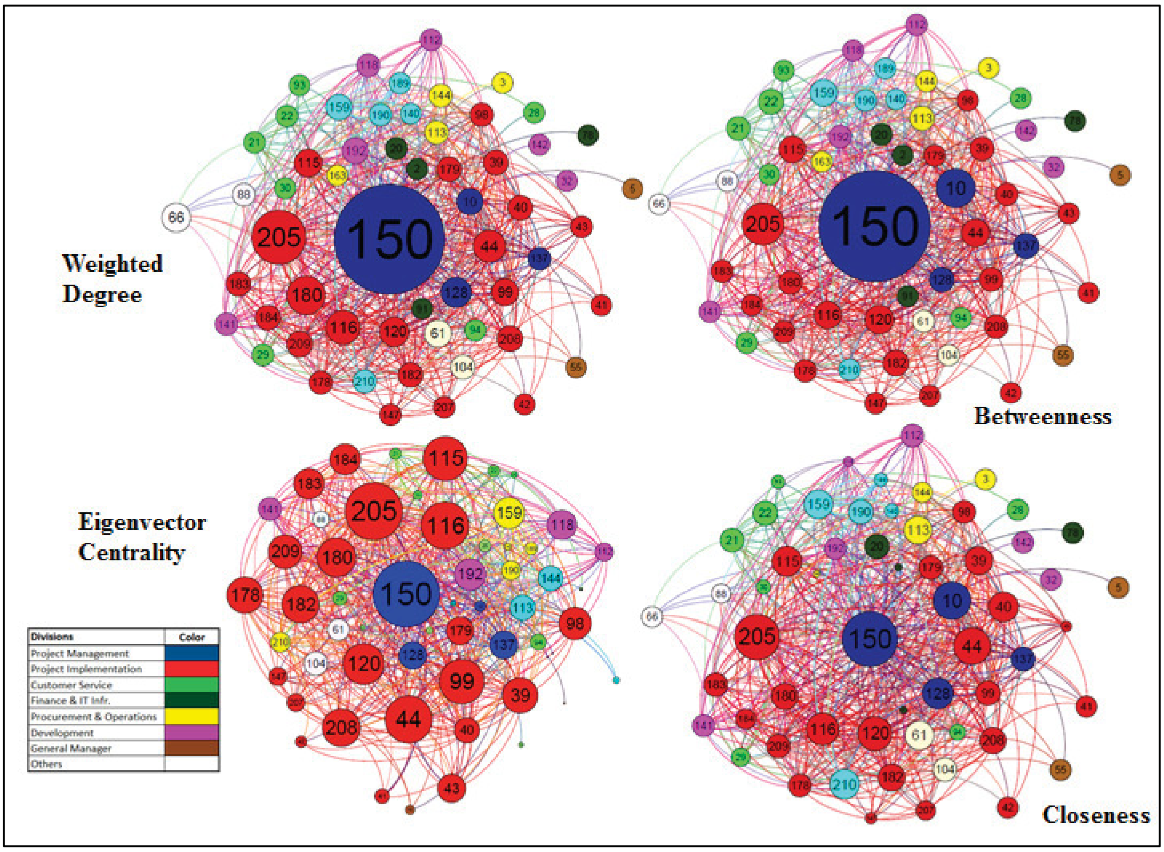
Note: Node size based on centrality measurements. PTRs received a colour depending on which organization they were sorted.
Source: Original research

b) Subsidiary Subnetwork

This subnetwork had 58 nodes (27.49% visible) and 675 edges (30.75% visible). The density of the directed sub-network was 0.204, indicating that approximately one-fifth of the possible arcs were present.

The Subsidiary's Project Manager (node 150) had the highest degree centrality, indicating that it was the most active role in this subnetwork. It is important to note that this node had the maximum value of Eigenvector measurement (1.0), which means that it had the greatest authority in this subnetwork. Similarly, this role had the highest betweenness and closeness centrality. That means this node was the most intermediate and critical node for connecting other nodes to one another, and, at the same time, the one that could speed up the communication and/or exchange of information, resources and knowledge in this subnetwork. Worthy of note are the centrality ratios of the Technical Project Leader (node 205): It had the second highest values in all four of the measurements discussed above. Conversely, the Finance and IT Infrastructure, and General Manager were the idlest divisions in this subnetwork. That was probably because this project encountered no substantial financial or administrative problems during its entire project life (see figure 47).

Figure 47: Subsidiary's sub-network of PTRs organized by divisions



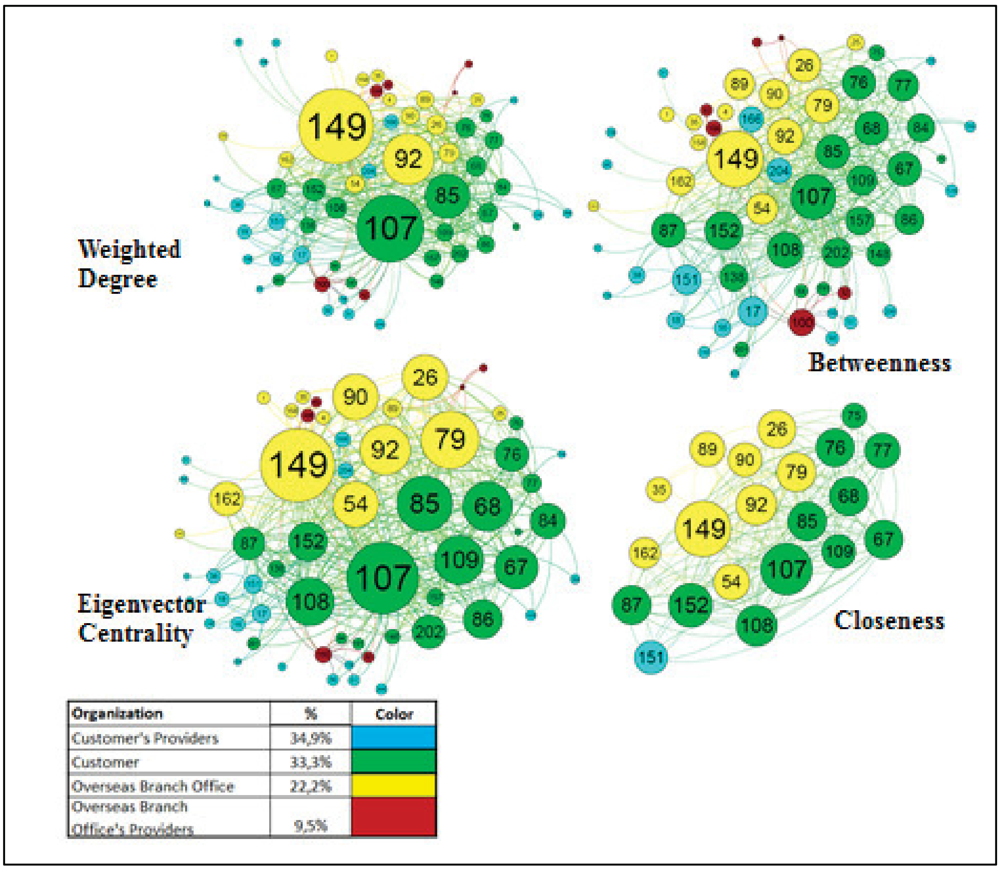
Note: Node size based on centrality measurements. PTRs received a colour depending on which division they were sorted.
Source: Original research

c) Overseas Branch Office, Customer and Customer's Providers Subnetwork

This subnetwork had 63 nodes (29.86% visible) and 402 edges (18.31% visible). The density of the directed sub-network was 0.103, indicating that approximately one-tenth of the possible arcs were present.

The Overseas Branch Office's Project Manager and Customer's Logistics Operations Manager (node 149 and 107) had the highest values of weighted centrality, eigenvector, betweenness and closeness centrality. The preceding indicates that they were the most active and authoritative PTRs in this subnetwork. Likewise, it indicates that they were the most intermediate and critical nodes in terms of their ability to facilitate or limit the interaction between the nodes they linked, as well as the nodes that could speed up the communication and/or exchange of information, resources and knowledge in this subnetwork. It should be noted that, in this sub-network, the role of the Customer's Project Manager (node 152), did not have the greatest influence and authority at the customer side. It seems that this role was somewhat overtaken by the Customer's Logistics Operations Manager, especially in the final phases of this project (see figure 48).

Figure 48: Sub-network of PTRs classified by organizations



Note: Node size based on centrality measurements. PTRs received a colour depending on which organization they were sorted. This subnetwork only includes PTRs belonging to Customer and Overseas Branch Offices.
Source: Original research

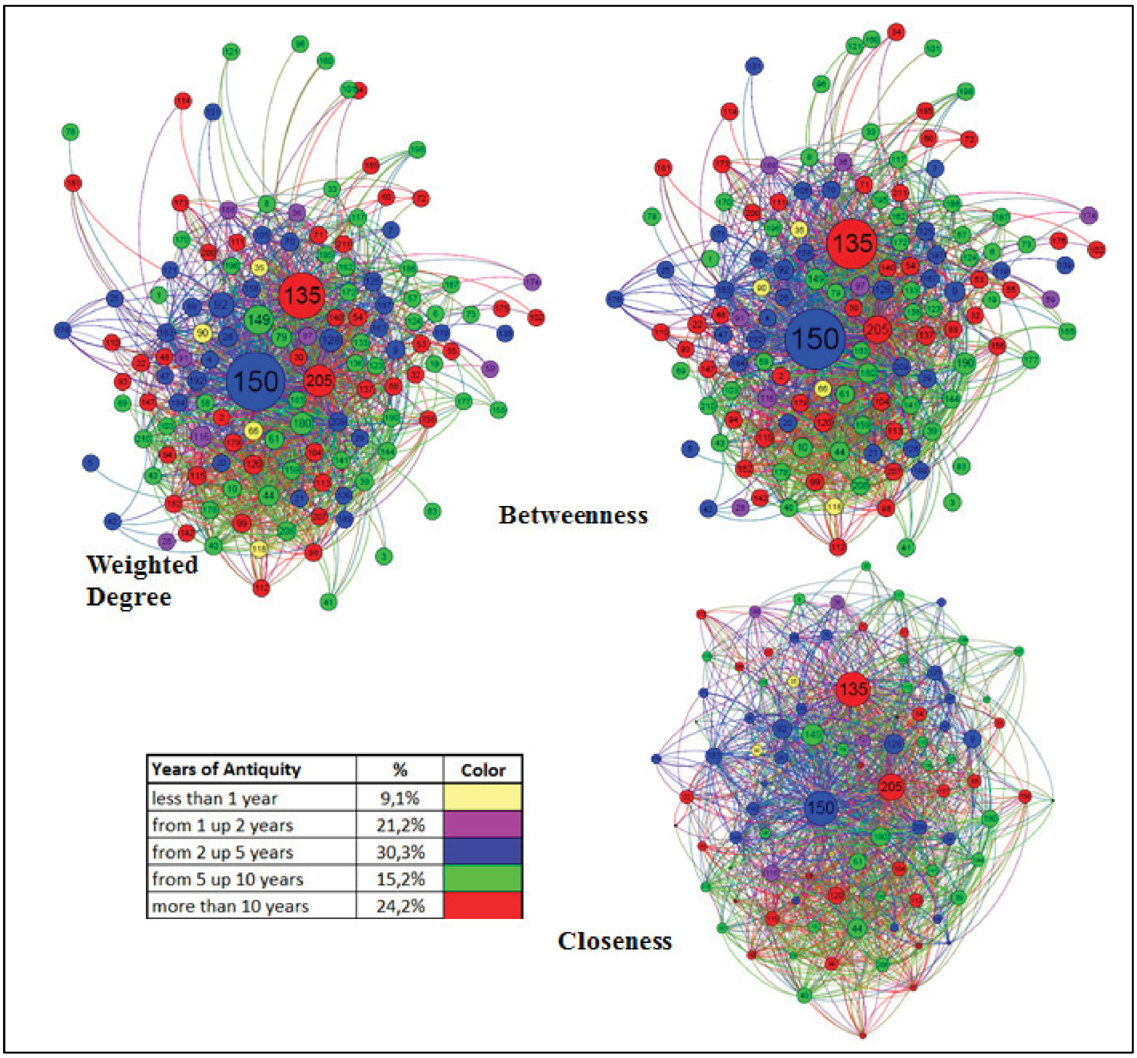
4) Employee's Seniority Characterized

PTRs belonging to this network were analysed in terms of the attribute "Employee's Seniority Characterized" according to years of service in one of the specified companies (Headquarters, Subsidiary and Overseas Branch Office) and ranging as follow: less than one year's service (0), from 1 to 2 years' service (1), from 2 to 5 years' service (2), from 5 to 10 years' service (3), and more than 10 years' service (4).

The visual and descriptive analysis of the Collaboration Intensity Network suggests, that two PTRs from this sub-network[272] would not tend to share Collaborative Relationship Ties with other team roles as a function of the length of service with their employer (see figure 49).

[272] customer and customer's providers organizations were not included in this analysis due to the lack of information

Figure 49: Sub-network of PTRs organized by employee seniority



Note: Node size based on centrality measurements. PTRs received a colour according to which level of employee seniority they were sorted. This subnetwork only includes PTRs belonging to Headquarters, Subsidiary and Overseas Branch Offices.
Source: Original research

4.2.3 Stochastic Modelling

As mentioned in section 4.1.3.2, ERGMs were performed to understand the implications of structural parameters and node level attributes in the Collaboration Intensity Network formed by the PTRs in this SCDP (collaborative links between PTRs). Forty-four parameters were included in the dyadic independent model: two for edges; one for mutuality as a structural parameter; differential homophily of Organization as a seven-level factor; differential homophily on Level of Management (six-level); differential homophily on Employee Seniority Characterized as a five-level factor; differential homophily on Modularity Class (six-level); differential homophily on Native Language as a four-level factor; differential homophily on Communication Language as a three-level factor; differential homophily on Ethnic Group (four-level); two parameters for the Frequency of Contact factor effect; and four for the sets of GWTs (GWIdegree, GWOdegree, GWESP and GWDSP). The fitted values of these parameters, standard errors, and the AIC and BIC criterion for the four models applied to the Collaboration Intensity Network are presented in table 25.

Table 25: Stochastic models predicting the Collaboration Intensity Network

Coefficient	Model 1			Model 2			Model 3			Model 4		
	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR
Ostar	-4.51***	0,02	0,01	-6,05***	0,05	0,002	-5,36***	0,07	0,005	-4,58***	0,08	0,01
Istar	0,71***	0,02	2,03	0,01	0,05	1,01	0,14*	0,07	1,15	-0,57***	0,08	0,57
Mutual	-	-	-	2,41***	0,15	11,09	1,92***	0,17	6,85	1,96***	0,16	7,12
Organization												
Customer	-	-	-	0,93***	0,17	2,54	0,52*	0,24	1,69	0,50*	0,21	1,65
Customer'Provider	-	-	-	-0,11	0,33	0,89	0,63*	0,28	1,88	0,59*	0,30	1,81
Headquarter	-	-	-	-0,08	0,15	0,92	0,59**	0,19	1,81	0,66**	0,21	1,93
Headquarter's Provider	-	-	-	0,9	0,69	2,46	0,8	0,77	2,22	1,56**	0,49	4,77
Overseas Branch Office	-	-	-	0,65**	0,22	1,91	0,24	0,32	1,28	0,31	0,28	1,37
Overseas Branch Office's Provider	-	-	-	0,82	0,72	2,28	1,79*	0,8	6,01	1,92**	0,70	6,82
Subsidiary	-	-	-	0,60***	0,12	1,82	0,18	0,13	1,2	0,24*	0,12	1,27
Level of Management												
General Mgmt.	-	-	-	0,91***	0,24	2,47	0,70*	0,31	2,02	0,79*	0,36	2,20
Middle Mgmt.	-	-	-	0,06	0,24	1,06	0,08	0,31	1,08	0,16	0,27	1,18
Low Mgmt.	-	-	-	0,45***	0,09	1,57	0,15	0,1	1,16	0,10	0,08	1,10
Non- Managerial	-	-	-	-0,32*	0,14	0,73	-0,09	0,14	0,91	-0,12	0,13	0,89
Native Language												
Dutch	-	-	-	1,86***	0,45	6,4	2,26***	0,62	9,58	1,98**	0,67	7,23
German	-	-	-	-0,92***	0,24	0,39	-0,18	0,28	0,84	-0,08	0,12	0,92
Portuguese	-	-	-	1,23***	0,22	3,41	0,79*	0,39	2,2	0,80***	0,13	2,23
Spanish	-	-	-	-0,09	0,52	0,92	-0,08	0,75	0,92	0,61	0,48	1,84
Ethnic Group												
Dutch	-	-	-	0,05	0,45	1,05	0,25	0,62	1,28	-	-	-
Germanic	-	-	-	0,90***	0,25	2,45	0,14	0,28	1,15	-	-	-
Latin America	-	-	-	0,12	0,2	1,12	0,12	0,37	1,12	-	-	-
Latin Europe	-	-	-	1,92*	0,97	6,83	2,33	1,35	10,29	-	-	-
Communication Lang.												
English	-	-	-	0,58***	0,08	1,79	0,29**	0,09	1,34	0,29***	0,08	1,34
German	-	-	-	0,76***	0,13	2,13	0,71***	0,13	2,04	0,74***	0,13	2,1
Portuguese	-	-	-	-0,02	0,19	0,98	0,2	0,22	1,22	0,22	0,21	1,24
Employee's Seniority Characterized												
< to one year	-	-	-	1,42	1,13	4,14	1,14	1,59	3,13	-	-	-
1 to 2 years	-	-	-	0,46	0,76	1,59	0,13	0,92	1,14	-	-	-
2 to 5 years	-	-	-	0,24	0,18	1,28	0,29	0,21	1,34	-	-	-
5 to 10 years	-	-	-	0,11	0,17	1,11	-0,09	0,21	0,91	-	-	-
>10 years	-	-	-	0,06	0,14	1,07	0,22	0,17	1,25	-	-	-
Nodecov												
Freq_of_contact (Nodeicov)	-	-	-	0,01***	0,00	1,01	0,01***	0,00	1,01	0,01***	0,00	1,01
Freq_of_contact (Nodeocov)	-	-	-	0,01***	0,00	1,01	0,01***	0,00	1,01	0,01***	0,00	1,01

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
Source: Original research

Table 25 (cont.): Stochastic models predicting the Collaboration Intensity Network

Coefficient	Model 1			Model 2			Model 3			Model 4		
	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR
Modularity												
Group 0 (Subsidiary)	-	-	-	2,52***	0,24	12,389	2,16***	0,21	8,70	2,02***	0,21	7,53
Group 1 (Headquarters)	-	-	-	2,62***	0,24	13,745	2,48***	0,22	11,99	2,26***	0,21	9,59
Group 2 (Customer)	-	-	-	0,95***	0,19	2,585	0,98***	0,25	2,66	1,00***	0,26	2,72
Group 3 (Admin & Human Resources)	-	-	-	0,93***	0,11	2,529	1,01***	0,13	2,76	0,95***	0,11	2,58
Group 4 (Portfolio Managers)	-	-	-	0,78***	0,11	2,185	0,92***	0,11	2,52	0,86***	0,10	2,36
Group 5 (Sys. Admin.)	-	-	-	-0,54	0,99	0,584	0,00	1,36	1,00	-0,21***	1,24	0,81
High Degree Dist.												
GWIdegree	-	-	-	-	-	-	-0,83**	0,26	0,43	-0,88***	0,25	0,41
GWOdegree	-	-	-	-	-	-	-3,19***	0,28	0,04	-3,21***	0,26	0,04
GWESP (clustering)	-	-	-	-	-	-	0,52***	0,09	1,69	0,54***	0,09	1,72
GWDSP	-	-	-	-	-	-	-0,04***	0,01	0,96	-0,04***	0,01	0,96
Model Fit	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**
	-4666.32	9337	9354	-3120.84	6318	6648	-2698,14	5480	5846	-2704,87	5476	5763

*Note: * P < 0.05; ** P < 0.01; *** P < 0.001.*
Source: Original research

Model 1 includes two parameters associated with the density of the network (ostar, istar). The second model expands on model 1 by including a structural characteristic (mutuality effect), as well as several statistics based on nodal covariates. This approach was used to describe and explain the main effects of continuous covariates and categorical factors in the Collaboration Intensity Network. Three structural characteristics of the collaboration network (GWTs) were included in model 3. Finally, using the outputs of model 3, the nodal attributes Ethnic Group and Employee's Seniority Characterized were excluded from the model because it appeared that they were not playing important roles in the generative process that gave rise to the Collaboration Intensity Network (that is, they were not statistically significant for the model). After the comparison of the AIC and BIC scores[273] between models, the results indicated that Model 4 had the best data fit and therefore made the best prediction.

The results from model 4 confirm the expectations of this research. The ostar and istar coefficients, which were statistically significant at the 0.001 level, indicate that the probabilities that a tie would be formed was equal to the probability of [exp(-4.58)/(1+exp((-4.58))] = 0.010 and [exp(-0.57)/(1+exp((-0.57))] = 0.36, respectively. The positive and statistically significant effect of Mutuality indicates that there was a tendency in the network toward reciprocal ties, which indicated that if one PTR collaborated with another PTR, the other PTR tended to collaborate with him back. The negative and statistical significant effect of GWD statistics (GWIdegree and GWOdegree) suggest that PTRs with higher out-degree or in-degree values were unlikely to share a collaborative tie with other PTRs that also had higher out-degree or high in-degree values. In contrast, the positive and statistically significant effect of triangles (GWESP) indicate that PTRs were more likely to enter into collaboration jointly (in small triads or cluster) rather than unilaterally. The negative and

[273] Given a set of candidate models for the data, *the preferred model is the one with the minimum AIC and BIC values.* Hence both scores reward goodness of fit (as assessed by the likelihood function), but also include a penalty term for the number of parameters in the model. This penalty discourages problems of overfitting.

statistically significant value of GWDSP indicates that there was no evidence of structural equivalence in the network; that is, a pair of PTRs in the network did not tend to share Collaborative Relationships Ties with the same sets of partners.

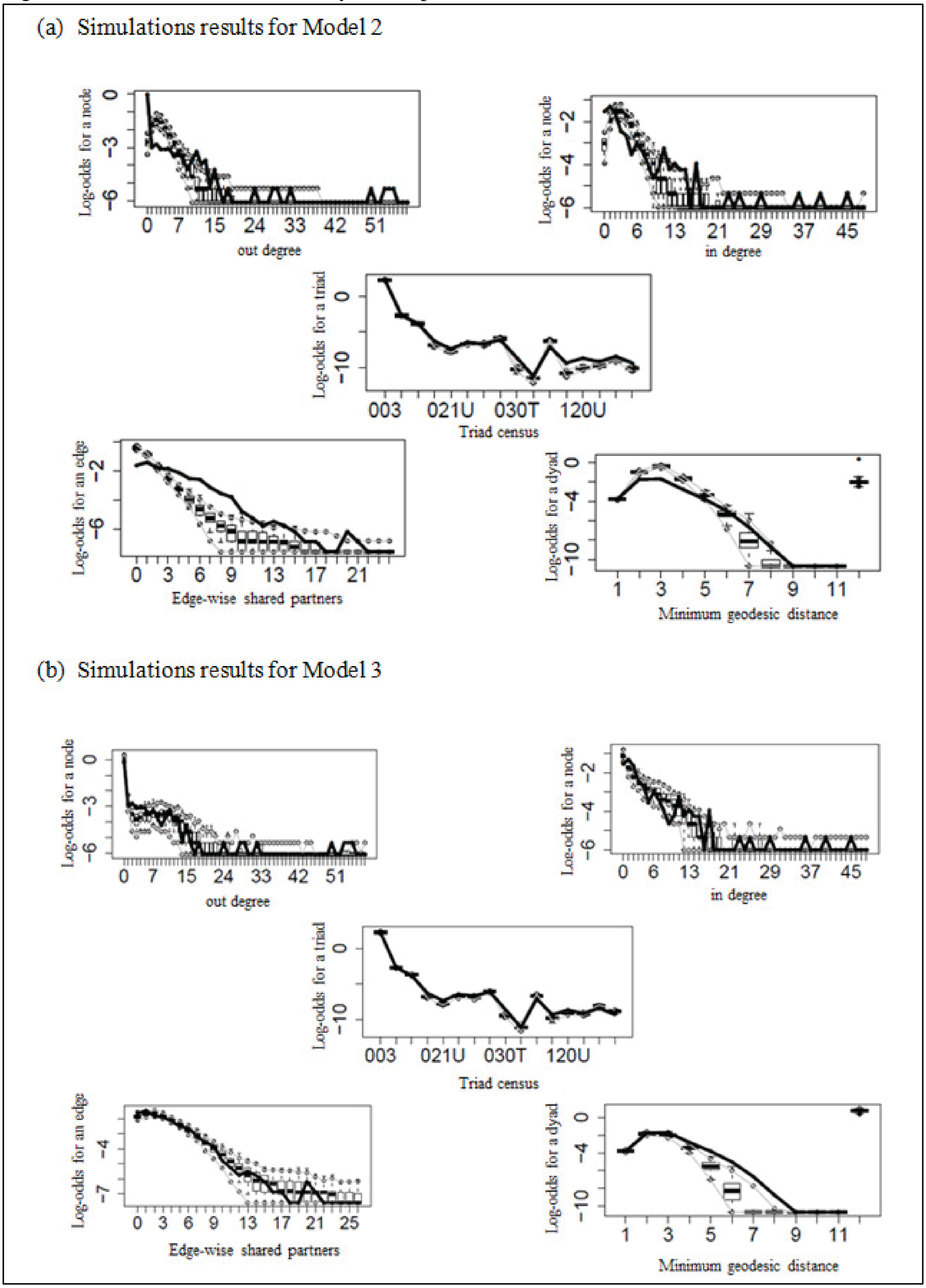
Equally important considerations in the analysis were the effects that accounting for the network structure (Collaboration Intensity Network) had, by incorporating inferences about the heterogeneity of actors through nodal covariate effects. Many empirical works on social networks confirm that nodal covariates are also important in predicting most types of social relationships, and this study on project team relationships was certainly no exception. In fact, the positive and statistically significant effect of the differential homophily on the Modularity class confirms that the PTRs tended to establish Collaborative Relationships Ties by communities. Thus, PTRs belonging to the same community were more likely to collaborate with those in their own community than with those in other communities. The positive and statistically significant effect of the differential homophily on Organization in six-level factors[274] indicates that PTRs were more likely to establish Collaborative Relationship Ties with those PTRs belonging to their own organization than with those in another organization. Similarly, the positive and statistically significant effect of the differential homophily on Level of Management (at the General Manager-level factor) suggests that PTRs were more likely to form Collaborative Relationship Ties with other team roles if they belonged to the General Management level. In addition, the positive and statistically significant effect of the differential homophily on both Native Language and Communication Language reveals that PTRs were more likely to share a Collaborative Relationship Ties with those PTRs that shared the same native language (Dutch or Portuguese) or used the same Communication Language (English or German-levels factors) than with those who either had a different native language or used different communication languages. Furthermore, the positive and statistically significant effect of the nodal factor Frequency of Contact indicates that PTRs that contacted one another more often would have a greater-than-chance probability to form Collaborative Relationship Ties.

Finally, in the ERGM results, neither the effects of the differential homophily on Ethnic nor Employee Seniority Characterized were distinguishable from zero at the 0.05 level of significance; therefore these two parameters were excluded from model 4.

In addition, to estimate how much the structural features of the observed data were predicted by the fitted ERGMs, a set of common network statistics (degree, edge-wise shared partners, minimum geodesic distance, and triad census) were used. These goodness-of-fit tests were performed by comparing a set of observed network statistics with the range of the same statistics obtained by simulating many networks from the fitted ERGM (see figure 50).

[274] The parameter Overseas Branch Office is not distinguishable from zero at the 0.05 level of significance.

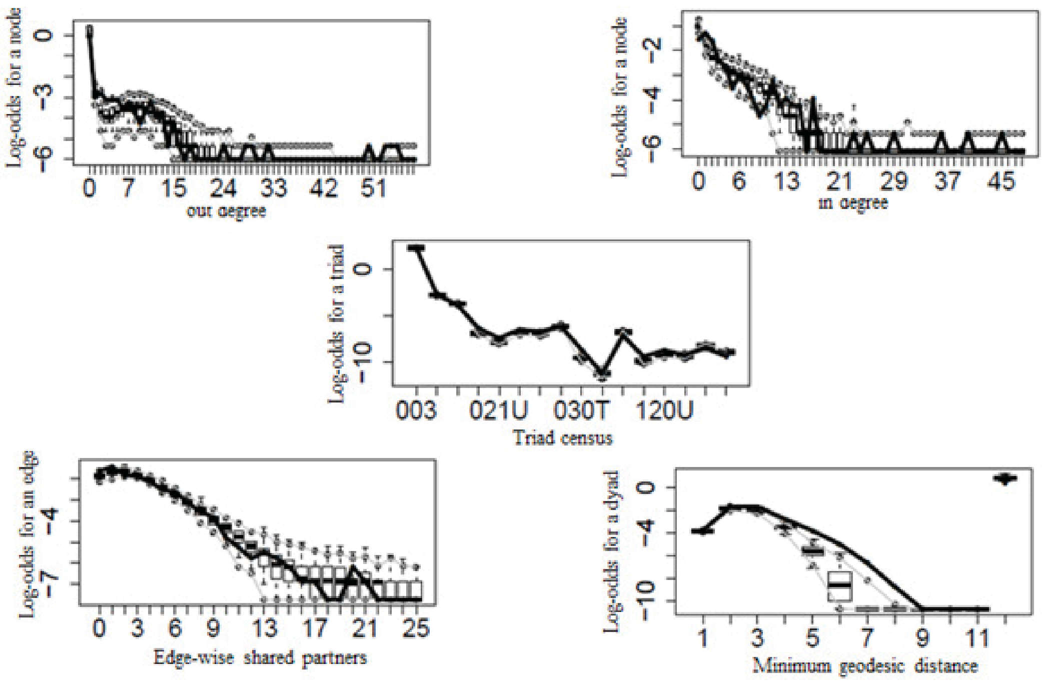
Figure 50: Simulation results for dyadic dependence ERGMs of table 25



Note: In all plots the vertical axis is the logit of relative frequency; the observed network statistics are indicated by the solid lines; the boxplot include the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fell.
Source: Original research

Figure 50 (cont.): Simulation results for dyadic dependence ERGMs of table 25

(c) Simulations results for Model 4



Note: In all plots the vertical axis is the logit of relative frequency; PTRs relationship statistics are indicated by the solid lines; the boxplot include the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fell.
Source: Original research

Figure 50(a) shows that model 2 did a poor job of capturing the shared partner distributions. Comparing figure 50(a) with figures 50(b) and 50(c), it seems that incorporating local structural dependencies (endogenous factors) into the model improved the fitted network data much better than modelling edges, Mutuality and nodal covariates alone. These results should not to be too surprising, because it was expected that the formation of edges for the Collaboration Intensity Network depended not only on the heterogeneity of the actors captured through nodal covariates, but also on typical local network structures. Models 3 and 4 did a good job of recreating the degree distributions, triad census distribution, and shared partner distribution of the observed data. The lack of fit in the geodesic distribution plot reflects the fact that those models underestimated the values of geodesic distance of the observed data.

Finally, it can be concluded that both the traditional statistical measures such as AIC and BIC criterion and the goodness-of-fit plots indicate that model 4 fit the network data much better than the previous models. Thus, it can be affirmed that the fitted model 4 performed well in capturing the heterogeneity of the actors through nodal covariates, as well as in capturing the local structures that were guiding forces in the formation of the Collaboration Intensity Network. Besides that, this is a simpler model, as it includes only nodal covariates and local network structures with statistically significant effects (see formulation of model 4 below).

=====================
Formulation of model 4
=====================

Formula: intensity ~ ostar + istar + mutual + nodematch (Organization) + nodematch (Level_of_Management) + nodematch (Native_Language) + nodematch (Communication_Language) + nodematch (Modularity_Class) + nodeicov (Frequency_of_Contact) + nodeocov (Frequency_of_Contact) + gwidegree + gwodegree + gwesp + gwdsp

4.3 Case Study B – Standard Project

4.3.1 Data Collection

For case study B, 49 different nodes/actors were identified. These nodes belonged to 6 different organizations. These organizations were: Headquarters, Subsidiary Office, Overseas Branch Office, Customer Company and two Customer Providers.

4.3.2 Descriptive and Visual Analysis

As was done previously in the first case of study, the following centrality measures were deemed appropriate to this project scope and were applied to the project network to get a holistic view of the respective networks, as well as to identify the prominent actors.

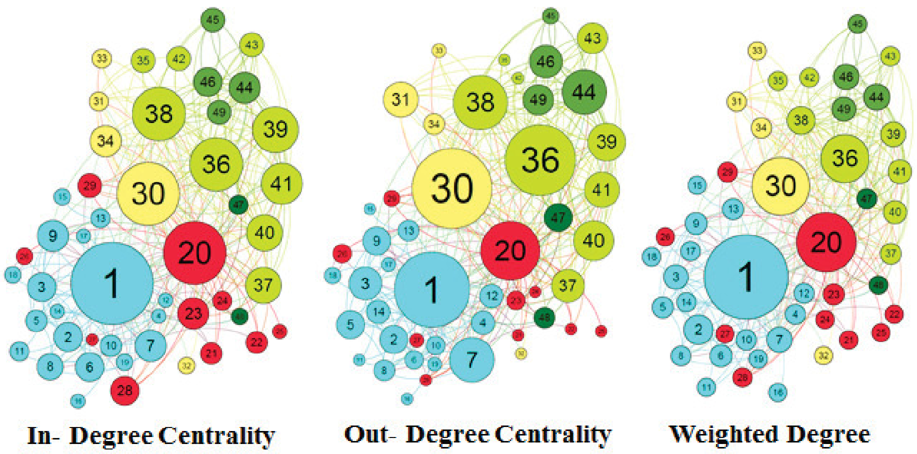
4.3.2.1 Degree Centrality

The size of the network was 49 (49 team roles). The density of the directed network was 0.134, indicating that approximately one-eighth of the possible ties were present. The average path length (average geodesic distance) to get from one node to another node in the network was 2.04 (see figure 51). The degree centrality ratios show that four roles (Subsidiary's Project Manager, Overseas Branch's Project Manager, Customer's Project Manager and Headquarters Project Manager) were the actors with the highest degree centrality index in the network and therefore the most prominent and visible actors involved in relationships with other actors in the network.[275] It is worth highlighting that all these actors had project management team roles, and were the closest to other nodes in the network.

The in-degree measurement for the project relationship network showed that the Subsidiary's Project Manager team role (node 1) had the highest in-degree ratio. In other words, focusing on the actors as recipients, this project team role became the object of many relationship ties and was the most prominent actor in the network. In terms of the out-degree measurement, the Overseas Branch Project Manager team role (node 30) had the highest out-degree ratio, and thus was the most central actor in spreading information and influencing other nodes in the network. (This is unsurprising, given the closeness of the Overseas Branch Office to the customer). Finally, in terms of the weighted degree measurement, the Subsidiary's Project Manager team role (node 25) was the most important actor in both receiving and spreading Collaborative Relationship Ties.

[275] Wasserman and Faust (1994)

Figure 51: Network of PTRs organized by degree measurements



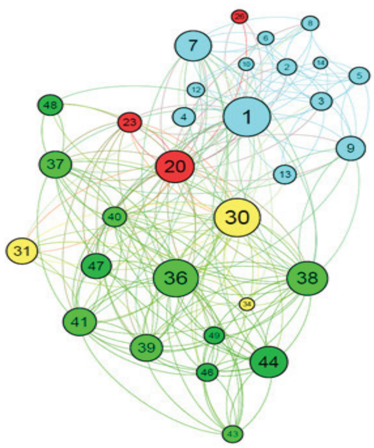
Id	Label	In-Degree	Out-Degree	Degree	Weighted Degree
Subsidiary's Project Manager	1	29	27	56	2213
Headquaqrter's Project Manager	20	21	20	41	1386
Overseas Branch's Project Manager	30	21	29	50	1332
Customer's Project Manager	36	17	25	42	1003

Note: Node size based on degree centrality measurements
Source: Original research

4.3.2.2 Closeness Centrality

The closeness centrality measure shows that nodes 1, 20, 30 and 36 had the highest closeness centrality values, and therefore the one with the greatest influence in speeding collaborative relationships over the entire network (see figure 52).

Figure 52: Network of PTRs organized by closeness centrality



Id	Label	Closeness Centrality
Overseas Branch's Project Manager	30	1,38
Subsidiary's Project Manager	1	1,43
Customer's Project Manager	36	1,47
Headquaqrter's Project Manager	20	1,57

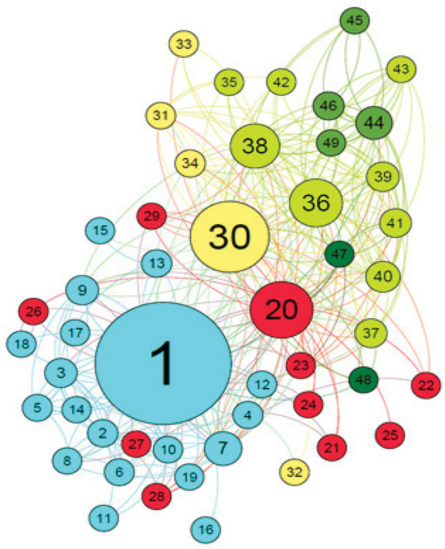
Note: Node size based on closeness centrality measurements[276]
Source: Original research

[276] How close a PTR is to all other PTRs in the network

4.3.2.3 Betweenness Centrality

The betweenness centrality measure shows that the actor Subsidiary's Project Manager (node 1) has the highest betweenness centrality value, and was therefore acting as a bridge between other team roles in the network which were not directly connected (see figure 53).

Figure 53: Network of PTRs organized by betweenness centrality



Id	Label	Betweenness Centrality
Subsidiary's Project Manager	1	702
Overseas Branch's Project Manager	30	327
Headquaqrter's Project Manager	20	221
Customer's Project Manager	36	157

Note: Node size based on betweenness centrality measurement.[277]
Source: Original research

4.3.2.4 Community Detection

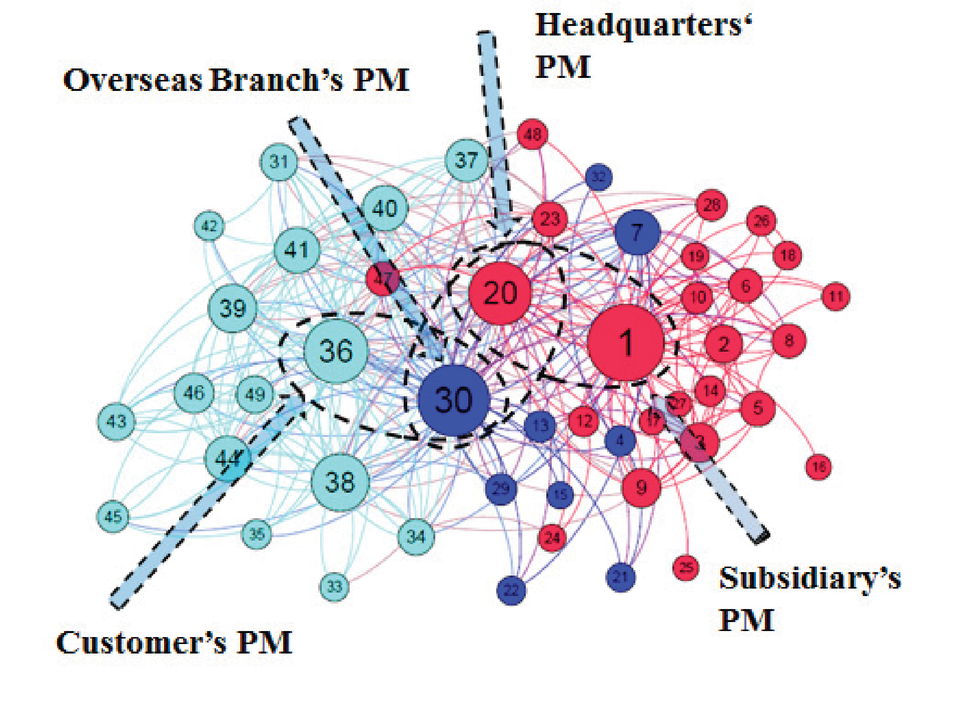
As in the previous case, a community detection analysis was carried out to detect groups of PTRs working together in the network. Using the degree relationship (collaborative relationships) and weighted relationship (weighted collaborative relationships) matrices, different groups of nodes working together in close collaboration were identified.

First, based on the degree relationship matrix, three groups of nodes were identified as follows: Commissioning Technicians (blue); Planning & In-house Activities (red); and Customer and Customer Providers (light blue). (See figure 54). A deeper analysis showed that these communities were cross-organizational groups of interacting PTRs. The first community was formed by PTRs who were in charge of the on-site implementation activities for this project. The most central node of this community was the Overseas Branch's Project Manager (30). This node was given the necessary administrative support for the installation and start-up activities of the project. The second community was formed by actors who came from the Subsidiary and Headquarters offices. They were carrying out planning and in-house

[277] Number of times a PTR is acting as a key intermediary between other PTRs that are not directly connected

activities for the project. The last identified community was formed by the customer's team roles and its providers.

Figure 54: Network of PTRs organized by communities

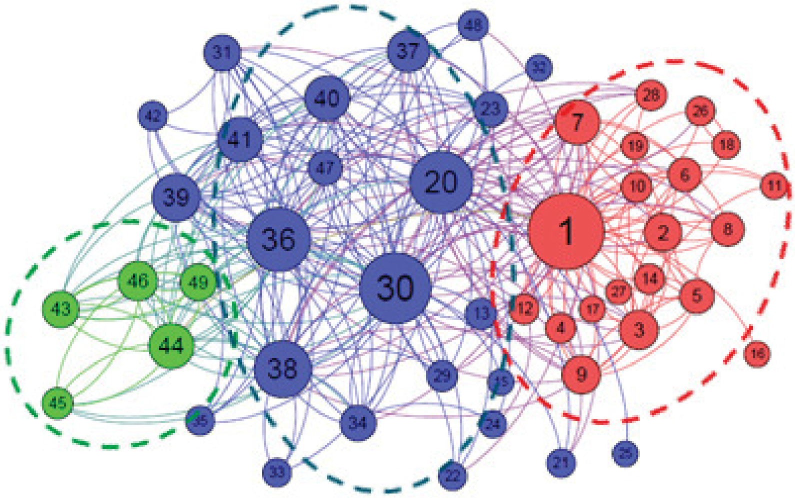


Community	%	Color
Commissioning Technicians	16,3%	
Planning & In-House Activities	44,9%	
Customer & its Providers	38,8%	

Note: Node size and communities based on degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

Second, using the weighted degree relationship matrix, three communities of nodes working together in a tight collaboration were identified (see figure 55). The first community (red) corresponds to PTRs at the subsidiary office who were sharing planning, engineering, manufacturing, and controlling activities for the project. The second community (blue) was formed by PTRs who came from Headquarters, the Overseas Branch Office and the Customer. Finally, the third community identified (green) was a cross-organizational group of PTRs who shared foreign trade functions. This community was providing customer support for all issues related to the import process, as well as carrying out all the clearance procedures for all the machines and equipment within the scope of supply of this project.

Figure 55: Network of PTRs organized by communities



Community	%	Color
Subsidiary Office	40,8%	
Headquarters, Overseas Office and Customer	49,0%	
Foreign Trade Cross-Organizational group	10,2%	

Note: Node size and communities based on weighted degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

4.3.2.5 Attribute Analysis

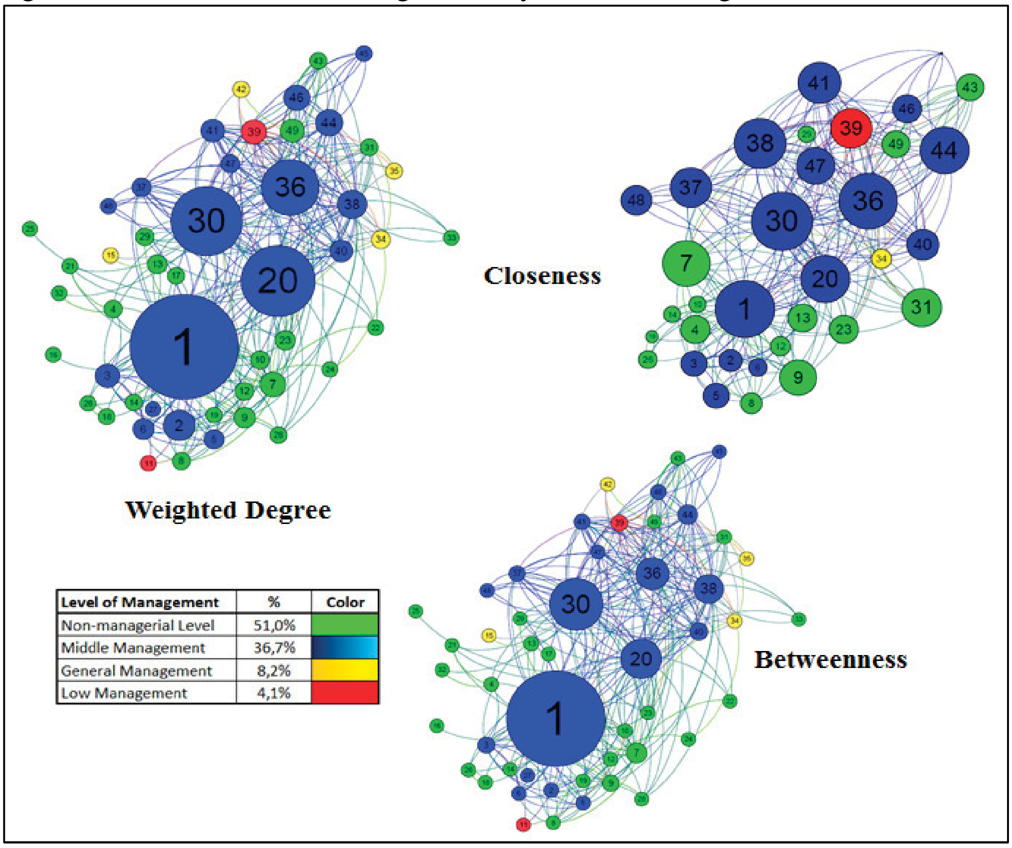
As in the previous case, the software Gephi was used to understand the implications of the different attributes proposed in this research in the Collaboration Intensity Network formed by the PTRs in this SCDP; in other words, to give a line of empirical evidence that the development of Collaborative Relationship Ties among the PTRs participating in this project was affected by the presence of some of the attributes here identified. This research explored five attributes for the development of effective collaborative relationships between different team members in a SCDP: (1) Level of Management; (2) Native Language and Frequent Communication Language; (3) Organization; (4) Employee's Seniority Characterized

1) Level of Management

As described in section 4.1.2, the attribute "Levels of Management" was categorized in four levels. A visual and descriptive analysis for the network of PTRs classified according to this attribute is shown in figure 56 and table 26. Based on the top 10 ranked actors according to weighted degree centrality, it can be observed that Middle Management actors, were the most central actors in this network. Thus, they were the most prominent and visible nodes in the network.

Similarly, four of these team roles (nodes 1, 20, 30 and 36) were found to have the highest scores of betweenness and closeness centrality. Thus, these actors were the key intermediary actors in the network, as well as the ones most likely to be in communication paths between other nodes. In addition, it seems PTRs at the middle level of management were those who were supporting the formation of Collaborative Relationship Ties between other PTRs in the network.

Figure 56: Network of PTRs organized by level of management



Note: Node size based on centrality measurements. PTRs received a colour according to which level of management they were sorted.
Source: Original research

Table 26: Top ten ranked PTRs based on centrality measures

Id	Organization	Level_of_Management	Degree	Weighted Degree	Closeness Centrality	Betweenness Centrality
1	Subsidiary Office	Middle Management	47	2119,5	1,36	376,0
20	Headquarter	Middle Management	35	1350,5	1,58	104,7
30	Overseas Branchoffice	Middle Management	43	1284,5	1,33	193,7
36	Customer	Middle Management	37	961,5	1,39	101,8
2	Subsidiary Office	Middle Management	13	371	2,09	4,8
38	Customer	Middle Management	32	325,5	1,52	61,6
44	Customer's Provider	Middle Management	22	281	1,58	34,0
46	Customer's Provider	Middle Management	16	254	1,97	10,0
7	Subsidiary Office	Non-managerial level	21	241	1,61	38,0
39	Customer	Low Management	23	223	1,73	10,8

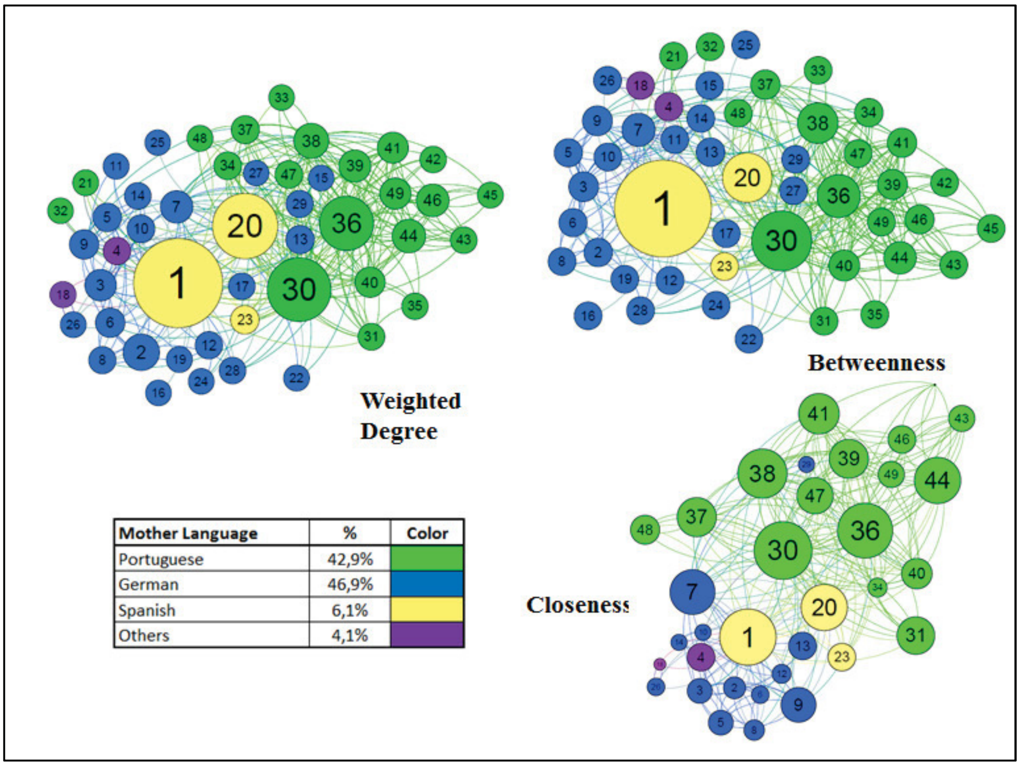
Source: Original research

2) Native Language and Frequent Communication Language

Relationships of PTRs belonging to this network were analysed, as in the previous case, in terms of two nodal attributes: first, by the attribute "Native Language," which was classified in four categories: German, Portuguese, Spanish, and Others; and by the attribute "Communication Language," which was classified in three categories: English, German, and Portuguese.

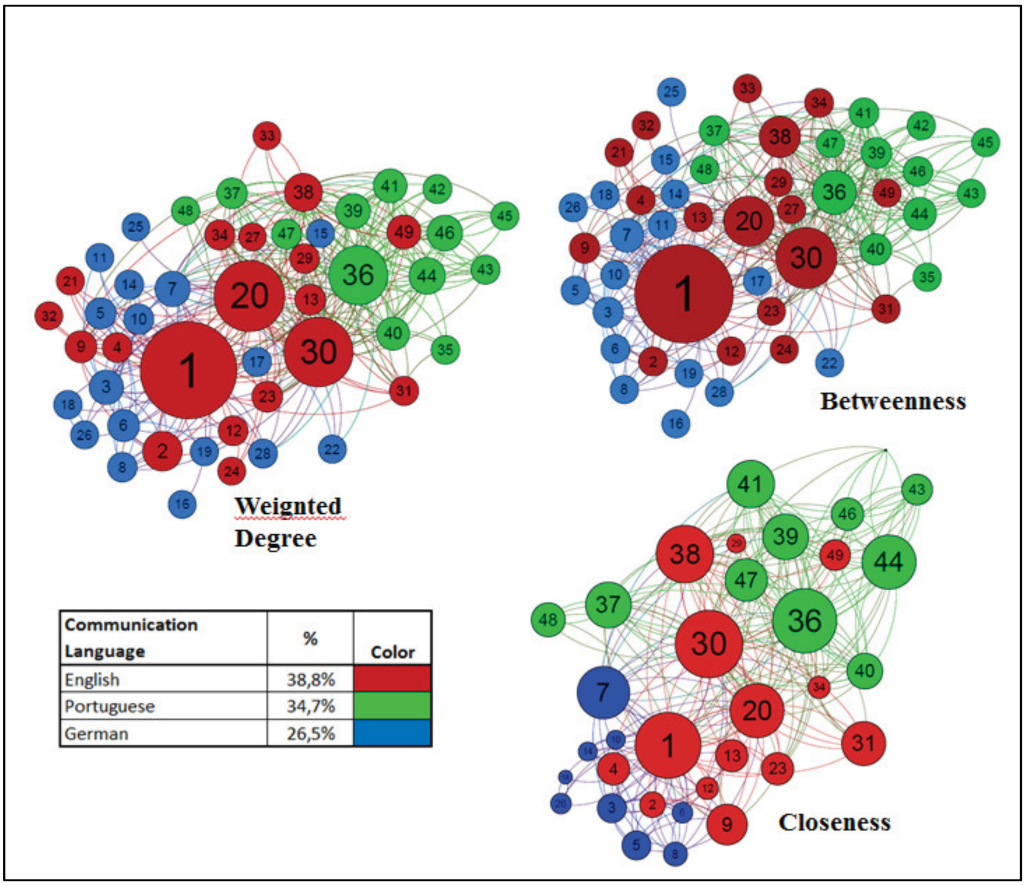
The visual and descriptive analysis shows that two PTRs tended to share a collaborative tie if they either shared the same native language or interacted more frequently through the same communication language (see figures 57 and 58). In other words, the physical proximity of some nodes (PTRs) in the depicted networks suggests that a PTR was more likely to establish Collaborative Relationship Ties with those partners that shared the same native language than with those that didn't. The same occurred with the Communication Language attribute. That is, nodes interacting during the project life in the same communication language tended to form more Collaborative Relationship Ties with each other than with those that were interacting through different.

Figure 57: Network of PTRs organized by native language



Note: Node size based on centrality measurements. PTRs received a colour according to which native language they were sorted.
Source: Original research

Figure 58: Network of PTRs organized by Frequent Communication Language



Note: Node size based on centrality measurements. PTRs received a colour depending on which communication language they were sorted.
Source: Original research

Additionally, based on their central position in the depicted network (see figures 57 and 58) and the higher centrality ratios showed by the nodes 1, 20 and 30 (see table 27), it appears that those nodes were the bridge between the German and Portuguese communities.

Table 27: Top ten ranked PTRs based on centrality measures

Id	Organization	Communication Language	Native Language	Degree	Weighted Degree	Closeness Centrality	Betweenness Centrality
1	Subsidiary Office	English	Spanish	47	2119,5	1,36	376,0
20	Headquarter	English	Spanish	35	1350,5	1,58	104,7
30	Overseas Branchoffice	English	Portuguese	43	1284,5	1,33	193,7
36	Customer	Portuguese	Portuguese	37	961,5	1,39	101,8
2	Subsidiary Office	English	German	13	371	2,09	4,8
38	Customer	English	Portuguese	32	325,5	1,52	61,6
44	Customer's Provider	Portuguese	Portuguese	22	281	1,58	34,0
46	Customer's Provider	Portuguese	Portuguese	16	254	1,97	10,0
7	Subsidiary Office	German	German	21	241	1,61	38,0
39	Customer	Portuguese	Portuguese	23	223	1,73	10,8

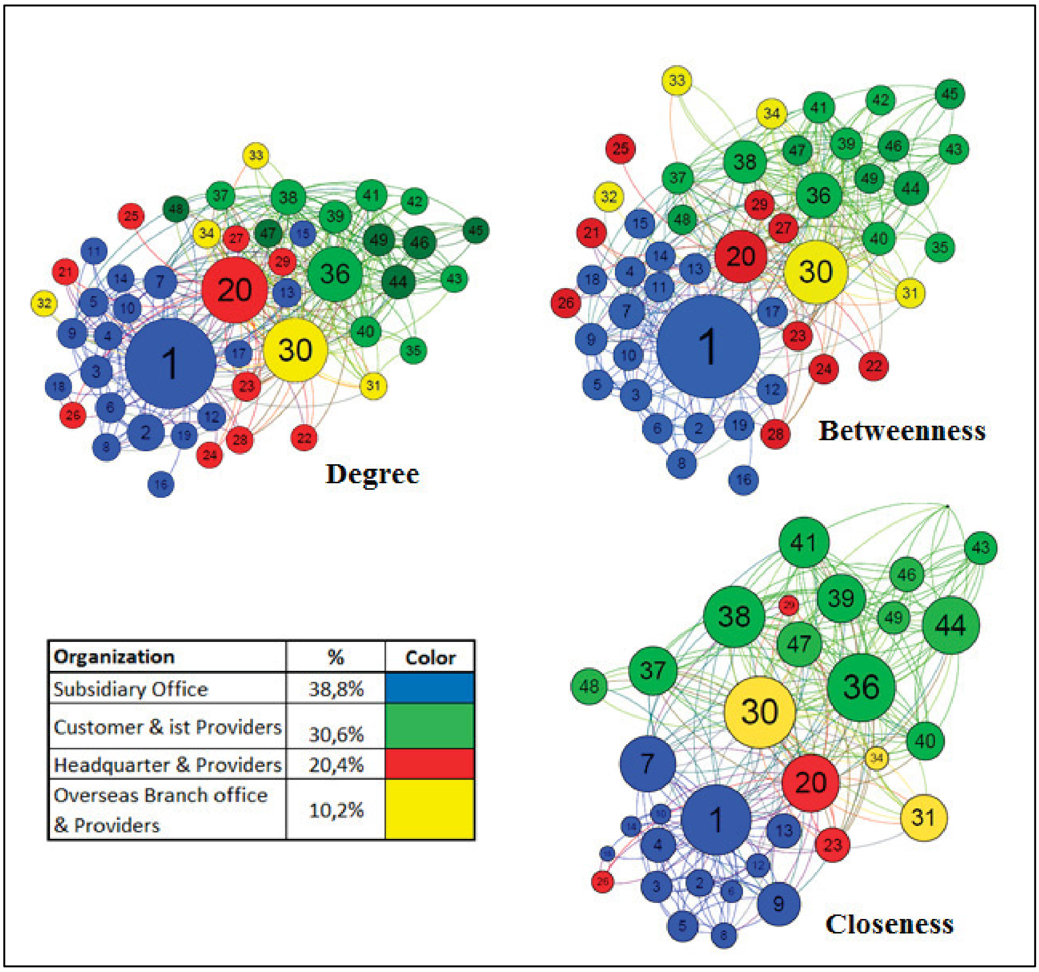
Source: Original research

3) Organization

Figure 59 portrays the network of PTRs classified by organization type. As explained before, this attribute was categorized in order of importance (calculated as a ratio of the total number of nodes each organization has in the network) as follows: Subsidiary Office (38.8%), Customer and its Providers (30.6%), Headquarters (20.4%), and Overseas Branch Office (10.2%).

Because of the closeness location of some nodes (PTRs) on the depicted networks, it appears that two PTRs tended to share a collaborative tie with those in their own organization than with those from another organization, particularly for the Subsidiary Office and Customer and its Providers.

Figure 59: Network of PTRs classified by organization



Note: Node size based on centrality measurements. PTRs received a colour depending on which organization they were sorted
Source: Original research

Worthy of note are the positions of the nodes 20 and 30, belonging to the Headquarters Office and Overseas Branch Office, respectively. As can be seen, they are located close to the Customer nodes (green) and therefore it can be presumed that they were acting as intermediaries between the Customer and Subsidiary organizations.

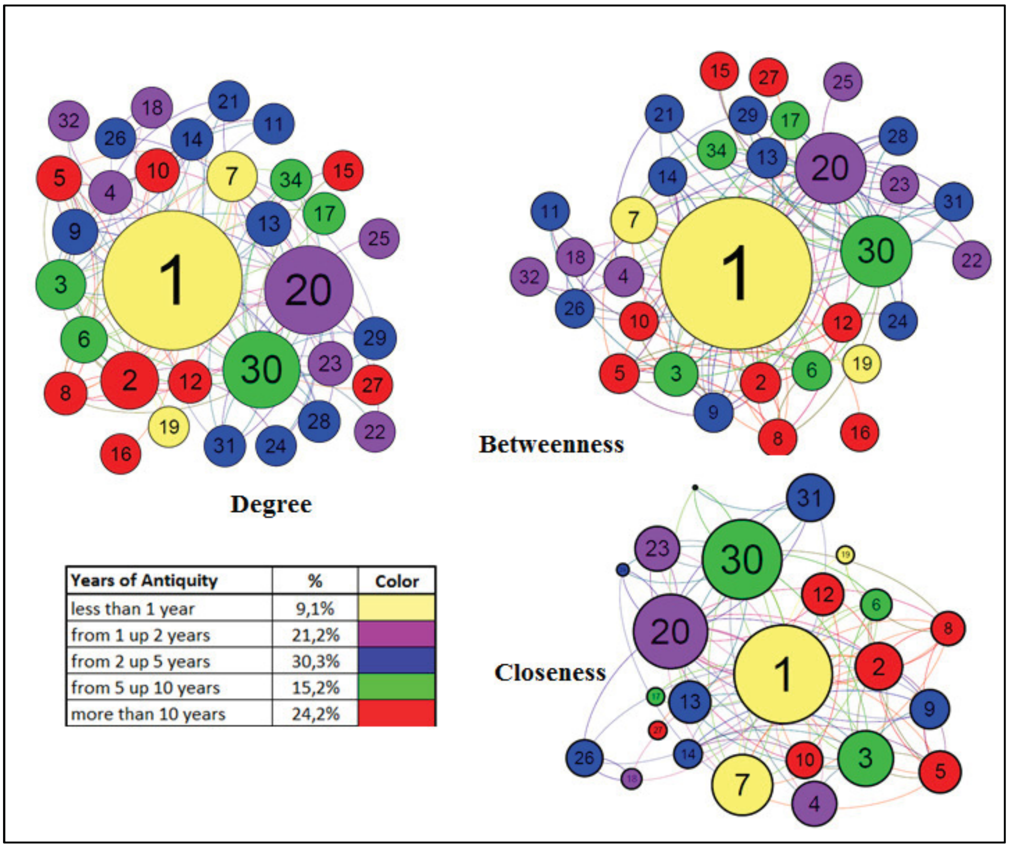
Finally, due to the facts that this network did not have many actors and that the key player of every subnetwork was already identified in the previous visual analysis, it was decided not to carry out the low level analysis for this case.

4) Employee's Seniority Characterized

The Collaboration Intensity Network, as was done in the previous case study, was analysed in terms of the attribute "Employee's Seniority Characterized" and as mentioned above, categorized according to years of service in one of the specified companies (Headquarters, Subsidiary and Overseas Branch Companies) as follows: less than one year's service (0), from 1 to 2 years' service (1), from 2 to 5 years' service (2), from 5 to 10 years' service (3), and more than 10 years' service (4).

The visual and descriptive analysis of the Collaboration Intensity Network suggests, that two PTRs from this sub-network[278] would not tend to share Collaborative Relationship Ties with other team roles as a function of the length of service with their employer (see figure 60).

Figure 60: Sub-network of PTRs organized by employee seniority



Note: Node size based on centrality measurements. PTRs received a colour according to which level of employee seniority they were sorted. This subnetwork only includes PTRs belonging to Headquarters, Subsidiary and Overseas Branch Offices.
Source: Original research

[278] customer and customer's providers organizations were not included in this analysis due to the lack of information

4.3.3 Stochastic Modelling

As mentioned in section 4.1.3.2, ERGMs were applied to understand the implications of structural parameters and node level attributes in the Collaboration Intensity Network formed by the PTRs in this SCDP. Twenty-seven parameters were included in the model: two for edges; one for Mutuality as a structural parameter; three for differential homophily on Organization, two for differential homophily on Level of Management; three for differential homophily on Native Language; two for differential homophily on Ethnic Group; three for differential homophily on Communication Language; three for differential homophily on Employee Seniority Characterized; two for differential homophily on modularity class; two for the Frequency of Contact factor effect; and four for the sets of GWTs (GWIdegree, GWOdegree, GWESP and GWDSP). The fitted values of the parameters, standard errors, and the AIC and BIC criterion for the models applied to the Collaboration Intensity Network are listed in table 28.

Model 1, as explained in the previous case, included two parameters associated with the density of the network (ostar, istar). The second model, besides the density parameters, included a structural process (mutuality effect) and several nodal covariates. These parameters were used to describe and explain the main effects of continuous covariates and categorical factors in the Collaboration Intensity Network. Three structural characteristics (GWTs) were included in model 3. Finally, using the outputs of model 3, the nodal covariates Organization, Level of Management and Employee's Seniority Characterized, as well as the structural parameters istar, Mutuality, GWIdegree, GWESP and GWDSP were excluded from model 4, because it appeared that they were not playing important roles in the generative process that gave rise to the Collaboration Intensity Network (i.e., they were not statistically significant for the model). After the comparison of the AIC and BIC scores[279] between models, the results indicated that model 4 had the best data fit and therefore allowed for better identification the structures that characterized the Collaboration Intensity Network formed by the PRTs for this project.

The negative and statistically significant value of the ostar coefficient at the 0.001 level, indicates that the probability that a tie would be formed was equal to the probability of [exp(-6.07)/(1+exp((-6.07] = 0,0023. In terms of Mutuality, results were not distinguishable from zero at the 0.05 level of significance. Thus, there was no evidence that PTRs in the network were engaged in mutual, reciprocated ties. The negative and statistically significant effect of GWOdegree statistics indicates that PTRs with higher out-degree were unlikely to share Collaborative Relationship Ties with other PTRs that also had higher out-degree values. As the GWDSP and GWESP parameters were excluded from the model 4, there was no evidence to support that a pair of PTRs in the network tended to share arcs with the same sets of partners or tended to form complete triangles or clusters with others to collaborate. This means there were no local forces in this network to influence the creation of triads of collaborative links.

---

[279] Given a set of candidate models for the data, *the preferred model is the one with the minimum AIC and BIC values.* Hence both scores reward goodness of fit (as assessed by the likelihood function), but also include a penalty term for the number of parameters in the model. This penalty discourages problems of overfitting.

Table 28: Stochastic models predicting the Collaboration Intensity Network

Coefficient	Model 1			Model 2			Model 3			Model 4		
	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR
Ostar	-5,29***	0,07	0,005	-7,83***	0,43	0	-7,68***	0,54	0	-6,07***	0,77	0,00
Istar	0,71***	0,02	4,11	-0,01	0,43	0,99	1,44**	0,54	4,21	-	-	-
Mutual	-	-	-	0,13	0,7	1,14	0,85	0,72	2,33	-	-	-
Organization												
Customer	-	-	-	-2,11	1,16	0,12	-1,09	0,79	0,34	-	-	-
Headquarters	-	-	-	0,97	1,04	2,63	1,02	1,03	2,77	-	-	-
Subsidiary	-	-	-	1,23	0,76	3,43	0,86	0,69	2,36	-	-	-
Level of management												
Middle Management	-	-	-	0,23	0,46	1,26	0,12	0,42	1,12	-	-	-
Non- Managerial	-	-	-	-0,89	0,68	0,41	-0,89	0,65	0,41	-	-	-
Native Language												
German	-	-	-	11,30***	0,33	81032	13,23***	0,29	559573	12,23***	0,24	205486
Portuguese	-	-	-	-2,44*	1,21	0,09	-1,78	1,2	0,17	-1,5	1,12	0,22
Spanish	-	-	-	4,80***	1,29	122,07	4,15**	1,29	63,23	3,95***	1,04	51,8
Ethnic Group												
Germanic	-	-	-	-12,05***	0,33	0,00	-13,84***	0,29	0,00	-12,82***	0,24	0,00
Latin America	-	-	-	1,95	1,1	7,03	1,58	1,08	4,84	1,25	1,03	3,48
Communication Lang.												
English	-	-	-	0,68	0,42	1,97	0,41	0,4	1,51	0,38	0,38	1,46
German	-	-	-	-1,91	1,09	0,15	-1,23	0,93	0,29	-1,34	1	0,26
Portuguese	-	-	-	2,27**	0,83	9,67	1,78*	0,74	5,94	1,51*	0,61	4,53
Employee Seniority Characterized												
< to one year	-	-	-	0,38	1,09	1,47	0,7	1,11	2,01	-	-	-
1 to 2 years	-	-	-	-0,86	1,88	0,42	-1,19	1,81	0,31	-	-	-
>10 years	-	-	-	0,52	0,92	1,68	0,23	0,87	1,26	-	-	-
Nodecov												
Freq_of_contact (Nodeicov)	-	-	-	0,01*	0,01	1,01	0,03**	0,01	1,03	0,03***	0,01	1,03
Freq_of_contact (Nodeocov)	-	-	-	0,02***	0,01	1,02	0,01*	0,01	1,01	0,01**	0	1,01
Modularity												
Group 0	-	-	-	4,02***	1,03	55,48	4,00***	0,99	54,76	4,43***	0,73	84,25
Group 1	-	-	-	3,04***	0,8	20,89	2,83***	0,76	16,97	2,82***	0,71	16,79
High Degree Dist.												
GWIdegree	-	-	-	-	-	-	0,46	0,88	1,59	-	-	-
GWOdegree	-	-	-	-	-	-	-3,26***	0,68	0,04	-3,27***	0,57	0,04
GWESP	-	-	-	-	-	-	-0,15	0,29	0,86	-	-	-
GWDSP	-	-	-	-	-	-	-0,05	0,09	0,95	-	-	-
Model Fit	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**
	-2.343.132	472.6	484.2	-141.91	329.8	462.4	-127,45	308,9	464,5	-133,71	295,4	376,1

Note: $* P < 0.05$; $** P < 0.01$; $*** P < 0.001$.
Source: Original research

The effects of incorporating the heterogeneity of PTRs through nodal covariates effects on the structure of the Collaboration Intensity Network were also tested in this case study. In fact, the positive and statistically significant effect of the differential homophily on both Native Language and Communication Language reveals that PTRs were more likely to share Collaborative Relationship Ties with those PTRs with whom they shared the same native language (German or Spanish) or that used the same communication language (Portuguese) than with those who had either different native languages or used different communication languages. Likewise, the positive and statistically significant effect of the nodal factor “Frequency of Contact” indicates that PTRs who contacted one another more often would have a greater-than-chance probability to form Collaborative Relationship Ties. Furthermore, the negative and statistically significant effect of the differential homophily on Ethnic group suggests that PTRs sharing the Germanic ethnic group were unlikely to share Collaborative Relationship Ties.

Finally, the ERGM results indicate that the effects of differential homophily on Organization, Level of Management, and Employee's Seniority Characterized were not distinguishable from zero at the 0.05 level of significance. These three parameters were therefore excluded from model 4.

As described in the previous case, goodness-of-fit tests were conducted as a way to estimate how well a model fits, by comparing a set of observed network statistics (namely, degree, edge-wise shared partners, minimum geodesic distance, and triad census) with the range of the same statistics obtained by simulating many networks from the fitted ERGMs (see figure 61).

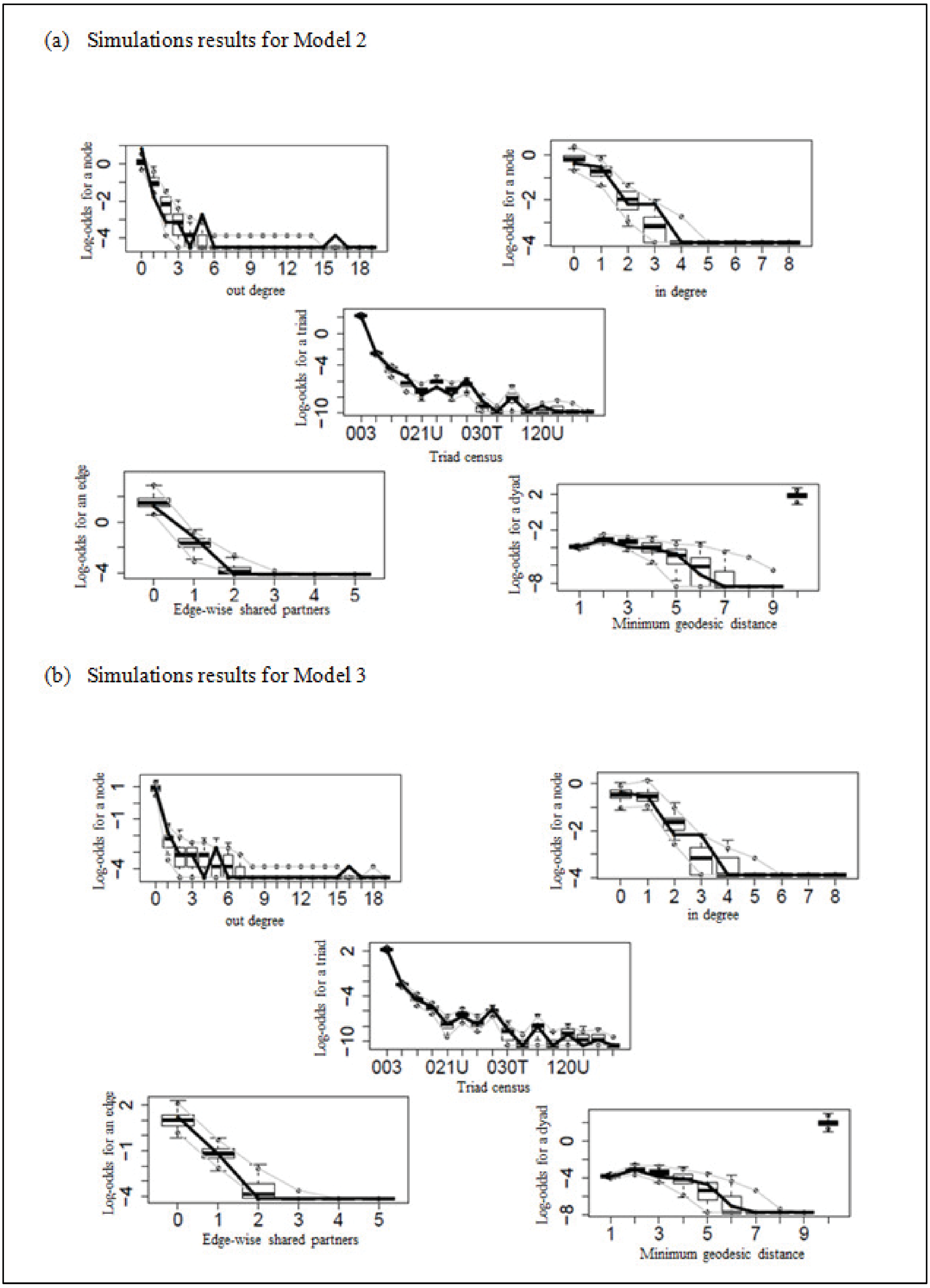
In figure 61(a), it can be seen that model 2—by including edges, mutuality and several nodal covariates–performs a relatively good job of capturing the shared partner distributions.

When local structural dependencies are added (see table 28; model 3) by including high degree distributions, the fit of the AIC and BIC criterion improved a bit. Finally, comparing figures 61(a) and 61(b) with figure 61(c), it appears that model 4 performed well in capturing the heterogeneity of PTRs through nodal covariates, as well as in capturing some local structural forces that gave rise to the formation of this network. This last model is preferred for its simplicity, as it excluded those parameters (nodal attributes and local network structures) whose estimated coefficients were not distinguishable from zero at the 0.05 level of significance. Furthermore, this model had a much better fit as measured by the graphical criterion and by the AIC and BIC criterion employed in this research (see formulation of model 4 below).

=====================
Formulation of Model 4
=====================

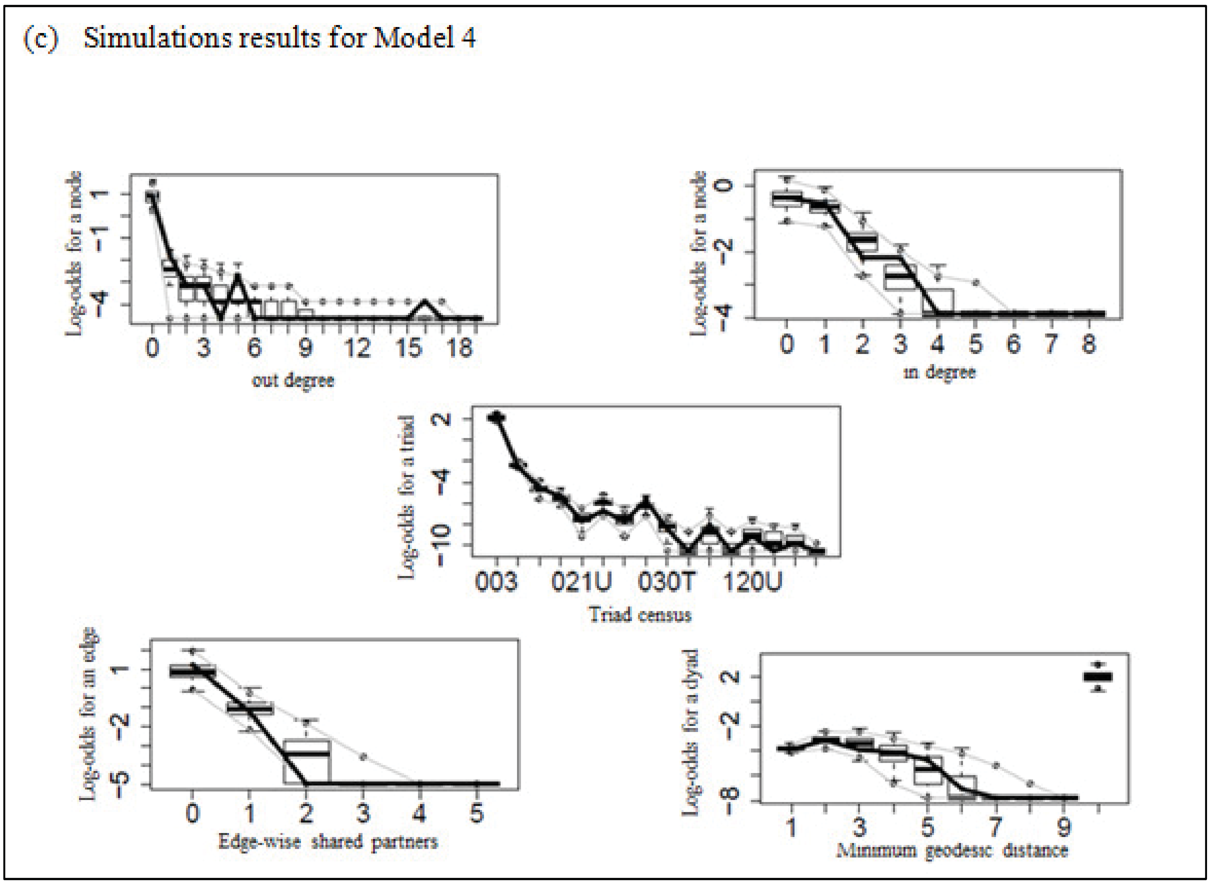
Formula: intensity ~ ostar + nodematch (Native_Language) + nodematch (Ethnic_Group) + nodematch (Communication_Language) + nodeicov (Frequency_of_Contact) + nodeocov (Frequency_of_Contact) + nodematch (Modularity_Class) + gwodegree

Figure 61: Goodness-of-fit tests for models of table 28



Note: In all plots, the vertical axis is the logit of relative frequency; PTR relationship statistics are indicated by the solid lines; the boxplot includes the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fall.
Source: Original research

Figure 61 (cont.): Goodness-of-fit tests for models of table 28



Notes: In all plots, the vertical axis is the logit of relative frequency; PTR relationship statistics are indicated by the solid lines; the boxplot include the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fall.
Source: Original research

4.4 Case Study C – Small Project

4.4.1 Data Collection

For case study C, 35 different nodes/actors were identified. These nodes belonged to 4 different organizations. These organizations were: Headquarters, Subsidiary Office, Subsidiary's Provider and Customer.

4.4.2 Descriptive and Visual Analysis

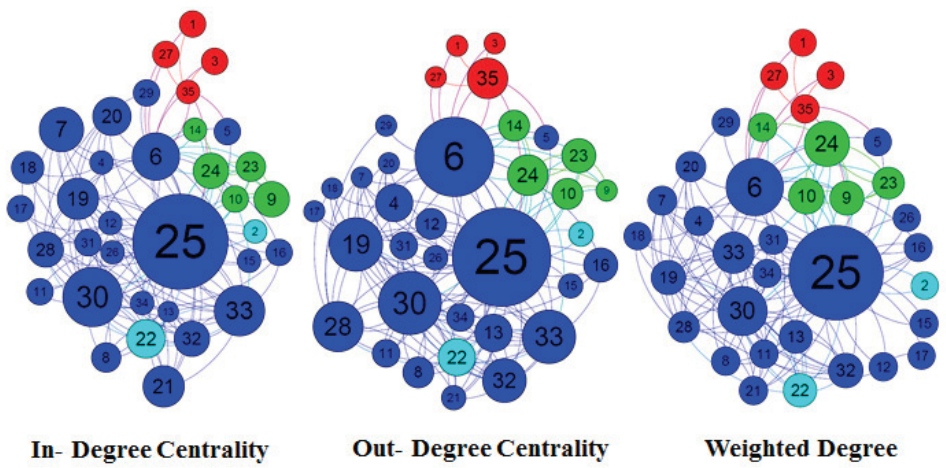
As in the previous cases, the following centrality measures were deemed appropriate to this project scope and were applied to the project network to get a holistic view of the respective networks, as well as to identify the prominent actors.

4.4.2.1 Degree Centrality

The size of the network was 35 (35 team roles). The density of the directed network was 0.125, indicating that approximately one-eighth of the possible ties were present. The average path length (average geodesic distance) to get from one node to another node in the network was 1.98. The degree centrality measurements show that three roles (Subsidiary's Project Manager**,** Subsidiary's Customer Care Manager, and Subsidiary's Commissioning Engineer) were the actors with the highest degree centrality index in the network. Thus, these were the most prominent and visible actors involved in relationships with other actors in the network (see figure 62).

The degree centrality measurements for this project network show that the Subsidiary's Project Manager node (node 25) had the highest in-degree, out-degree, and weighted degree ratios. In other words, it was the most prestigious and central PTR in this network. This is not surprising, given the predefined role of a project manager in a project. In terms of the in-degree measurement, it became the recipient of many relationship ties; similarly in terms of the out-degree measurement, it was the most central PTR in spreading information and influencing other PTRs in the network. Finally, in terms of the weighted degree measurement, it was the most important actor in both receiving and spreading Collaborative Relationship Ties.

Figure 62: Network of PTRs organized by degree measurements



Id	Label	In-Degree	Out-Degree	Degree	Weighted Degree
Subsidiary's Project Manager	25	25	24	49	763
Subsidiary's Customer Care Manager	6	9	18	27	345
Subsidiary's Commissioning Engineer	30	13	13	26	253
Customer's Project Manager	24	5	6	11	206

Note: Node size based on degree centrality measurements
Source: Original research

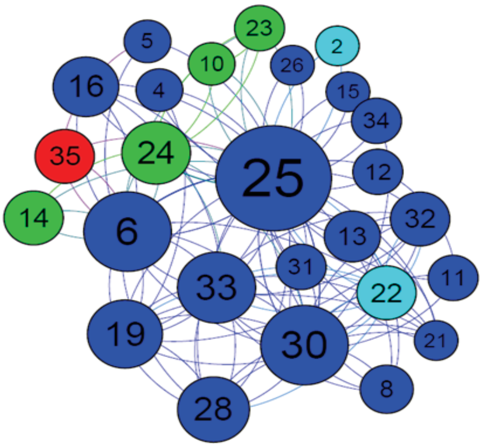
4.4.2.2 Closeness Centrality

The closeness centrality measure shows that nodes 6, 25, 6 and 30 had the highest closeness centrality values, and therefore they were the closest to other nodes in the network. That is, they were the PTRs nearest to all other PTRs and therefore were the ones with the greatest influence in speeding communication and/or exchange over the entire network (see figure 63).

4.4.2.3 Betweenness Centrality

The betweenness centrality measurement clearly shows that the Subsidiary's Project Manager actor (node 25) had the highest betweenness centrality value. Thus, it was acting as a key intermediary between other PTRs in the network which were not directly connected and had the capacity to facilitate or limit relationships between the nodes it linked (see figure 64).

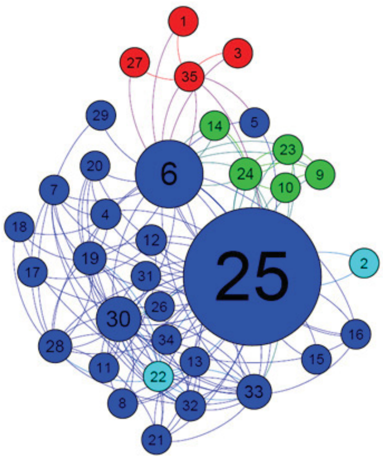
Figure 63: Network of PTRs organized by closeness centrality



Id	Label	Closeness Centrality
Subsidiary's Project Manager	25	1,27
Subsidiary's Customer Care Manager	6	1,45
Subsidiary's Commissioning Engineer	30	1,61

Note: Node size based on closeness centrality measurements[280]
Source: Original research

Figure 64: Network of PTRs organized by betweenness centrality



Id	Label	Betweenness Centrality
Subsidiary's Project Manager	25	509
Subsidiary's Customer Care Manager	6	179
Subsidiary's Commissioning Engineer	30	71
Subsidiary's Technical Project Manager	33	24

Note: Node size based on betweenness centrality measurements.[281]
Source: Original research

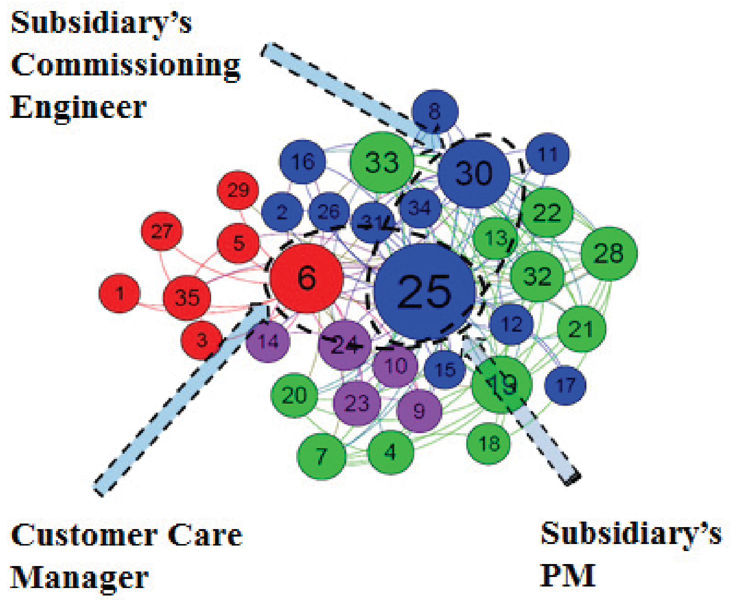
[280] How close a PTR is to all other PTRs in the network
[281] Number of times a PTR is acting as a key intermediary between other PTRs that are not directly connected

4.4.2.4 Community Detection

As was done in the previous cases, a community detection analysis was carried out to detect groups of PTRs working together in the network. The degree relationship and weighted degree relationship matrices were used to uncover groups of PTRs working together in close collaboration.

First, based on the degree relationship matrix, four groups of nodes working in collaborative relationship were identified: Customer (purple); Commercial & Administrative roles (blue ones); Technical roles (green); and Financial roles (red) (see figure 45). The first community was formed by PTRs who worked at the Customer organization. The second community corresponded to PTRs carrying out commercial and administrative activities for the project. The third community corresponded to PTRs who came from the Subsidiary office and were supporting technical activities for the project. The last community consists of a cross-organizational group of PTRs who came from Headquarters and Subsidiary offices and were in the relationship to carry out financial activities for the project (see figure 65).

Figure 65: Network of PTRs organized by communities

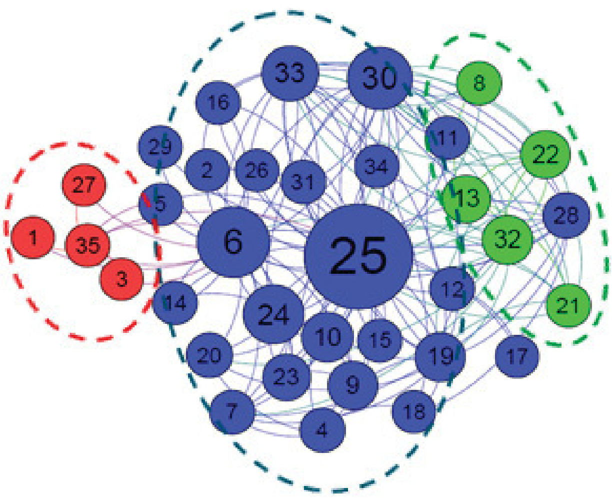


Community	%	Color
Customer	14,3%	
Commercial & Administrative roles (Subsidiary office)	34,3%	
Technical roles (Subsidiary office)	31,4%	
Financial roles Cross-organizational group	20,0%	

Note: Node size and communities based on degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

Second, using the weighted degree relationship matrix, three communities of PTRs working together in close collaboration were identified (see figure 66). The first community (red) consists of PTRs who were carrying out financial roles for the project at the Headquarters office. The second community (blue) was formed by PTRs groups belonging to the Subsidiary and Customer organizations who were sharing management roles such as planning, engineering, manufacturing, implementation, and controlling. The most central node of this community was the Subsidiary's Project Manager (node 25). A deeper analysis showed that this node had important control and stability roles for this project. Finally, the third community identified (green) corresponds to PTRs who were sharing Software Development and System Administration roles. The nodes belonging to this community were working together to ensure effective provisioning, installation/configuration, operation, and maintenance of the hardware, operating system, software development, and related infrastructure for this project.

Figure 66: Network of PTRs organized by communities (modularity)



Community	%	Color
Financial roles (Headquarters)	14,3%	
Management role (Cross organizational Team)	74,3%	
Software Development & System Adm. (Subsidiary office)	11,4%	

Note: Node size and communities based on weighted degree centrality. PTRs were assigned a colour depending on the community to which they were belonged.
Source: Original research

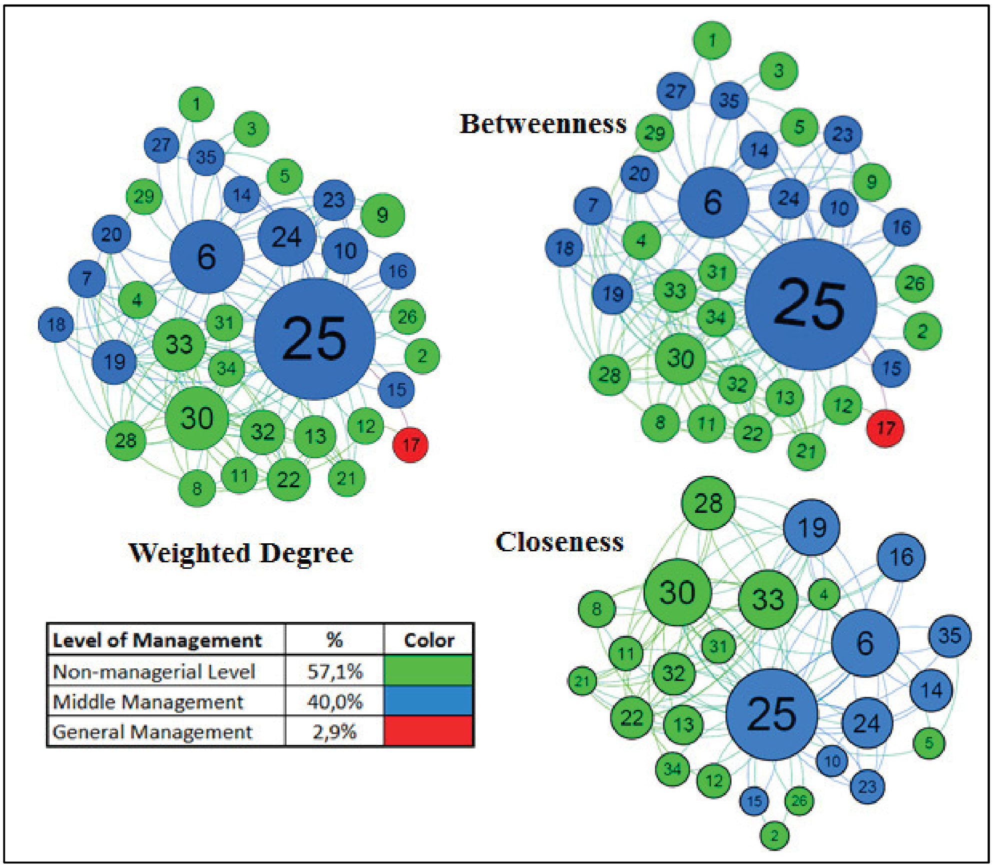
4.4.2.5 Attribute Analysis

The attribute analysis, as in the previous cases, used the software Gephi to understand the implications of the different attributes proposed in this research in the Collaboration Intensity Network formed by the PTRs in this SCDP; that is, to give a line of empirical evidence that the development of Collaborative Relationship Ties among the PTRs participating in this project was affected by the presence of some of the attributes here identified. This analysis explored four attributes for the development of effective collaborative relationships between team roles in a SCDP: (1) Level of Management; (2) Native Language and Frequent Communication Language; (3) Organization; (4) Employee's Seniority Characterized.

1) Level of Management

As described in section 4.1.2, the attribute "Levels of Management" was categorised in four levels. It can be observed in this network that the Top Level of Management was not fully involved in this project; only one General Manager was involved during the project life. This phenomenon could be explained by small projects usually needing less executive support; instead, more support from medium managers was needed.

Figure 67: Network of PTRs organized by level of management



Note: Node size based on centrality measurements. PTRs were assigned a colour according to which level of management they were sorted
Source: Original research

A visual and descriptive analysis for this attribute is shown in figure 67 and table 29. Based on the top 10 ranked actors according to weighted degree centrality, it can be inferred that the Middle Management actors were the most central actors in this network. Thus, they were the most visible and prestigious nodes in the network. Similarly, two of these team roles (nodes 25 and 6) were found to have the highest scores of betweenness and closeness centrality. Thus, these actors were the key intermediary actors in the network as well as the ones most likely to be communication paths between other nodes. In other words, PTRs having at the middle level of management are those who supported the formation of Collaborative Relationship Ties between other PTRs in the network.

Table 29: Top ten ranked PTRs based on centrality measures.

Id	Organization	Level_of_Management	Degree	Weighted Degree	Closeness Centrality	Betweenness Centrality
25	Subsidiary Office	Middle Management	49	763	1,27	509,00
6	Subsidiary Office	Middle Management	27	345	1,45	179,26
30	Subsidiary Office	Non-managerial level	26	253	1,61	71,11
24	Customer	Middle Management	11	206	1,82	12,96
33	Subsidiary Office	Non-managerial level	20	161	1,70	24,10
10	Customer	Middle Management	5	98	2,18	0,00
19	Subsidiary Office	Middle Management	17	85	1,70	15,64
9	Customer	Non-managerial level	5	81	0,00	0,00
23	Customer	Middle Management	7	56	2,15	1,00
28	Subsidiary Office	Non-managerial level	14	48	1,73	17,16

Source: Original research

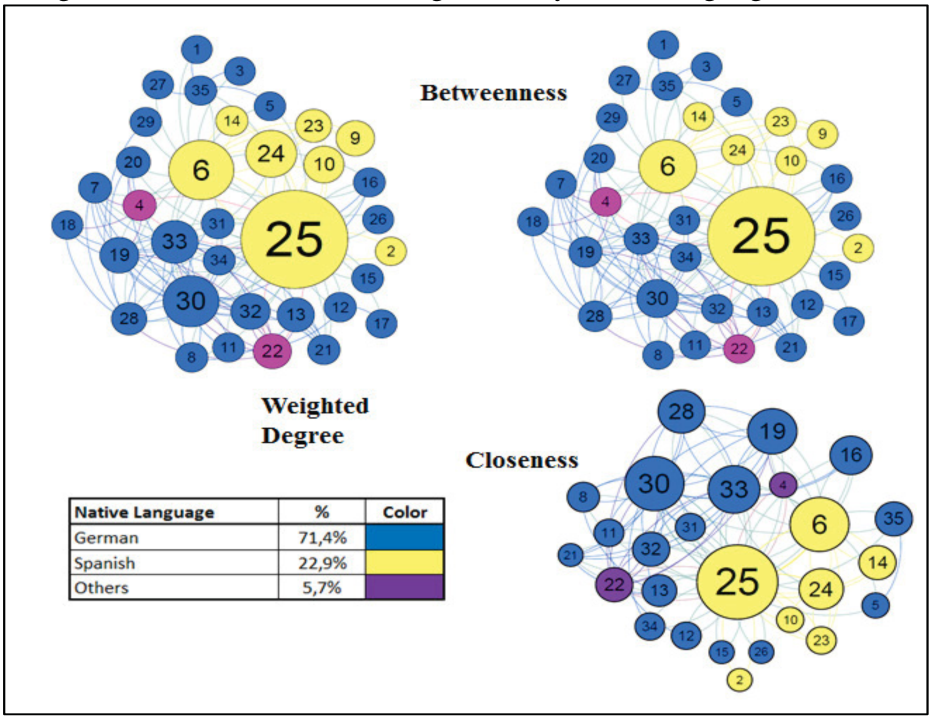
2) Native Language and Frequent Communication Language

As in the previous cases, the nodal attribute "Native Language" was classified in three categories: German, Spanish, and Others. Similarly, the nodal attribute "Communication Language" was classified in three categories: German, Spanish, and English.

Because of the closeness location of some nodes (PTRs) on the depicted networks, it appears that two PTRs tended to share a collaborative tie with other nodes if they either shared the same native language, or interacted more frequently through the same communication language (see figure 68 and 69). Thus, PTRs that interacted with each other during the project's lifetime in the same communication language or that shared the same native language tended to form more Collaborative Relationship Ties than those PTRs that which either interacted through different communication languages or didn't share the same native language.

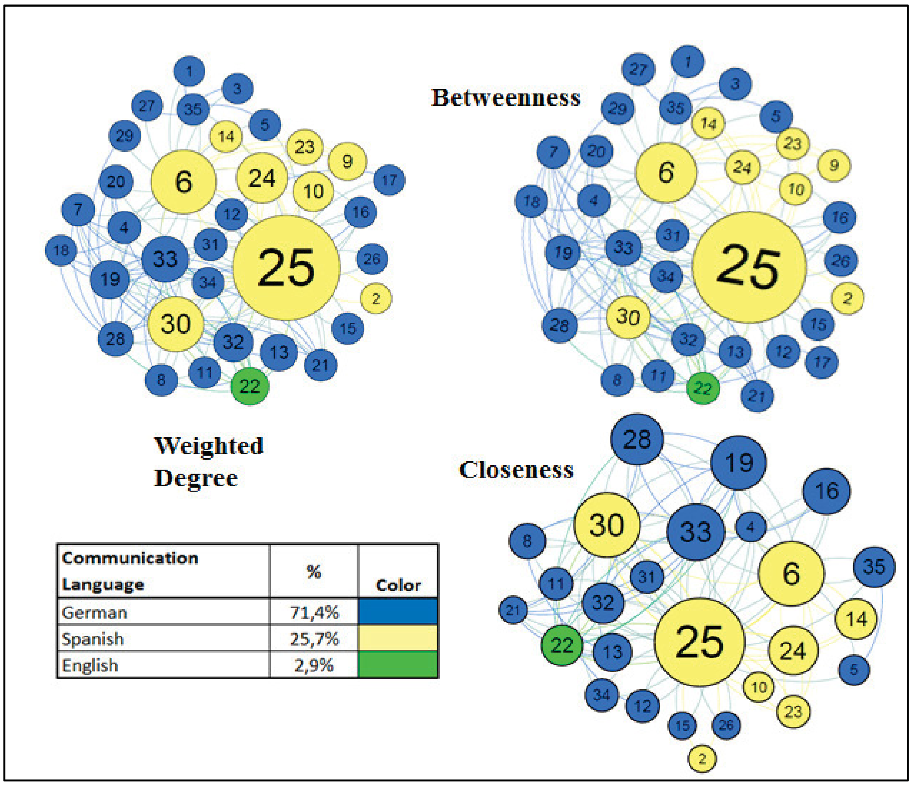
Additionally, based their the central position in the depicted network (see figures 68 and 69) and the higher centrality ratios showed by the nodes 25, 6, and 30 (see table 30), it appears that those nodes were the bridge between German and Spanish communities. Also the data collection demonstrates that those actors were able to establish communication with other actors in this network in at least three different languages (Spanish, English and German).

Figure 68: Network of PTRs organized by native language



Note: Node size based on centrality measurements. PTRs received a colour depending on which native language they were sorted.
Source: Original research

Figure 69: Network of PTRs organized by frequent communication language



Note: Node size based on centrality measurements. PTRs received a colour depending on which communication language they were sorted.
Source: Original research

Table 30: Top ten ranked PTRs based on centrality measures

Id	Organization	Communication Language	Native Language	Degree	Weighted Degree	Closeness Centrality	Betweenness Centrality
25	Subsidiary Office	Spanish	Spanish	49	763	1,27	509,00
6	Subsidiary Office	Spanish	Spanish	27	345	1,45	179,26
30	Subsidiary Office	Spanish	German	26	253	1,61	71,11
24	Customer	Spanish	Spanish	11	206	1,82	12,96
33	Subsidiary Office	German	German	20	161	1,70	24,10
10	Customer	Spanish	Spanish	5	98	2,18	0,00
19	Subsidiary Office	German	German	17	85	1,70	15,64
9	Customer	Spanish	Spanish	5	81	0,00	0,00
23	Customer	Spanish	Spanish	7	56	2,15	1,00
28	Subsidiary Office	German	German	14	48	1,73	17,16

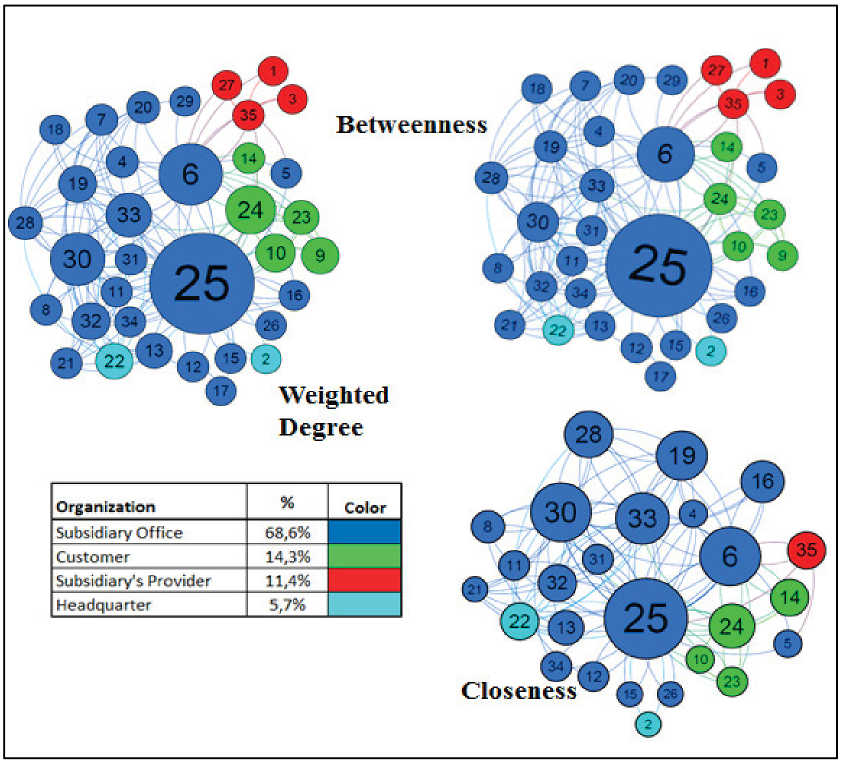
Source: Original research

3) Organization

Figure 70 displays the network of PTRs classified by organization type. As explained, this attribute was categorized in order of importance (calculated as a ratio of the total number of nodes each organization has in the network) as follows: Subsidiary Office (68.6%), Customer (14.3%), Subsidiary's Provider (11.4%), and Headquarters (5.7%).

Because of the closeness location of some nodes (PTRs) on the depicted networks, it appears that two PTRs tended to share a collaborative tie with those in their own organization than with those from another organization.

Figure 70: Network of PTRs classified by organization



Note: Node size based on centrality measurements. PTRs received a colour depending on which organization they were sorted

Source: Original research

Worthy of note are the positions of the nodes 25 and 6, belonging to the Subsidiary Office; as can be seen, they were located close to the Customer nodes (green) and therefore it can be presumed they were acting as intermediaries between the Customer and Subsidiary Office.

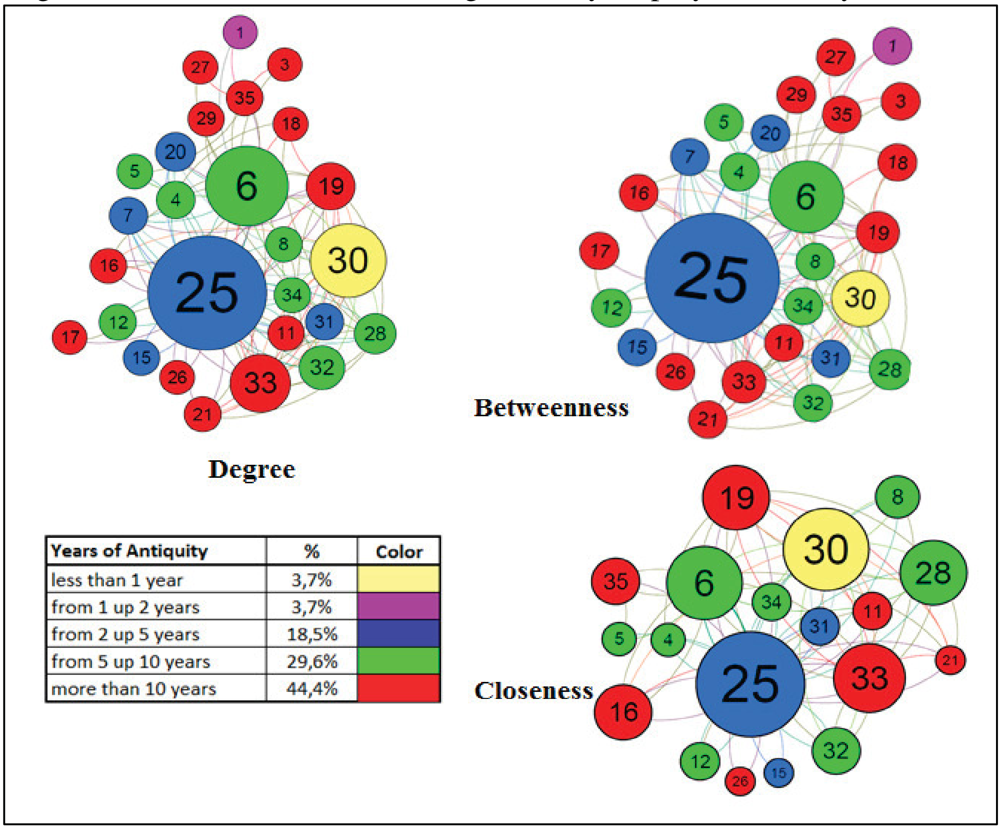
Finally, due to the fact that this network did not have many actors and that the key player of every subnetwork was already identified in the previous visual analyses, it was decided not to carry out a low level analysis for this case.

4) Employee's Seniority Characterized

As indicated above in the previous case studies, PTRs relationships were categorized and analysed in terms of the attribute "Employee's Seniority Characterized".

The visual and descriptive analysis of the Collaboration Intensity Network suggests, that two PTRs from this sub-network[282] would not tend to share Collaborative Relationship Ties with other team roles as a function of the length of service with their employer (see figure 71).

Figure 71: Sub-network of PTRs organized by employee seniority



Note: Node size based on centrality measurements. PTRs received a colour according to which level of employee seniority they were sorted. This subnetwork only includes PTRs belonging to Headquarters, Subsidiary and Overseas Branch Offices.
Source: Original research

[282] customer and customer's providers organizations were not included in this analysis due to the lack of information

4.4.3 Stochastic Modelling

As mentioned in section 4.1.3.2, a stochastic analysis using ERGMs was applied to understand the implications of structural parameters and node level attributes in the Collaboration Intensity Network formed by the PTRs in this SCDP. Twenty-two parameters were included in the model: two for edges; one for mutuality as a structural parameter; two for differential homophily on Organization; two for differential homophily on Level of Management; two for differential homophily on Native Language; two for differential homophily on Ethnic Group; two for differential homophily on Communication Language; one for differential homophily on Employee Seniority Characterized; two for differential homophily on Modularity class; two for the Frequency of Contact factor effect; and four for the GWTs (GWIdegree, GWOdegree, GWESP and GWDSP). The fitted values of the parameters, standard errors, and the AIC and BIC criterion for the models applied to the Collaboration Intensity Network are listed in table 31.

Table 31: Stochastic models predicting the Collaboration Intensity Network

Coefficient	Model 1			Model 2			Model 3			Model 4		
	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR	Logit	Std. error	OR
Ostar	-4,17***	0,08	0,005	-5,42***	0,30	0,00	-3,69*	1,46	0,02	-4,75***	0,40	0,01
Istar	0,71***	0,08	2,03	0,45	0,30	1,56	0,19	1,46	1,21	-	-	-
Mutual	-	-	-	2,42***	0,68	11,27	3,71	5,43	40,84	2,27***	0,66	9,68
Organization												
Customer	-	-	-	16,50***	0,48	14.691.505	17,92***	4,76	60.311.298	15,19***	0,31	3.933.735
Subsidiary	-	-	-	1,15	0,64	3,16	0,69	1,72	2,0	15,41***	0,40	4920890,2
Level of Management												
Middle Mgmt.	-	-	-	0,42	0,43	1,52	0,37	2,64	1,44	0,31	0,33	1,36
Non- Managerial	-	-	-	1,10*	0,56	3,01	0,52	2,09	1,69	0,75*	0,37	2,11
Native Language												
German	-	-	-	-2,57***	0,33	0,08	-0,74	1,94	0,48	-1,88***	0,27	0,15
Spanish	-	-	-	16,80***	0,46	19.741.015	16,76***	4,39	18.955.544	1,81**	0,67	6,13
Ethnic Group												
Germanic	-	-	-	0,71*	0,33	2,02	-0,03	1,94	0,97	-0,25	0,27	0,78
Latin	-	-	-	-15,1***	0,48	0,00	-16,0***	4,76	0,00	-15,10***	0,31	0,00
Frequent Communication Language												
German	-	-	-	-0,02	0,75	0,98	-0,10	5,04	0,90	-	-	-
Spanish	-	-	-	-15,4***	0,46	0,00	-16,7***	4,39	0,00	-	-	-
Employee Seniority Characterized												
2 to 5 years	-	-	-	-0,55	1,0	0,57	0,0	1,46	1,0	-	-	-
Nodecov												
Freq_of_contact (Nodeicov)	-	-	-	0,00	0,00	1,00	0,06	0,08	1,06	-	-	-
Freq_of_contact (Nodeocov)	-	-	-	0,01*	0,00	1,01	0,00	0,05	1,00	-	-	-
Modularity												
Group 1	-	-	-	0,67	1,01	1,95	0,91	16,86	2,49	-	-	-
Group 2	-	-	-	-0,21	0,45	0,81	0,09	2,04	1,10	-	-	-
High Degree Dist.												
GWIdegree	-	-	-	-	-	-	0,46	6,49	1,59	-	-	-
GWOdegree	-	-	-	-	-	-	-4,05	5,87	0,02	-	-	-
GWESP	-	-	-	-	-	-	0,39	1,37	1,47	0,74***	0,20	2,09
GWDSP	-	-	-	-	-	-	-0,55	0,77	0,58	-	-	-
Model Fit	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**	**Likelihood**	**AIC**	**BIC**
	-161.4	326.8	336.9	-109.87	255.7	347,2	-497.7	1039	1151	-111,83	245,7	301,6

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
Source: Original research

Model 1 includes two parameters used to capture the density of the network (ostar, istar). The second model describes and explains the effects of continuous covariates and a categorical factor in the Collaboration Intensity Network. Model 3 was built by introducing the GWTs.

Finally, using the outputs of model 3, the nodal covariates Frequent Communication Language, Employee's Seniority Characterized, Frequency of Contact, and Modularity class, as well as the structural parameters istar, GWIdegree, GWOdegree and GWDSP were excluded from model 4, because it appeared that those parameters were not contributing meaningful information to the generative process that gave rise to the Collaboration Intensity Network. After the comparison of the AIC and BIC scores[283] between models, the results indicate that model 4 had the best data fit and therefore allowed for better identification of the structures that characterized the Collaboration Intensity Network.

The negative and statistically significant value of the ostar coefficient at the 0.001 level, indicates that the probability that a tie would be formed was equal to the probability of [exp(-4,76)/(1+exp((-4,76))] = 0,0085. The positive and statistical significance of Mutuality effect indicates that there was a tendency of PTRs in the network to engage in mutual, reciprocated ties. This effect indicates that if one PTR collaborated with another PTR, the other PTR tended to collaborate with him back. The positive and statistically significant effect of GWESP statistics indicate that PTRs were likely to undertake activities jointly (forming complete triangles or clusters) rather than unilaterally. The ERGM results indicate that the effects of differential homophily on Communities were not distinguishable from zero at the 0.05 level of significance. This result could be explained by the short duration of this project (about five months). So it is not expected that collaboration will be accomplished in communities, in a short period of time. Instead, collaborative relationships in this project were more influenced by organizations and small triads or subgroups of nodes as was found with the positive and statistically significant effects of both the GWESP weighted term and the differential homophily on Organization.

The effects on the structure of the Collaboration Intensity Network of incorporating the heterogeneity of PTRs through nodal covariate effects were also tested in this case study. In fact, the positive and statistically significant effect of the differential homophily on Organization (in the Customer and Subsidiary Office categories) indicates that PTRs were more likely to collaborate with those PTRs in their own organization than with those in other organizations. The positive and statistically significant effect of the differential homophily on Level of Management (at the Non-managerial level factor) indicates that PTRs were more likely to share Collaborative Relationship Ties each other if they didn't have managerial responsibilities. This could also be explained by the short duration of the project. It seems that, there was less time for planning activities and of course more operative work would have been needed. Likewise, the positive and statistically significant effect of the differential homophily on Native Language at the Spanish level factor suggests that PTRs were more likely to share Collaborative Relationship Ties with those PTRs that shared Spanish as a native language. On the contrary, the negative and statistically significant effect of the differential homophily on Native Language at the German level factor suggests that PTRs were unlikely to share Collaborative Relationship Ties with those PTRs that shared German as a native language. The same happened with the negative and statistically significant effect of the differential homophily on Ethnic group. Thus, PTRs who shared the same ethnic group

[283] Given a set of candidate models for the data, *the preferred model is the one with the minimum AIC and BIC values.* Hence both scores reward goodness of fit (as assessed by the likelihood function), but also includes a penalty term for the number of parameters in the model. This penalty discourages problems of overfitting.

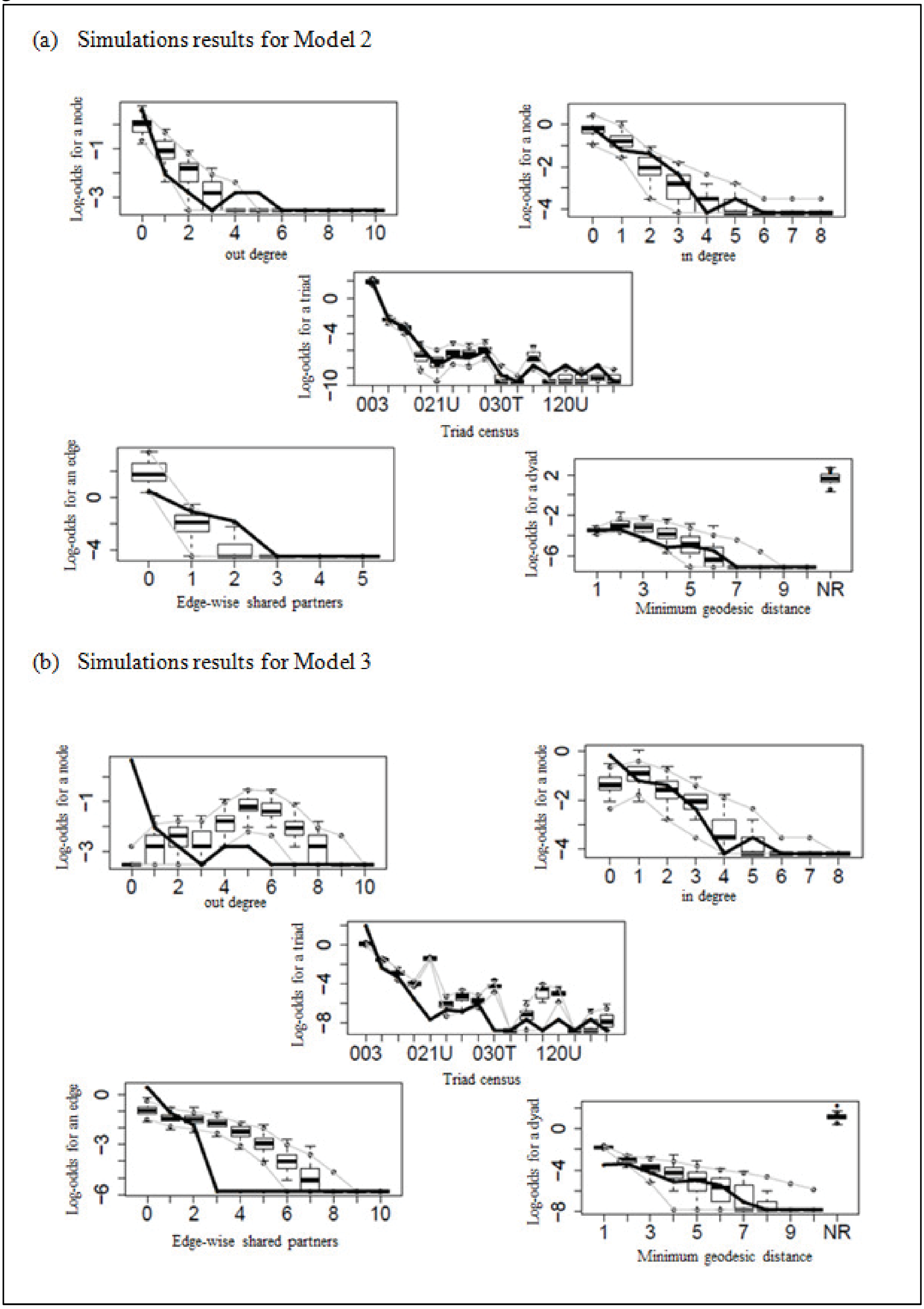
(at the Latin American-European level factor) were unlikely to share Collaborative Relationship Ties. Finally, the ERGM results indicate that the effects of the nodal covariates Frequent Communication Language, Employee's Seniority Characterized, and Frequency of Contact were not distinguishable from zero at the 0.05 level of significance; these parameters were therefore excluded from model 4.
Goodness-of-fit tests were conducted to estimate how well a model fit by comparing a set of observed network statistics (degree, edge-wise shared partners, minimum geodesic distance, and triad census) with the range of the same statistics obtained by simulating many networks from the fitted ERGMs (see figure 72).

It can be seen in figure 72(a) that model 2 did a poor job of capturing the out-degree distribution and the shared partner distribution. It performed relatively well for the in-degree distribution, triad census distribution, and the geodesic distribution. Adding all high degree distributions (i.e., GWIdegree, GWOdegree, GWESP, GWDSP) improved the AIC and BIC criterion, but the graphical criterions show a strong divergence when capturing the out degree distribution, shared partner distribution and triad census distribution of the observed data (see figure 72(b)). This situation reveals that the local structural dependences introduced by the high degree distributions ought to be tested in order to develop a robust sense of goodness-of fit. Finally, from a comparison of figures 72(a) and 72(b) to figure 72(c), it seems that excluding those parameters whose estimated coefficients were not distinguishable from zero at the 0.05 level of significance dramatically improved model fit. It can be affirmed that model 4 fit much better as measured by the graphical criterion and by the AIC and BIC criterion employed in this research. Moreover, it is a more simplistic model, as it includes only nodal covariates and local network structures with statistically significant effects (see formulation of model 4, below).

=====================
Formulation of Model 4
=====================

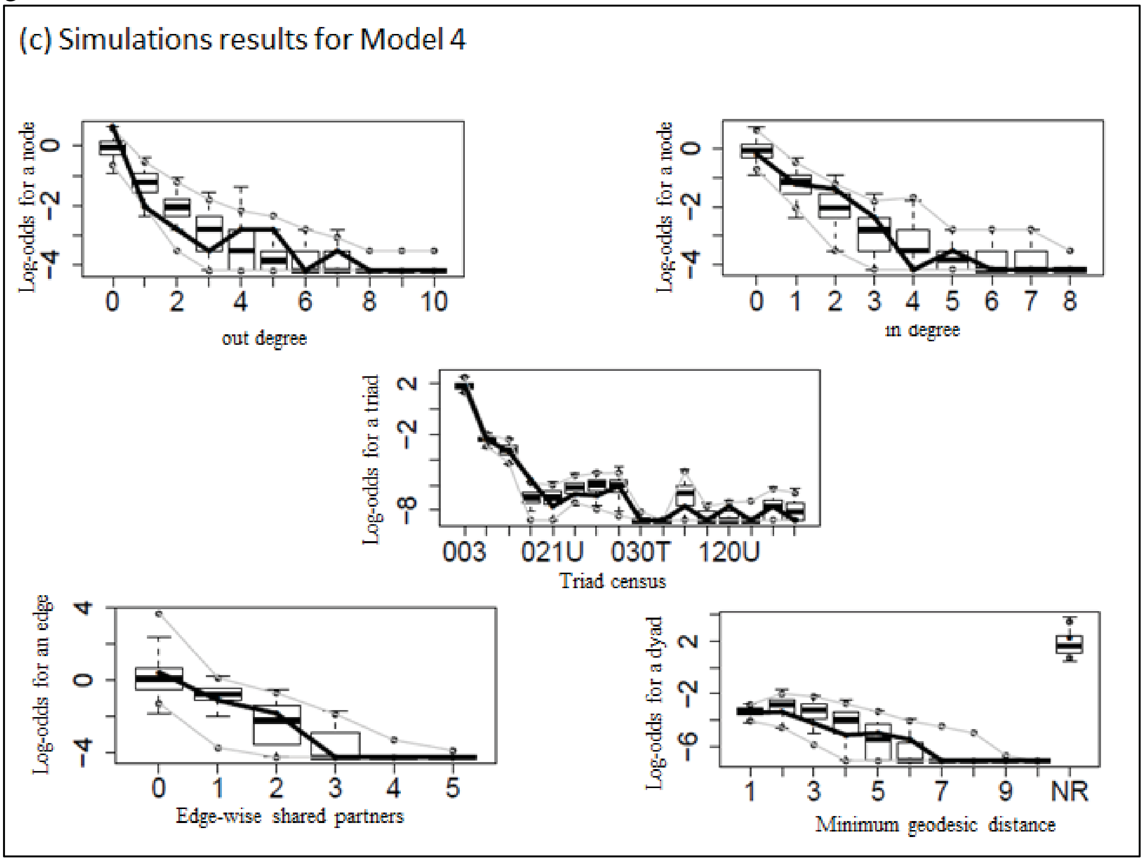
Formula: intensity ~ ostar + mutual + nodematch (Organization) + nodematch (Level_of_Management) + nodematch (Native_Language) + nodematch (Ethnic_Group) + gwesp

Figure 72: Goodness-of-fit tests for model 4 of table 31



Note: In all plots, the vertical axis is the logit of relative frequency; PTR relationship statistics are indicated by the solid lines; the boxplot includes the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fall.

Figure 72: Goodness-of-fit tests for model 4 of table 31



Notes: In all plots, the vertical axis is the logit of relative frequency; PTR relationship statistics are indicated by the solid lines; the boxplot includes the median and interquartile range; and the light grey lines represent the range in which 95 per cent of simulated observations fall.

5 Findings and Discussions

5.1 Partial Results of Case A

The outcomes of this first case provide insight on how the Intensity of Collaboration is structured in this SCDP and what explains the collaboration between PTRs. Both visual and descriptive analyses and ERGMs have depicted and described the main properties and characteristics of this network. In addition, graphical and descriptive results indicate that the presence of both nodal attributes and structural parameters increased the likelihood of forming Collaborative Relationship Ties between PTRs involved in this project.

The visual and descriptive analysis here performed allows the identification and description of the main characteristics of the Collaboration Intensity Network formed by PTRs. In terms of the centrality measures, four Project Manager roles were identified: Subsidiary's Project Manager**,** Headquarters' Project Manager, Subsidiary's Project Manager**,** and Overseas Branch Office's Project Manager. They were the roles who became the object of many relationships (in-degree) and who were the most central roles in spreading information and influencing other PTRs (out-degree) in the network. In addition, the Subsidiary's Project Manager had the highest betweenness centrality values (i.e., it was acting as the key intermediary between other team roles which were not directly connected in the network). Likewise, the Headquarters' Project Manager had the highest closeness centrality values. Thus, it was the closest PTR to other PTRs in the network and therefore had the greatest influence in speeding communication and/or exchange over the entire network. So, Project Managers were the most central, prominent, visible actors in the network and appeared to be the most likely to be communication paths between other nodes, serving as facilitators in the creation, management and control of the collaborative relationships among PTRs over the entire network.

Social Networks generally exhibit local clustering structural forces that can come from at least two different sources: (1) team members forming partnerships on the basis of existing dyadic-dependence partnerships; and (2) team members matching on exogenous attributes.[284] Both Gephi and ERGM results indicate that there was a tendency for PTRs to form Collaborative Relationship Ties by communities as well as by small triads or clusters. Six communities of PTRs working together in tight collaboration were identified: The first community consisted of PTRs working in the Subsidiary Office; the second community corresponded to PTRs working at the Headquarters Company; the third community was formed by PTRs working by the Customer; the fourth community, corresponded to a cross-organizational group of PTRs who came from Headquarters, Subsidiary and Providers for Overseas Branch Offices and were carrying out administrative and human resource support; the fifth community was comprised of Portfolio Managers; and community sixth corresponded to a cross-organizational group of PTRs who worked in the System Administration area. In addition, collaboration in small cluster or triads was identified, as confirmed by positive and statistically significant effect of the GWESP distribution.

[284] Hunter *et al.* (2006)

The outputs of the ERGMs indicate that the set of attributes proposed in the CCPM model are playing important roles in the generative processes that gave rise to the Collaboration Intensity Network formed by PTRs in this SCDP. Thus, it seems that PTRs were more likely to form Collaborative Relationship Ties with other PTRs if they shared similar values for the following attributes: Organization at all level-factors (except Overseas Branch Office); Level of Management, at Portfolio Management level-factor; Native Language, at both the Dutch and Portuguese level-factors; and Communication Language, at both the English and German level-factors. Thus, if two PTRs belonged to the same Organization then there was a greater-than-chance probability that they would share Collaborative Relationship Ties. Similarly, if two PTRs shared the same native language (Dutch or Portuguese) or used the same communication language (English or German), then there would be a greater-than-chance probability that they would create Collaborative Relationship Ties. Likewise, if two PTRs belonged to the same Management level (General Manager), then there was a greater-than-chance probability that they would share Collaborative Relationship Ties.

Moreover, the ERGM results indicate that Frequency of Contact was positively correlated to the likelihood of forming Collaborative Relationship Ties; i.e., there was a greater-than-chance probability for PTRs who communicated more frequently to form Collaborative Relationship Ties.

Finally, all graphical and stochastically results offer a line of empirical evidence that indicates that the set of attributes proposed in the CCPM model performed well in capturing the heterogeneity of the actor through the nodal attributes as well as in capturing the local forces that gave rise to the formation of edges in the Collaboration Intensity Network formed by PTRs in this SCDP. (There was no empirical evidence for the association of either the Employee's Seniority or Ethnic Group attributes with a higher probability that PTRs share Collaborative Relationship Ties.)

5.2 Partial Results of Case B

The results of the second case also provide insight on how the Intensity of Collaboration was structured in this SCDP and what explains collaboration between PTRs. The results of visual and descriptive analyses and ERGMs have depicted and described the main properties and characteristics of this network. Moreover, these results indicate that the presence of both nodal covariates and structural parameters increased the likelihood of forming Collaborative Relationship Ties between PTRs involved in this project.

Visual and descriptive analyses were performed to identify and describe the principal characteristics of the Collaboration Intensity Network. In terms of the centrality measures, four Project Manager roles were identified as having the most central, prominent and visible roles in the network: Subsidiary's Project Manager, Overseas Branch Office's Project Manager, Headquarters' Project Manager and Customer's Project Manager. They were the ones who became the object of many relationships (in-degree) and who were the most central roles in influencing and spreading information among other PTRs (out-degree) in the network. In addition, the Subsidiary's Project Manager had the highest betweenness centrality values (i.e., it was acting as the key intermediary between other team roles which were not directly connected in the network). Likewise, the Overseas Branch Office's Project Manager had the highest closeness centrality values. Thus, it was the closest PTR to other PTRs in the network and therefore had the greatest influence in speeding communication and/or exchange of information over the entire network. It is worth highlighting that these PTRs seemed more likely to be communication paths between other nodes, serving as facilitators in the creation, management and control of relationship and collaboration ties with other PTRs over the entire network.

Regarding the local clustering structural forces and nodal covariates that gave rise to Collaborative Relationship Ties, both Gephi and ERGM results indicate that collaboration was only happening here by communities. So it seems PTRs were more likely to collaborate with those PTRs in their own community than with those belonging to other communities. Indeed, two communities of PTRs working together in close collaboration were identified: The first community was comprised of PTRs working at the Subsidiary Office, and the second community consisted of a cross-organizational cluster formed by PTRs belonging to Headquarters, Overseas Branch Office and Customer Offices.

The outputs of the ERGMs indicate that the set of attributes proposed in the CCPM model are playing important roles in the generative processes that gave rise to the Collaboration Intensity Network. Thus, judging by their statistical significance, it seems that PTRs were more likely to form Collaborative Relationship Ties if they shared similar values for the following attributes: Native Language at both the German and Spanish level-factors; Ethnic Group (negative and statistically significant at Germanic level-factor); and Communication Language, at the Portuguese level-factor. For instance, if two PTRs shared the same native language (German or Spanish), then there was a greater-than-chance probability that they would create Collaborative Relationship Ties. Likewise, if two PTRs used the same communication language (Portuguese), then there was a greater-than-chance probability that they would create Collaborative Relationship Ties. Furthermore, the negative and statistically significant effect of the differential homophily on Ethnic Group suggests that PTRs sharing the Germanic ethnic group were unlikely to share Collaborative Relationship Ties

Moreover, the ERGM results suggest that Frequency of Contact is positively correlated to the likelihood of forming Collaborative Relationship Ties; i.e., there was a greater-than-chance probability for PTRs who communicated more frequently to form Collaborative Relationship Ties.

Finally, all graphical and stochastic results offer a line of empirical evidence that indicate that the set of attributes proposed in the CCPM model do a good job in capturing the heterogeneity of the actor through the nodal attributes as well as in capturing the local forces that gave rise to the formation of edges in the Collaboration Intensity Network formed by PTRs in this SCDP. (There was no empirical evidence for the association of the Organization, Level of Management, Employee's Seniority or Mutuality attributes with a higher probability that PTRs shared Collaborative Relationship Ties.)

5.3 Partial Results of Case C

The results of the third case have also depicted and described the main properties and characteristics of the Collaboration Intensity Network. In addition, graphical and ERGM results indicate that the presence of both nodal covariates and structural parameters increased the likelihood of forming Collaborative Relationship Ties between PTRs involved in this project.

Visual and descriptive outputs indicate that the Subsidiary's Project Manager was the most central, prominent and visible actor in this network in terms of the centrality measures. As such, it became the object of many relationships (in-degree), was the most central role in spreading information and influencing other PTRs (out-degree), and was the closest to other PTRs in the network. It therefore had the greatest influence in speeding communication and/or exchange of information over the entire network. Moreover, as it had the highest betweenness centrality values, it was acting as the key intermediary between other team roles in the network that were not directly connected.

Regarding the local clustering structural forces and nodal covariates that gave rise to Collaborative Relationship Ties, ERGM results indicate that there were local forces in this network encouraging the creation of triads of collaborative links among PTRs rather than the creation of collaborative links with those PTRs belonging to their own communities. Thus, it appears that collaboration in this small project was happening in small clusters or triads (as confirmed by the positive and statistically significant effect of the GWESP distribution).

The ERGMs' outputs indicate that the set of attributes proposed in the CCPM model are playing important roles in the generative processes that gave rise to the Collaboration Intensity Network. Thus, judging by their statistical significance, it appears that PTRs were more likely to form Collaborative Relationship Ties if they shared similar values for the following attributes: Organization at both the Customer and Subsidiary level-factors; Level of Management at the Non-managerial level-factor; Native Language (positive at the Spanish level-factor and negative at the German level-factor); and Ethnic Group (negative and statistically significant at the Latin American/European level-factor). For instance, if two PTRs belonged to the same Organization (at the Customer or Subsidiary level-factor), then there was a greater-than-chance probability that they would share Collaborative Relationship Ties. Similarly, if two PTRs shared the same native language (at the Spanish level-factor), then there was be a greater-than-chance probability that they would create Collaborative Relationship Ties. Likewise, if two PTRs belonged to the same Management level (Non-managerial level-factor), then there was a greater-than-chance probability that they would share a collaborative tie in the network. Furthermore, the negative and statistically significant effects of the differential homophily on Ethnic Group, as well as on Native Language, suggest that PTRs shared the same Ethnic Group (at the Latin American/European level-factor) or shared the same native language (at the German level-factor) were unlikely to share Collaborative Relationship Ties.

Finally, all graphical and stochastic results provide a line of empirical evidence that indicate that the set of attributes proposed in the CCPM model do a good job in capturing the heterogeneity of the actor through the nodal attributes, as well as in capturing the local forces that gave rise to the formation of edges in the Collaboration Intensity Network formed by PTRs in this SCDP. (There was no empirical evidence of the association of the Employee's Seniority, Frequency of Contact, or Communication Language attribute with a higher probability PTRs to share Collaborative Relationship Ties.)

6 Conclusions and Evaluation of the Research

6.1 Consolidated Results

Three case studies were carried out. The results of visual and descriptive analysis have depicted and described the main properties and characteristics of the network formed by PTRs in the SCDPs evaluated in this research (see table 32).

The consolidated analysis of the case studies shows that there were three distinct types of networks according to the size and complexity of the projects: (1) A project network with a great number of partners, low cohesion, and with strategic importance to the corporate headquarters (large-scale project); (2) a project network with a medium number of partners, low cohesion, and medium importance to the corporate headquarters (standard project); and (3) a project network with a small number of partners, low cohesion, and low importance to the corporate headquarters (small project). The low-density of the project networks (Graph density equal to 0.10 on average) may be explained by the important role of Project Managers in speeding communication and/or information exchange in the network. It was found that Project Managers in those three networks were the main source of relationships coming into and leading out of the node. Moreover, they were the most active, the closest to other PTRs, had the greatest authority, as well as being the most intermediate (the most easily reachable) and nearest to all PTRs in the network.

It is worth noting that the support of Corporate Headquarters diminished as the network size of the project decreased. Thus, it was found that the proportion of Headquarters actors in the network decreased from an about 36% in a large-scale project to 20% and 11% in a standard and small project, respectively. Conversely the proportion of the Subsidiary actors increased as the project size was reduced. That meant more autonomy for the Subsidiary office and reduced corporate support as the size and strategic importance of the project decreased.

The ERGM results of the three cases analysed in this research provide a line of empirical evidence that affirms that the set of attributes proposed in the CCPM model (except Employee's Seniority) are valid. Thus, the set of attributes proposed in this research perform well in capturing the heterogeneity of the actor through the nodal attributes, as well as in capturing the local forces gave rise to the formation of edges in the Collaboration Intensity Network formed by PTRs in these SCDPs. Moreover, the modelling results indicate that actors matching on exogenous attributes, as well as actors forming partnerships on the basis of existing shared partners, can be associated with greater-than-chance probabilities of PTRs to exhibit collaborative behaviours. In addition, the attributes proposed by the tactical perspective (both the differential homophily on Modularity class and local structural forces) allow the existence of some kind of collaboration structures in the analysed networks to be identified. Moreover, the results indicate that the longer the duration of the project, the higher the likelihood that complex collaborative behaviours will be exhibited in the network (e.g., from small clusters or triads to real communities of PTRs working in tight collaboration). Similarly, the statistical significance of the Native Language attribute in all the three analysed case studies indicates that if PTRs shared the same native language, then there was be a greater-than-chance probability that they would create Collaborative Relationship Ties.

However, it must be underlined that the results give no empirical evidence for the association of the Employee's Seniority attribute with a higher probability that PTRs would share Collaborative Relationship Ties; (i.e., there is no compelling evidence to confirm or reject the hypothesis: *The length of time a project team role has been engaged in project management work, the higher the likelihood of PTRs with the same Employee's Seniority level-factor sharing Collaborative Relationship Ties*. Table 33 shows the aggregate findings about the contributory factors enabling collaborative relationships among PTRs in each of the three SCDPs analysed.

Table 32: Main characteristics of the Collaboration Intensity Networks in selected SCDPs

<table>
<tr><th colspan="2">Network Characteristics</th><th>Large Project</th><th>Medium Project</th><th>Small Project</th></tr>
<tr><td colspan="2">Nodes</td><td>211</td><td>49</td><td>35</td></tr>
<tr><td colspan="2">Edges</td><td>2195</td><td>314</td><td>149</td></tr>
<tr><td colspan="2">Graph Density</td><td>0,05</td><td>0,13</td><td>0,125</td></tr>
<tr><td colspan="2">Avg. Path Length</td><td>2,19</td><td>2,03</td><td>1,98</td></tr>
<tr><td colspan="2">Network diameter</td><td>5</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Average Degree</td><td>10,40</td><td>6,41</td><td>4,26</td></tr>
<tr><td colspan="2">Key Team Roles</td><td>- Subsidiary's Project Manager
- Headquarters' Project Manager
- Subsidiary's Project Manager
- Overseas Branch Office's Project Manager</td><td>- Subsidiary's Project Manager
- Overseas Brach's Project Manager
- Headquarter's Project Manager
- Customer's Project Manager</td><td>- Subsidiary's Project Manager
- Subsidiary's Customer Care Manager
- Subsidiary's commissioning Engineer</td></tr>
<tr><td rowspan="6">Centrality Measures</td><td>in-degree</td><td>- Subsidiary's Project Manager</td><td>- Subsidiary's Project Manager</td><td rowspan="6">- Subsidiary's Project Manager</td></tr>
<tr><td>out-degree</td><td>- Headquarters' Project Manager</td><td>- Overseas Brach's Project Manager</td></tr>
<tr><td>betweenness</td><td>- Subsidiary's Project Manager</td><td>- Subsidiary's Project Manager</td></tr>
<tr><td>closeness</td><td>- Headquarters' Project Manager</td><td>- Overseas Brach's Project Manager</td></tr>
<tr><td>eigenvector</td><td>- Subsidiary's Project Manager</td><td>- Subsidiary's Project Manager</td></tr>
<tr><td>weighted degree</td><td>- Subsidiary's Project Manager</td><td>- Subsidiary's Project Manager</td></tr>
<tr><td colspan="2" rowspan="4">Project Organizational structure</td><td>- Subsidiary Office and ist providers:
70 nodes (visibility 33.18%); 709 edges (32.3%);
Network density: 0.147;
Avg. Path Length:1.98</td><td>- Subsidiary Office:
19 nodes (visibility 38.8%); 68 edges (21.7%);
Network density: 0.199;
Avg. Path Length:1.81</td><td>- Subsidiary Office and its providers:
26 nodes (visibility 74.3%); 115 edges (77.2%);
Network density: 0.177;
Avg. Path Length:1.86</td></tr>
<tr><td>- Headquarter Office and its providers:
76 nodes (visibility 36.0%); 236 edges (10,8%);
Network density: 0.04
Avg. Path Length: 1.98</td><td>- Headquarter Office:
10 nodes (visibility 20.4%); 10 edges (3,2%);
Network density: 0.11
Avg. Path Length: 1.66</td><td>- Headquarter Office:
4 nodes (visibility 11.4%); 3 edges (2.0%);
Network density: 0.25
Avg. Path Length: 1.0</td></tr>
<tr><td>- Overseas Brach Office and ist providers:
20 nodes (visibility 9.5%); 77 edges (3.5%);
Network density: 0.203;
Avg. Path Length: 1.84</td><td>- Overseas Brach Offices:
5 nodes (visibility 10.2%); 6 edges (1.9%);
Network density: 0.3;
Avg. Path Length: 1.33</td><td>- Customer:
5 nodes (visibility 14.3%); 8 edges (5.4%);
Network density: 0.4;
Avg. Path Length: 1.46</td></tr>
<tr><td>- Customer and ist providers:
45 nodes (visibility 21.3%); 170 edges (7.7%);
Network density: 0.09;
Avg. Path Length: 1.97</td><td>- Customer and ist providers:
15 nodes (visibility 30.6%); 86 edges (27.4%);
Network density: 0.41;
Avg. Path Length: 1.62</td><td></td></tr>
</table>

Source: Original research

Table 33: Contributory factors enabling collaborative relationships in selected SCDPs

Network Characteristics		Large Project (32 Months)	Medium Project (6 Months)	Small Project (5 Months)
Strategic Perspective	Organization	- Customer, Customer's Providers, Headquarter, Overseas Brach Office's Providers statistically significant	- Not strong evidence provided again the null hypothesis	- Customer and Subsidiary Positive and statistically significant
	Level of Management	- At portfolio management level-factor positive and statistically significant	- Not strong evidence provided again the null hypothesis	- At non-managerial factor-level positive and statistically significant
	Employee Seniority	- Not strong evidence provided again the null hypothesis	- Not strong evidence provided again the null hypothesis	- Not strong evidence provided again the null hypothesis
Tactical Perspective	Join Actions (Collaboration Structure)	- Collaboration in 6 Communities identified: * Subsidiary team roles * Headquarter team roles * Customer team roles * Cross-company Community: Admin. & Human Resources * Cross-company Community: Portfolio Managers * Cross- company Community: Sys Administrators - Collaboration in small cluster or triads identified (GWESP significant) - GWIdegree, GWOdegree and GWDSP: negative and statistically significant	- Collaboration in 2 Communities identified: * Subsidiary team roles * Cross-company Community: Headquarter, Overseas Brach's Office and Customer - GWOdegree: negative and statistically significant	- Collaboration in small clusters or triangles identified (GWESP significant)
	Information Sharing Structure	- 4 Communities in Networking: * Subsidiary team roles * Headquarter team roles * Customer team roles * Cross-company Community: Admin. & Hum. Resources	- 3 Communities in Networking: * Commisioning technicians * Planning & In-house activities at Subsidiary and Headquarters Offices * Customer & Providers team roles	- 4 Communities in Networking: * Customer team roles * Commercial & Admin. Roles (Subsidiary) * Technical roles (Subsidiary) * Financial roles (Headquarter-Subsidiary)
Interpersonal Perspective	Mutuality	- Positive and statistically significant	- Not strong evidence provided again the null hypothesis	- Positive and statistically significant
	Trust	- Frequency of Contact positive and statistically significant	- Frequency of Contact positive and statistically significant	- Not strong evidence provided again the null hypothesis
	Cultural Diversity & Background	- Native Language: at Dutch and Portuguese level-factors positive and statiscally significant - Comm. Language: at English and German level-factors positive and statistically significant - Ethnic Group: Not strong evidence provided again the null hypothesis	- Native Language: at German and Spanish level-factors positive and statiscally significant - Comm. Language: at Portuguese level-factor positive and statistically significant - Ethnic Group: at Germanic level-factor negative and statistically significant	- Native Language: at German level-factor negative and statistically significant; at Spanish level-factor positive and statiscally significant - Comm. Language: Not strong evidence provided again null hypothesis - Ethnic Group: negative and statistically significant at Latin America factor-level negative significant correlation

Source: Original research

6.2 Shortcomings and Further Research

This study is particularly interested in modelling collaborative networks where interactions are strongly mediated by information technology and systems. That is, it assumes that emails relationships, teleconference and face-to face meetings are the modes of communication more frequently used in SCDPs. While the author of this study recognizes that verbal communication also occurs also in SCDPs, it was not addressed in this research because it leaves no trail that can be examined. Additionally, based on the contributions of Clark and of McConachy and Caine [285], this study assumes that written communication between dispersed teams should be the preferred mode of communication for project team members when dealing with SCDPs. According to these authors, e-mail relationships can be beneficial in culturally diverse and dispersed teams, because: (1) They lead to fewer language errors within the team; (2) The lack of visual contact diminishes prejudices on the basis of "gender, age, clothing, gestures, and verbal capability;" and (3) The focus is on the content of the message, rather than on the sender.

There are many promising opportunities for understanding SCDPs through a social network analysis. Researchers can use the proposed model for future project management-related studies. They may additionally expand this to other fields of knowledge like SCM and other branches of management science, because these systems are usually driven by complex sociotechnical inter- and cross-firm interactions. Additional case studies could help to demonstrate the validity of this model, and validate the effect of the set of attributes here identified on the Collaboration Intensity Network. Further study may also leverage it as a tool to characterize the collaborative relationships between PTRs and the features of the associated Collaborative Relationship Ties between them.

Future research could amplify the framework used in this work to include, for instance, the "Extent of the Collaboration" dimension identified by Gruat La Forme *et al.*[286]; this additional dependent variable may lead to greater insight or conclusions on how collaborative relationships among PTRs are spread throughout the entire network. [287] (E.g., inter-functional collaborative relationships, inter-organizational collaborative relationships, and cross-organizational collaboration may be measured). Similarly, the inclusion of one additional attribute, "Resource Sharing Structure," is encouraged. Since there are other resources to be leveraged within the context of collaborative relationships (aside from single information sharing),[288] the author encourages the inclusion in further research of an additional attribute that encompasses all of these resources (the assets, knowledge, and inventories that other people and organizations have). The flow of resources between the actors when they interact can be measured; the number of bits of information transferred from one place to another, for instance, can be used as an indicator of knowledge-sharing among the actors in a network.

Another interesting research direction would be the investigation of the impact of collaborative performance on the performance indicators of a project. Meta-analysis studies

[285] McConachy and Caine (2006); Clark (2008)
[286] Gruat La Forme *et al.* (2007)
[287] Meisel and Zsifkovits (2013)
[288] Xu (2006)

could be used for that to evaluate the correlation of high levels of Intensity of Collaboration to a positive influence on project performance indicators.

7 References

Achabal, D., **Mcintyre**, S., **Smith**, S., **Kalyanam**, K.: A Decision Support System for Vendor Managed Inventor. Journal of Retailing, 76(4), 2000, pp. 430-454.

Amaral, J., **Anderson** Jr. E. G., **Parker**, G.G.: Putting it together: How to succeed in distributed product development. MITSloan Management Review, 52(2), 2011, pp. 51–58.

Ancona, D. G., **Caldwell,** D.F.: Bridging the boundary: External activity and performance in organizational teams. Administrative Science. Q. 37(4), 1992, pp. 634–665.

Andraski, J.: Foundations for Successful Continuous Replenishment Programs. International Journal of Logistics Management, 5(1), 1994.

Arranz, N., **de Arroyabe Fdez,** J.C.: Joint R&D projects: Experiences in the context of european technology policy. Technological Forecasting & Social Change, 73(7), 2006, pp. 860-85.

Arranz, N., **de Arroyabe Fdez,** J.C.: Can innovation networks projects result in efficient performance?. Technological Forecasting & Social Change, 79, 2012, pp. 485-97.

Aryee, G., **Naim,** M.: Supply chain integration using a maturity scale. Journal of Manufacturing Technology, 19(5), 2008, pp. 559-575.

Association of Project Management (APM), Body of Knowledge (BoK). Revised January 1995, version 2.

Ayers, J.B.: Supply Chain Project Management: A structures collaborative and measurable approach. St. Lucie Press, 2004.

Ayers, J.B.: Handbook of Supply Chain Management. Auerbach Publications, 2006.

Bain, M., **Bowen,** J.: The role of information technology in international business research, in Roche, E. and Blaine, M. (Eds), Information Technology in Multinational Enterprises: New horizons in international business. Northampton, MY: Edward Elgar, 2000.

Baker, G.: The effects of synchronous collaborative technologies on decision making: A study of virtual teams. Information Resources Management Journal, 2002, 15(4), p.p.79–93.

Bal, J., **Foster,** P.: Managing the virtual team and controlling effectiveness. International Journal of Production Research, 38(17), 2000, pp. 4019-4032.

Ballou, R. H.: The evolution and future of Logistics and Supply Chain Management. European Business Review, 19(4), 2007, pp. 332-348.

Bahinipati, B.K., **Kanda**, A., **Deshmukh**, S.G.: Horizontal collaboration in semiconductor manufacturing industry supply chain: An evaluation of collaboration intensity index. Computers & Industrial Engineering, 12 March, 2009, pp. 880-95.

Barhand, I., **Krishnan**, V.V., **Lin**, S.: Team dispersion, information technology, and project performance, production and operation management, 2012, p.p. 1-16. DOI:10.11111/j..1937-5956.2012.01366.x

Barratt, M, **Oliveira**, A.: Exploring the experiences of collaborative planning initiatives. International Journal of Physical Distribution & Logistics Management, 31(4), 2001, pp. 266-289.

Barratt, M,.: Positioning the role of Collaborative Planning in Grocery Supply Chains. International Journal of Logistics Management, 14(2), 2003, pp. 53-66.

Basu R.: Managing project supply chains: Advances in Project Management. Gover Publishing Limited, 2011, ISBN: 978-1-4094-2515-1.

Bell, B. S., **Kozlowski**, S. W. J.**:** A typology of virtual teams. Group & Organization Management, 2002, 27, p.p. 14-49.

Bellamy M.A., **Basole** R.C.: Network analysis of Supply Chain Systems: A systematic review and future research. Wiley Online Library, 2012, DOI 10.1002/sys.21238.

Besag, J.**:** Statistical analysis of non-latticce data. Journal of the Royal Statistical Society. Series D (The statistician), 24(3), 1975, p.p. 179-959.

Bitici, U.S., **Martinez**, V., **Albores**, P., **Parung**, J.: Creating and managing value in Collaborative Networks. International Journal of Physical Distribution & Logistics Management, 34 (3/4), 2004, pp. 251.

Bitici, U.S., **Butler**, P., **Cahill**, W., **Kearney**, D.: Collaboration: a key competence for competing in the 21st century. Supply chain Perspectives, 10 (1), 2009, pp. 24-33.

Blondel, V.D., **Guillaume** J-L., **Lambiotte** R., **GLefebvre** E.: Fast unfolding of communities in large networks. Journal of Statistical Mechanics. Theory and Experiments. 10: P10008, 2008.

Borgatti, S.P., **Li,** X.: On social network analysis in a Supply Chain. Journal of Supply Chain Management, Spring, 2009.

Bouas, K. S., **Arrow,** H.: The development of group identity in computer and face-to-face groups with membership change. Computer Supported Cooperative Work, 1996, 4, p.p. 153-178.

Bourgault, M., **Drouin**, N., **Hamel**, E.: Decision-making within distributed project teams: an exploration of formalization and autonomy as determinants of success. Project Management Journal, 39(S97-S110), 2008, pp. 97-110.

Bowersox, D.J., **Closs**, D.J., **Stank**, T.P.: How to master cross-enterprise collaboration, Supply Chain Management Review, 7(4), 2003, pp. 18.

British Standard in Project Management 6079, ISBN 0 58025594 8.

Burke, R.: Project management: Planning and control techniques. John Wiley and Sons, Chichester, 1993. ISBN W71-98762-X.

Cai S., **Jun** M., **Yang** Z.: Implementing Supply Chain information integration in China: The role of institutional forces and trust. Journal of Operations Management, 28(3), 2010, p.p. 257-268.

Camarinha-Matos, L M., **Afsarmanesh**, H.: Collaborative Networks: Formal modelling methods for collaborative networks, In Collaborative Networked Organizations: a research agenda for emerging business models, Edited by: **Camarinha-Matos,** L M., **Afsarmanesh**, H., Kluwer Academic Publishers, Boston, 2004, pp. 237-244. ISBN 1-4020-7833-1.

Camarinha-Matos, L M., **Afsarmanesh**, H.: Collaborative Networks: A new scientific discipline. Journal of Intelligent Manufacturing, 16 (4-5), 2005, pp. 439-452.

Camarinha-Matos, L M., **Afsarmanesh**, H.: Collaborative Networks: Value creation in a Knowledge Society, In Proceedings of PROLAMAT'06 (Springer), Shanghai, China, 14-16 Jun 2006.

Cameron, J.: Ten concepts for an eBusiness collaborative project management framework. In Proceedings of the 18th Bled eConference eIntegration in Action, 2005, Slovenia, June 6-8.

Chen, F., **Tucson,** A.Z., **Nunamaker** J.F., **Romano, N.C.**: A collaborative project management architecture. In Proceedings of the 36th Annual Hawaii International Conference on System Sciences. IEEE, Vol 12, Jan. 2003, pp. 6-9. doi: 10.1109/HICSS.2003.1173655

Chutnik, M., **Grzesik,** K.: Leading a virtual intercultural team. Implications for virtual team leaders. 1(1), 2009, pp. 82-90.

Christopher, M. L..: Logistics and Supply Chain Management. London: Pitman Publishing, 1992.

Christopher, M. L..: Logistics and Supply Chain Management. Person Education Limited, fourth edition, 2011.

Clark, C.: The impact of deadline reminders on task efficiency in project management: A Q methodology study. UMI/ProQuest LLC(Ann Arbor, MI), 2008, pp. 48.

Collins English Dictionary - Complete & Unabridged 10th Edition. HarperCollins Publishers. Available at http://dictionary.reference.com/browse/collaborate, last accessed date, September 2015.

Cranmer, S.J, **Desmarais**, B.A.: Inferential network analysis with Exponential Random Graph Models. Political Analysis, 19, 2011, pp. 66-86, doi: 10.1093/pan/mpq037.

Crawford, J.K.: Project Management Maturity Model: Providing a proven path to project management excellence. Project management Solutions, Inc, Pennsylvania, 2002.

Crawford, J.K.: Project Management Maturity Model. Project Management Solutions, Inc, CRC Press, Taylor and Francis Group, 2015, third edition.

Crosby, F.: Quality is free: The art of making quality certain. New York: McGraw-Hill. 1979, ISBM 0-07-014512-1.

Crum, C**., Palmatier**, G.E.: Demand collaboration: What's holding us back?. Supply Chain Management Review, 8(1), 2004, pp. 54-61.

Cox, A., **Sanderson**, J., **Watson**, G.: Supply Chain and power regimes: Toward and analytical framework for managing extended networks of buyer and supplier relationships. Journal of Supply Chain Management, 37(2), 2001, pp. 28-35.

Council of Supply Chain Management professionals (CSCMP).: CSCMP Supply Chain Management definitions. Council of SCM Professionals. Available at https://cscmp.org/about-us/supply-chain-management-definitions, last accessed date, September 2015.

Curtis, B**., Alden**, J.: The Business Process Maturity Model (BPMM): What, why and how, BP Trends, 2007, February.

De Dreu, C.K.W., **Weingart**, L.R.: Task versus relationship conflict: team performance, and team member satisfaction: A meta-analysis. Journal of Applied Psychology, 88(4), 2003, pp. 741-749.

De la Haye K., **Robins** G., **Mohr** P., **Wilson** C.: Obesity-related behaviours in adolescent friendship networks. Elsevier B.V., 32/3, 2010, p. 161-167. doi:10.1016/j.socnet.2009.09.001

Denison, D.R., **Stuart**, L.H., **Kahn**, J.A.: From chimneys to cross-functional teams: Developing and validating a diagnostic model. Academy of Management Journal, 39(4), 1996, pp. 1005-1023.

Diehn, D.: Seven steps to build a successful collaborative forecasting process. The Journal of Business Forecasting Methods & Systems, 19(4), Winter 2000/2001, pp. 23, 28-9.

Disney, M, **Towill**, D.: The effect of Vendor Managed Inventory (VMI) dynamics on the Bullwhip Effect in Supply Chain. International Journal of Production Economics, 85, 2003, pp. 199-215.

Drouin, N., **Bourgault**, M., **Gervais**, C.: Effects of organizational support on components of virtual project teams, International Journal of Managing Projects in Business, 2010, 3(4), pp. 625-641.

Drouin, N., **Bourgault**, M.: How organizations support distributed project teams. Journal of Management Development, 32(8), 2013, pp. 865 – 885. DOI: 10.1108/JMD-07-2012-0091

Duarte, D. L., **Snyder**, N. T.: Mastering Virtual Teams: Strategies, tools and techniques that succeed, Jossey-Bass, San Francisco, CA, 2nd ed., 2001.

Duffy, R.S.: Towards a better understanding of partnership attributes: An exploratory analysis of relationship type classification. Industrial Marketing Management, Vol. 37, 2008, pp. 228-244.

European Collaborative Networked Organizations Leadership Initiative. ECOLEAD Consortium.: A reference model for Collaborative Networks. Edited by UNINOVA and UvA, 2007.

Eggert, A. : The role of communication in virtual Teams. Virtual Organization Net. 32(4), 2001, p.p. 20-28. Available at htpp://www.virtual-organizations.net/files/articles/eggert.pdf, last accessed date, September 2015.

Ehrlich, K., **Carboni**, I.: Inside Social Network Analysis. Boston College, 2005.

Ellram, L.M., **Edis**, O.R.V.: A case study of successful partnering implementation. International Journal of Purchasing and Materials Management. 32(4), 1996, pp. 20-28.

Eppinger, S. D., **Chitkara**, A. R.: The new practice of global product development. MITSloan Management Review, 1, 2009.

Frazier, G.L., **Rody**, R.C.: The use of influence strategies in interfirm relationships in industrial product channels. Journal of Marketing 55(1), 1991, pp. 52–69.

Fienberg, S.E., **Meyer**, M.M., Wasserman, S.: Statistical analysis of multiple sociometric relations. Journal of the American Statistical Association, 80(39), 1985, pp. 51-57.

Fink, L.: Coordination, learning, and innovation: the organizational roles of e-collaboration and their impacts. International Journal of e-Collaboration, 2007, 3 (3), pp. 53-70.

Finley, F., **Srikanth**, S.: 7 imperatives for successful collaboration. Supply Chain Management Review, 9(1), 2005, pp. 30-7.

Fiorito, S.S., **May**, E.G., **Straughn** K.: Quick response in retailing: Components and implementation. International Journal of Retail & Distribution Management, 23(5), 1995, pp. 12-21.

Fitterer, R., **Rohner,** P.: Towards assessing the networkability of health care providers: A maturity model approach. Springer-Verlag, 2009.

Franz, O., **Strauss, D**.: Markov graphs. Journal of the American Statistical Association, 81(395), 1986, pp. 832-42.

Freeman, L.C.: Graphic techniques for exploring social network data sets. In Models and methods in social network analysis, Edited by: **Carrington,** P.J., **Scott**, J., **Wasserman**, S., Cambridge University Press, Cambridge, 2005, pp. 248-269. ISBN-13 978-0-511-11103-7.

Gartner.: Gartner says Social Network Analysis can help enterprises achieve a pattern–based strategy™ that leverages relationship information, 2009. Available at http://www.gartner.com/newsroom/id/1239913, last accessed date, October 2015.

Gartner.: Gartner reveals five social software predictions for 2010 and beyond, 2010. Available at http://www.gartner.com/newsroom/id/1293114, last accessed date, October 2015.

Geyer, C. J., **Thompson**, E. A.: Constrained Monte Carlos maximum likelihood for dependent data. Journal of the Royal Statistical Society Series, B54(3), 1992, pp.657-99.

Ganesan, S.: Determinants of long-term orientation in buyer–seller relationships. Journal of Marketing, 58(2), 1994, pp.1–19.

Global Commerce Initiative (GC1).: Global Commerce Initiative recommended guidelines**:** Collaborative Planning, Forecasting and Replenishment (CPFR®), as approved by the Voluntary Interindustry Commerce Standards (VICS) Association, version 2.0, 2002.

Gattorna, J.L., **Walters**, D.W.: Managing the Supply Chain. Macmillan, Basingstoke, 1996.

Geyskens I., **Steenkamp** J-B., **Scheer** L.K., **Kumar** N.: The effects of trust and interdependence on relationship commitment: A Trans-Atlantic study. International Journal of Research in Marketing. Vol.13, 1996, pp. 303-317**.**

Gibson C.B., **Cohen** S.G.: Virtual teams that work: creating conditions for virtual team effectiveness. Published by Jossey-Bass. 2003

Giesen G.: Creating Collaboration: A process that works!. Greg Giesen & Associates, Inc. 2002.

Gratton L., **Erickson** T.J.: Eight ways to build Collaborative Teams. Hardware Business Review. Nov, 2007.

Goffin, K., **Lemke**, F., **Szwejczewski**, M.: An exploratory study of „close" supplier-manufacturer relationships. Journal of Operations Management, 24(2), 2006, pp. 189-209.

Goodreau, S.M.: Advances in Exponential Random Graph (p*) Models applied to a large social network. Soc Networks**,** 29, 2007, pp. 231–248.

Goodreau, S.M., **Handcock**, M. S., **Hunter**, D. R., **Butts,** C. T., **Morris**, M.: A statnet tutorial. Journal of Statistical Software**,** 24/9, 2008.

Goodreau, S.M., **Butts,** C.T., **Krivitsky**, P.N., **Carnegie**, N.B., **Handcock**, M.S., **Hunter**, D.R., **Morris**, M.: Introduction to exponential-family random graphs (ERG or p*) modeling with statnet. INSNA Sunbelt**,** St. Pete Beach, Florida, 2011.

Golicic, S.L., **Foggin**, J.H., **Mentzer,** J.T.: Relationship magnitude and its role in inter-organizational relationship structure. Journal of Business Logistics. 24(1), 2003, p.p. 57-75.

Golicic, S.L., **Mentzer,** J.T.: Exploring the drivers of inter-organizational relationship magnitude. Journal of Business Logistics. 26(2), 2005, p.p. 47-71.

Gonzales, N., **Marle,** F., **Bocquet,** J.C.: Measuring project maturity: Example in a French automotive organization. In Proceedings of the International Conference on Engineering Design, ICED'07. 2007.

Gruat La Forme, F.-A, **Genoulaz,** V.B., **Campagne** J.-P.: A framework to analyse collaborative performance. Computers in industry. Vol. 58, 2007, pp. 687-697.

Gunasekaran, A., **Patel**, C., **Tirtiroglou**, E.: Performance measure and metrics in a supply chain environment. International Journal of Operations & Production Management, 21(1/2), 2001, pp. 71-87.

Häkansson, H.; **Snehota**, I.: Developing relationships in business networks. First edition, printed by Routledge: London, 1995.

Hammer, M.: The process audit. Harvard Business Review, 2007, April.

Hammer, M., **Stanton,** S.: How processes enterprise really work. Harvard Business Review, 77(6), 1999, pp. 108-18.

Handcock, M.S., **Hunter**, D.R., **Butts,** C.T., **Goodreau**, S.M., **Krivitsky**, P.N., **Morris**, M., **Wang** L., **Kirk**, L.: Fit, simulate and diagnose exponential-family models for networks, 2015. Available at https://statnet.org/trac/wiki/Resources, last accessed date, February 2016.

Harland, C., **Lamming,** R., **Zheng,** J., **Johnsen,** T.: A Taxonomy of Supply Networks. Journal of Supply Chain Management, Fall, 2001, pp. 21-27.

Harrigan N., Exponential Random Graph (ERG) models and their application to the study of corporate elites. Oxford UK: Center for research methods in the social sciences, Department of Politics and International Relations, University of Oxford, 2009.

Harris, J., **Swatman,** P., **Kurnia,** S.: Efficient Consumer Response (ECR): a survey of the Australian Grocery Industry. Supply Chain Management, 4(1), 1999, pp. 35-42.

Hartono, E., **Holsapple** C.: Theoretical foundations for collaborative commerce research and practice. Information Systems and e-Business Management, 2(1), 2004, pp. 1-30.

Heide, J.B., **John,** G.: Alliances in industrial purchasing: The determinants of joint action in buyer-supplier relationships, Journal of Marketing Research, 27(1), 1990, pp. 24-36.

Hennttonen, K., **Blomqvist,** K.: Managing distance in a global virtual team: The evolution of trust through technology-mediated relational communication. Strategic Change, 14(2), 2005, pp. 107-119.

Holmlund, M., **Törnroos,** J.-Åke.: What are relationships in business networks?. Management Decision, 35(4), 1997, pp. 304–309.

Holland PW., **Leinhardt** S.: An exponential family of probability distributions for directed graphs: Rejoinder. Journal of the American Statistical Association. 76(373), 1981, pp. 62-65.

Hossain, L., **Wigand** R.T.: Knowledge sharing through social networks. In Proceedings of the SOTICS 2012: The Second International Conference on Social Eco-Informatics, 2012.

Houlihan, J.: Supply Chain Management. In Proceedings of 19th International Technical Conference, BPICS, 1984, pp. 101-110.

Horvath, L.: Collaboration: the key to value creation in Supply Chain Management. Supply Chain Management: An International Journal, 6(5), 2001, pp. 205-07.

Hrebiniak, L.G.: Effects of job level and participation on employee attitudes and perception of influence. Academy of Management Journal. Vol. 17, 1990, pp. 649-62.

Hsien, Y., **Kruchten,** P., **MacGregor,** E.: Matching expectations: when culture wreaks havoc with Global Software Development. Electrical and Computer Engineering. University of British Columbia, 2008.

Hunter DR., **Goodreau** SM., **Handcock** MS.: Goodness of fit of Social Network Models. J Am Stat Assoc. 103(481), 2006, pp. 248–58.

Hunter DR., **Handcock** MS., **Butt** CT., **Goodreau** SM., **Morris** M. (2008): ERGM: A package to fit, simulate and diagnose Exponential-Family Models for Networks. Journal of Statistical Software, 24(3), 2008.

Huxham C., **Vangen** S.: Managing to collaborate: The theory and practice of collaborative advantage. New York: Free Press, 2005.

InnoSupport.: Supporting innovation in SMEs, Education and Culture. Leonardo da Vinci Pilot Projects, 2009, available at http://www.innosupport.net/index.php?id=2362&L=10, last accessed date, November 2015.

Ireland, R., **Bruce**, R.: CPFR Only the beginning of collaboration. Supply Chain Management Review, Vol Sept/Oct, 2000.

Jarvenpaa, S., **Shaw,** T.R.: Global virtual teams: integrating models of trust. In Sieber, P. and Griese, J. (Eds), Organizational virtualness. Bern: Simowa Verlag, 1998, pp. 35-53.

Jap, S.D., **Ganesan**, S.: Control mechanisms and the relationship life cycle: Implications for safeguarding specific investments and developing commitment. Journal of Marketing Research, 37(2), 2000, pp. 227–245.

Jaruzelski, B., **Dehoff**, K.: Beyond borders: The Global Innovation 1000, Strategy + Business, 53, winter, 2008, pp. 52-68.

Jasny, L, **Acton**, R. M.: Moving beyond Descriptives: An introduction to basic network statistics with statnet. In Proceedings of the Sunbelt Social Network Conference, Redondo Beach, California, 2012.

Jones, T. C., **Riley**, D. W..: Using Inventory for Competitive Advantage through Supply Chain Management, International Journal of Physical Distribution and Materials Management, 1985, 15(5), pp. 16-26.

Jonsson, N., **Novosel**, D., **Lillieskold** J., **Eriksson M**.: Successful management of complex, multinational R&D projects. In J. Ralph H. Sprague, (Eds.). In Proceedings of the Thirty-Fourth Annual Hawaii International Conference on Systems Sciences. “001. Maui, Hawai’i: IEEE computer Society Press, 2001.

Kahn, K.B., **Maltz**, E.N., **Mentzer**, J.T.: Demand collaboration: effects on knowledge creation, relationships, and supply chain performance. Journal of Business Logistics, 27(2), 2006, pp. 191-221.

Kanter, R.M.: Collaborative advantage: The art of alliances. Hardware Business Review, 72(4), 1994, pp. 96-108.

Kayworth, T., **Leidner**, D.: The global virtual manager: A prescription for success. European Management Journal, Vol 18, 2000, pp. 183-194.

Knoke, D., **Yang,** S.: Social Network Analysis. Series: Quantitative Applications in the Social Sciences, SAGE Publications, second edition, 2008, ISBN 978-1-4129-2749-9.

Krajewski, L.J., **Ritzman**, L.P., **Malhotra**, M.K.: Operations Management: Process and value chain, 8th Edition, Person Education, 2007.

Kratzer, J., **Leenders**, R.Th.A.J., **van Engelen**, J.M.L.: A social network perspective on the management of product development programs. Journal of High Technology Management Research, 20, 2009, pp. 169-81.

Krause, D.R., **Handfield**, R.B., **Tyler**, B.B. (2007): The relationship between supplier development, commitment, social capital accumulation and performance improvement. Journal of Operations Management. Vol. 25, pp. 528–545.

Kurt Salmon Associates, Efficient Consumer Response: Enhancing consumer value in the Grocery Industry. Food Marketing Institute, Washington , DC., January 1993.

Kwak, Y.H., **Ibbs**, W.: The Berkeley Project Management Process Maturity Model: Measuring the value of PM. IEEE, 2000.

Kwak, Y.H., **Ibbs**, W.: Project Management Process Maturity (PM)^2. Journal of Management in Engineering, 2002.

La Londe, B. J., **Masters**, J. M.: Emerging logistics strategies: Blueprints for the next century. International Journal of Physical Distribution and Logistics Management, 24(7), 1994, pp. 35-47.

Lambert, D. M., **Emmelhainz**, M. A., **Gardner**, J. T.: Developing and implementing Supply Chain partnerships. The international Journal of Logistics Management, 7 (2), 1996, pp. 1-18.

Lambert, D. M., **Cooper**, M. C., **Pagh**, J. D.: Supply Chain Management: Implementation issues and research opportunities. The international Journal of Logistics Management, 9 (2), 1998.

Lambert, D.M., **Emmelhainz**, M.A., **Gardner**, J.T.: Building successful partnership. Journal of Business Logistics, 20(1), 1999, pp. 165-81.

Lambert, D.M., **Knemeyer**, A.M.: We're in this together. Harvard Business Review, 82(2), 2004, pp.114-22.

Lazer, D., **Katz**, N.: Building effective intra-organizational networks: the role of teams. MIT Libraries, Center for Public Leadership Working Paper Series. 03/03, 2003, pp.114-22. Available at: http://hdl.handle.net/1721.1/55801, last accessed date, November 2015.

Lee, H.L., **Billington**, C.: Material management in decentralized Supply Chains. Operations Research, 41(5), 1993, p.p. 835-847.

Lee, H.L., **Lee**, C.Y.: Building Supply Chain excellence in emerging Economies. Chapter 1: Kouvelin P., Niederhoff. J.: On the globalization of operations and Supply Chain strategies, Springer Science, 2007, pp. 3-36, ISBN-10: 0-387-38428-6.

Loeser, B.O.: How to set up a Cooperation Network in the production industry: Example of the Huber + Suhner AG, International Marketing Management, 28, 1999, pp. 453-465.

Lockamy III, A., **McCormackian,** K.: The development of a Supply Chain Management Process Maturity Model using the concept of Business Process Orientation. Supply Chain Management: An International Journal, Emerald Group Publishing Limited, 9(4), 2004.

Lohtia, R., **Tian Xie,** F., **Subramaniam,** R.: Efficient Consumer Response in japan industry concerns: Current status, benefits, and barriers to implementation, Journal of Business Research, 57, 2004, pp. 306-311.

Lummus, R., **Krumwiede,** D., **Vokurka,** R.: The relationships of Logistics to Supply Chain: developing a common industry definition. Industrial Management & Data Systems, 101(8), 2001, pp. 426-431.

Lurey, **J.** S., **Raisinghani**, M. S.: An empirical study of best practices in virtual teams. Information & Management, Vol. 38, 2001, pp. 523-544.

Lusher, D., **Koskinen**, J., **Robins**, G. : Exponential Random Graph Models for Social

Networks: Theory, methods and applications. New York: Cambridge University Press. Structural Analysis in the Social Sciences Series. 2013.

Maoz, Z., **Ranan**, D. K., **Lesley**, T., **Ilan**, T.: Structural equivalence an international conflict: A social network analysis. The Journal of Conflict Resolution, 50, 2006, pp. 664–89.

Martins, L. L., **Gilson**, L. L., **Maynard**, M. T.: Virtual teams: What do we know and where do we go from here?. Journal of Management, 30(6), 2004, pp. 805–835.

Martínez Sánchez A., Pérez Pérez M.: Supply chain flexibility and firm performance. International Journal of Operations & Production Management, 25/ 7, 2005, pp. 681 – 700.

Maznevski, M. L., Chudoba, K. M.: Bridging space over time: Global virtual team dynamics and effectiveness. Organization Science, Vol. 11, 2000, pp. 473-492.

McConachy, B., **Caine**, C.A.: Expedited communications for Dispersed Project Teams, In PMI Global Congress Proceedings, Seattle Washington, 2006.

McCormack, K., **Bronzo Ladeira**, M., **Valadares de Oliveira** M.P.: Supply Chain Maturity and performance in Brazil. Supply Chain Management: An International Journal, 13(4), 2008, pp. 272-82.

McKelvey, M., **Alm**, H., **Riccaboni**, M.: 2003. Does co-location matter for formal knowledge collaboration in the Swedish biotechnology-pharmaceutical sector? Research Policy, 32(3), 2003, p.p. 483–501.

McPherson M., **Smith-Lovin** L., **Cook** JM.: Birds of a Feather: Homophily in Social Networks, Annu. 'Rev. Sociol. 27, 2001, pp. 415-44

Magalhaes, A., **Mendes de Araujo**, R., **Marcos R.S.** B., Designing collaborative processes, In Proceedings of the 19th International Conference on Advanced Information System Engineering, CAiSE'07 & Tapir Academic Press, Trondheim, June, 2007. ISBN 978-82-519-2245-6.

Meisel-Donoso, C.A., **Zsifkovits**, H. E.: Collaboration relationships in logistics: A case of project management social network analysis, In Logistics Systems Engineering: 1. Wissenschaftlicher Industrielogistik-Dialog in Leoben, Edited by: **Zsifkovits**, H. E., **Altendorfer**, S., Rainer Hampp Verlag, München, Mering, 2013, pp. 151-166. ISBN 978-3-86618-858-7.

Mentzer, J.T., **Min**, S., **Zacharia,** Z.G.: The nature of interfirm partnering in Supply Chain Management. Journal of Retailing, 76(4), 2000, pp. 549-568.

Mettler, T.: A Design science research perspective on Maturity Models in Information Systems. Universität St. Gallen, St. Gallen, 2009.

Mejza, M. C, **Wisner,** J. D.: The Scope and Span of Supply Chain Management. International Journal of Logistics Management, 12(2), 2001, pp. 37-55.

Min, H., **Yu**, W., Collaborative planning, forecasting and replenishment: demand planning in Supply Chain Management. International Journal of Information Technology and Management, 7(1), 2008.

Min, S., **Roath**, A.S., **Daugherty**, P.J., **Genchev**, S.E., **Chen**, H., **Arndt**, A.D., **Richey**, G.R.: Supply Chain Collaboration: what is happening?. International Journal of Logistics Management, 16(2), 2005, pp. 237–256.

Mohammad Jafari, M., **Ahmed**, S., **Zawiah MD Dawal**, S.: The relationship between Project management and E-Collaboration. In proceedings of the 2010 International

Conference on Industrial Engineering and Operations Management. Dhaka, Bangladesh, January, 2010.

Mohr, J., **Fisher**, R.J., **Nevin**, J.R.: Collaborative communication in interfirm relationships: Moderating effects of integration and control. Journal of Marketing, 60(3), 1996, pp. 103-115.

Mohr, J. and **Spekman**, R.: Characteristics of partnership success: partnership attributes, communication behaviour, and conflict resolution techniques. Strategic Management Journal. Vol. 15, 1994, pp. 135–152.

Monezka, R., **Morgan,** J.: What's wrong with Supply Chain Management?. Purchasing 16, January, pp. 69-72, 1997.

Montoya-Weiss, M., **Massey**, A., **Song**, M.: Getting it together: Temporal coordination and conflict management in global virtual teams. Academy of Management Journal, Vol. 44, 2001, pp. 1251-1262.

Moorman, C., **Gerald** Z., **Rohit** D.: Relationships between providers and users of market research: The dynamics of trust within and between organizations. Journal of Marketing Research, Vol. 29, 1992, p p. 314-28.

Morgan R.M, **Hunt** S.D. (1994): The commitment – trust theory of relationship market. Journal of Marketing, Vol. 58, pp. 20-30.

Morris M., **Handcock** MS., **Hunter DR**.: Specification of Exponential-Family Random Graph Models: Terms and computational aspects. Journal of Statistical Software, 24(4), 2008.

Morris M., **Goodreau** S.: Exponential random graph models (ERGMs) using statnet. In Proceedings of the 1st European Conference on Social Network, 2014.

Morris, P.: The Management of Projects, Thomas Telford, 1997

Munns, Q.K., **Bjeirmi**, B.F.: The role of Project management in achieving project success. International Journal of Project Management. 14(2), 1996, pp. 81-87.

Nambisan, S., **Sawhney**, M.: A buyer's guide to the innovation Bazaar. Harvard Business Review, 85(6), 2007, pp. 109-118.

Narus, J.A., **Anderson,** J.C.: Rethinking distribution: adaptive channels, Harvard Business Review, 74(4), 1996, pp. 112-120.

Nidiffer, K.E., Dolan, D.: Evolving Distributed Project Management, IEEE Software, 22(5), 2005, pp. 63-72.

Nyaga G. N., **Whipple** J. M., **Lynch** D. F.: Examining supply chain relationships: Do buyer and supplier perspectives on collaborative relationships differ?. Journal of Operations Management, 28(2), 2008, pp.101-114.

Oisen, RP.: Can project management be defined?. Project Management Quarterly, 2(1), 1971, pp. 12-14.

Office of Government Commerce.: Portfolio, Program and Project Management Maturity Model (P3M3). AXELOS Limited 2013, 2013. Version 2.1.

Oliver, R. K., **Webber**, M. D.: Supply Chain Management: Logistics catches up with strategy, In: **M.** Christopher, Logistics: The Strategic Issues, Chapman and Hall, London, UK, 1992, pp. 63-75.

Pagell, M.: Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics. Journal of Operation Management, 22(5), 2004, pp. 459-87.

Park, C. H., **Fu**, I-Pang., **Park** T.H.: Social Network Analysis as a needs assessment tool for team building intervention. Academy of Human Resource Development, The Pennsylvania State University, 2013.

Paulk, MC., **Curtis**, B., **Chrissis**, MB, Weber, C.V.: Capability Maturity Model (SM) for software, version 1.1, CMU/SEI-93-TR-024, ESC-TR-93-177, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, 1993.

Parung, J., **Bitici**, U.S.: Measuring contribution in collaborative enterprises. In Proceedings of the European Operations Management Association, EurOMa'2005, United Kingdom, 2005, pp.19-21.

Pereira, K. A. A., **Rabelo**, R.J., **Ferreira**, C. A., **Spinosa**. L.M.: Managing Distributed Business Processes in the Virtual Enterprise. Journal of Intelligent Manufacturing, 12(2), 2001, pp. 185–197.

Pick, J.M., **Romano**, N.C., **Roztocki**, N.: Synthesizing the research advances in electronic collaboration: theoretical frameworks. International Journal of E-Collaboration, 5(1), 2008, pp. 1-12.

Prahalad, C.k, **Hammel**, G.: The core competence of the corporation. Harvard Business Review, May-June, 1990.

Project Management Institute, Inc.: A guide to the Project Management Body of Knowledge (PMBOK® Guide). Project Management Institute, Inc., Fourth Edition, 2008, ISBN: 978-1-933890-51-7.

Project Management Institute, Inc.: Organizational Project Management Maturity Model (OPM3): Knowledge foundation, Newtown Square, 2003, ISBN 1-930699-40-9.

Qureshi, S.: The Effects of electronic collaboration in distributed project management. Group Decision and Negotiation, Vol. 15, 2006, pp. 55–75.

Ring, P.S., **Van de Ven**, A.H.: Development processes of cooperative interorganizational relationships. Academy of Management Review, 19(1), 1994, pp. 90-118.

Robins G, **Snijders** T, **Wang** P, **Handcock** M, **Pattison** P. Recent developments in Exponential Random Graph (p*) Models for social networks. Social Networks. 2007A; 29: pp. 192-215.

Robins G, **Pattison** P, **Kalish** Y, **Lusher** D. An introduction to Exponential Random Graph (p*) Models for social networks. Social Networks, 9(2), 2007B, pp.173-191.

Rolfes, M. (2001): Virtual Project management. a term paper for MSIS 489. Available at htpp://www.umsl.edu/~sauterv/analysis/488_f01_papers/rolfes.htm, last accessed date, March 2016.

Ross D.F.: Competing through Supply Chain Management: Creating market-winning strategies thorough supply chain partnership. Springer Science + Business Media New York, 1998. DOI 10.1007/978-1-4757-4816-1

Rosemann, M., **De Bruin,** T.: Application of a holistic model for determining BPM Maturity. BP Trends, February, 2005.

Rozwell, C.: Using Social Network Analysis to inform a Pattern-Based Strategy. 2009 Gartner, Inc. and/or its Affiliates. 2009 Stamford.

Sabath,, **Autry,** R. E., **Chad, W**.: Automatic Replenishment Programs: The impact of organizational structure. Journal of Business Logistics, 22 (1), 2001, pp. 91-105.

Sagawa, S., Segal E.: Common interest, common good: Creating value through business and social sector partnership. Boston: Harvard Business School Press, 2000.

Saha, P.: Factors influencing broad based CPFR Adoption. CPFR® Committee - Academic Papers, 2003, available at https://www.yumpu.com/en/document/view/8115613/factors-influencing-broad-based-cpfr-adoption-vics, last accessed date, October 2015.

Sandhoff, G.: Virtual Organizations as a power-asymmetrical networks. Project Management Journal. March, 2000, pp. 24-34.

Santanen E., **Kolfsschoten** G., **Golla K.**: The Collaboration Engineering Maturity Model, In Proceeding of the 39th Hawaii international Conference on System Sciences, 2006.

Sanders, N.R., **Premus**, R.: Modeling the relationship between firm it capability, collaboration, and performance. Journal of Business Logistics, 26(1), 2005, pp. 1.

Sari, K.: On the benefits of CPFR and VMI: a comparative simulation study. International Journal of Production Economics, Vol. 113, 2008, pp. 575-586.

Saunders, M.: Strategic purchasing and Supply Chain Management. Pitman, London, UK, 1994.

Schroeder, R., **Rungtusanatham**, M.J., **Goldstein**, S.: Operations Management in the Supply Chain: Decisions and Cases, 6th edition, McGraw-Hill/Irwin, 2012. ISBN-13: 978-0073525242.

Schweitzer, L.: Understanding virtual team effectiveness: An exploration, doctoral thesis, Carleton University, Ottawa, ON, 2005.

Scott, J.: Social Network Analysis: A Handbook. Second edition. London, Sage Publications, 2000.

Seifer, D.: Collaborative Planning, Forecasting and Replenishment: How to create a Supply Chain advantage. American Management Association, 2003. ISBN-0-8144-7182-x.

Sheffi, Y.: The value of CPFR. In RIRL Conference Proceedings, Lisbon, Portugal, October 13-16, (2002).

Shuman, J., **Twombly** J.: The real power of Collaboration. In White Paper Series. The Rhythm of Business®, Vol. 9, 2009.

Shuman, J., **Twombly** J.: Collaborating to win: Measuring collaborative ability. In White Paper Series, The Rhythm of Business®, Vol. 11, 2010, pp. 1-19.

Simatupang T., Sridharan R.: The collaborative Supply Chain. The International Journal of Logistics Management, 13(1), 2002.

Simatupang T., Sridharan R.: The Collaboration index: a measure for supply chain collaboration, International Journal of Physical Distribution and Logistics, 31(1), 2005, pp. 44-62. http://dx.doi.org/10.1108/09600030510577421.

Simpson, J. A., **Weiner**, E.S.C., The Oxford English Dictionary. Oxford University Press, Oxford, UK , 1989. Cited in Mettler (2009).

Smith, M.A., **Shneiderman** B., **Natasa** M-F.: Analyzing (social media) networks with NodeXL, 255. In Proceedings of the Fourth International Conference on communities and Technologies, 2009.

Snijders, T.A.B.: Markov Chain Monte Carlo estimation of Exponential Random Graph Models. ICS, Department of Statistics and Measurement Theory, University of Groningen, 2002.

Snijders, T.A.B., **Pattison**, P.E., **Robins**, G.L., **Handcock**, M.S.: New specifications for Exponential Random Graph Models. Sociological Methodology, 36, 2006, pp.99-153

Spencer-Oatey, H.: Culturally speaking: Managing rapport through talk across cultures. New York: Cassel, 2000.

Speakman, R.E., **Kamauff**, J.W., **Myhr**, N.: An empirical investigation into Supply Chain Management: A perspective on partnerships. Supply Chain Management: An international Journal, 3(2), 1998, pp. 53-67. http://dx.doi.org/10.1108/13598549810215379.

Stank, T.P., **Goldsby**, T.J., **Vickery**, S.K., **Savitskie**, K.: Logistics service performance: estimating its influence on market share. Journal of Business Logistics, 24(1), 2003, pp. 27-56.

Steglich, C.E.G., **Snijders**, T.A.B., **Pearson**, M.A.: Dynamics networks and behaviour: Separating selection from influence. Social Methodology, 40, 2010, pp. 329-93

Stevens, G. C.: Integrating the Supply Chain. International Journal of Physical Distribution and Materials Management, 19(8), 1989, pp. 3-8.

Stock, J-R., **Lambert**, D. M.: Becoming a “World Class” company with Logistics Service Quality. International Journal of Logistics Management, 31(1), 1992, pp. 73–81.

Subramani, M.R., **Venkatraman**, N.: Safeguarding investments in asymmetric interorganizational relationships: Theory and evidence. The Academy of Management Journal, 46(1), 2003, pp. 46–62.

Supply Chain Council.: Supply Chain Operations Reference Model. Supply Chain Council, 2010, ISBN 0-615-202594.

Svensson, G.: Efficient Consumer Response – its Origin and evolution in the history of marketing. Management Decision, 40(5) (2002a)

Svensson, G.: A firm’s driving force to implement and incorporate a business philosophy into its current business activities: the Case of ECR, European Business Review, 14 (1), 2002, pp. 20-29.

The Advisory Board.: Managing core competencies of the corporation, 1996, available at http://www.orgnet.com/OrgNetMap.pdf, last accessed date, March 2016.

Thomson, A.M., **Perry**, J.L.: Collaboration Processes: Inside the black box. Public Administration Review. December, special Issue, 2006.

Turner, JR.: The Handbook of Project-Based Management: Leading strategic change in organizations, 3rd edition, 2008, Mc Graw-Hill.

Toiviainen, T., **Hansen,** T. : Collaborative Planning, Forecasting, and Replenishment. Operation Consulting, spring, 2011.

Upton, D.: The management of manufacturing flexibility, California Management Review, 36(1), 1994, pp.72–89.

Van Duijn, M. A. J., **Gile**, K. J., **Handcock**, M. S.: A framework for the comparison of maximum pseudo-likelihood and maximum likelihood estimation of exponential family random graph models. Soc Networks 31(1), 2009, pp.52–62.

Vanpoucke, E., **Vereecke**, A.: Creating successful collaborative relationships. FalculteitEconomie En Bedrijfskunde. Vol. 488, Universiteit Gent, 2007.

Vereecke, A., **Muylle**, S.: Performance improvement through supply chain collaboration in Europe. International Journal of Operations & Production Management, 26(11), 2006, pp. 1176-98.

VICS, Roadmap to CPFR: The case studies. Voluntary Interindustry Commerce Standards, 1999, available at http://www.gs1us.org/industries/apparel-general-merchandise/workgroups/cpfr, last accessed date, October 2015.

VICS, CPFR Guidelines, Voluntary Interindustry Commerce Standards. Collaborative Planning, Forecasting and Replenishment (CPFR®): An Overview, 2004, available at http://www.gs1us.org/industries/apparel-general-merchandise/workgroups/cpfr, last accessed date, October 2015.

Vieira, J., **Yoshizaki**, H., **Ho**, L.: Collaboration intensity in the brazilian supermarket retail chain. Supply Chain Management: An International Journal, 14(1), 2009, pp. 11-21.

Wang, G.: Social Network Analysis of big data to improve marketing performance. Business 2 Community, July, 2012.

Available at http://www.business2community.com/marketing/social-network-analysis-of-big-data-to-improve-marketing-performance-0212081#rPjA7yQhUsgkO1X3.97, last accessed date, November 2015.

Wasserman, S., **Faust** K.: Social Network Analysis: methods and applications. Cambrige University Press. New York, NY, 1994.

Wasserman, S., **Pattison**, P.: Logit Models and Logistic Regression for social networks: An introduction to Markov Graphs and p*. Psychometrika 61, 1996, pp. 401-425.

Wasserman, S., **Robins**, G.: An introduction to random graphs, dependence graphs, and p*. In: Carrington, P., Scott, J., Wasserman, S. (Eds.), Models and Methods in Social Network Analysis. Cambridge University Press, New York, 2005, pp. 148-61.

West, M.A.: Effective teamwork: Practical lessons from organizational research. Blackwell Publishing, Oxford, 2004.

Williams, P. (2002): The competent Boundary Spanner. Public Administration, 80(1), p.p. 103-124.

Willcocks, L.P.: How corporations E-Source: From business technology projects to value networks. Information Systems Frontiers, C Kluwer Academic Publishers, 5(2), 2003, pp.175–193, Manufactured in the Netherlands.

Winkler, R.: Keywords and definitions around "Collaboration". SAP Design Guild, Edition 5(12), 2002.

Xu, L.: Supply Chain coordination and cooperation mechanisms: An attribute-based approach. The journal of Supply Chain Management: A global Review of Purchasing and Supply Copyright. February, 2006, p.p. 4-12.

Yao, Y., **Evers,** P., **Dresner,** M.: Supply Chain Integration in Vendor-Managed Inventory, Decision Support Systems, 43, 2007, pp. 663-674.

Yu, H., **Zeng,** A., **Zhao,** L.: Analyzing the evolutionary stability of the Vendors-Managed Inventory Supply Chains. Computers & Industrial Engineering, 56, 2009, pp. 274-282.

Yu, M.Y., **Lang**, K.R., **Kumar**, N.: Internationalization of online professional communities:

An empirical investigation of AIS-IS World. International Journal of E-Collaboration, 5(1), 2009, pp. 13-31.

Zhang, Q., **Vonderembse**, M.A., **Lim**, J.S.: Manufacturing flexibility: defining and analyzing relationships among competence, capability and customer satisfaction. Journal of Operation Management, 21(2), 2003, pp. 173-91.

Zaheer, A., **McEvily**, B., **Perrone**, V.: Does trust matter? Exploring the effects of interorganizational and interpersonal trust on performance, organization science, 9(2), 1998, pp. 141-159.

Zigurs, I.: Leadership in virtual teams: Oxymoron or opportunity? Organizational Dynamics, Vol. 31, 2003, pp. 339-351.

Zwikael, O.: Top management involvement in Project management: A cross country study of the software industry. International Journal of Managing Projects in Business, 1(4), 2008, pp. 498-511.

8 Appendix

8.1 Appendix 1: Project Categorization According to ABC Classification

In this appendix the project categorization for the other two case studies used in this research is presented.

8.1.1 Case Study B – Standard Project

Project Categorization								
Customer:	002*			***Start Date:***			21.11.11	
Project's Name:	Project B			***Finalization Date***			30.10.12	
Project's Number:	0002			***Project Manager:***			Node (1)	
Country	Brazil			***Communication Language:***			English	
Short description:	Upgrade of an existing warehouse solution in a greenfield location in the north of Brazil. It concerns to the supply and installation of new picking station for Pick to Light technology as described in the commercial offer and approved Layout.							
Categorization	**48**			**A - Project (Large-Scale Project)**				**up 60**
				B - Project (Standard Project)				**35 - 60**
				C - Project (Small Project)				**15 - 34**
Evaluation Criteria	**3 Points**		**2 Points**		**1 Point**		**Weights**	**Sums**
- Order Size	> 2,5 Mio €		1 Mio € - 2,5 Mio €		0,25 Mio€ -1 Mio €	x	5	5
- Estimated profit	<5%		<10%		>10%	x	1	1
- New Development / New product	substantial/ significant	x	negligible		none	x	3	9
- Estimated proportion of integration (with third party suppliers)	> 20%		5% bis 20%	x	< 5%		2	4
- Country / Industry risk	high		medium	x	low		2	4
- Credit / Currency / Payment risk	yes		no		none	x	1	1
- Critical project workflow	yes		no		none	x	2	2
- Deadline pressure / operational urgency	high		medium		low	x	2	2
- Mann hours	>10.000		< 10.000		<3000	x	2	2
- Strategic Importance	high		medium		low	x	1	1
- General Contractor	yes				no	x	3	3
- Complexity	Many parts and many processes		Many parts or many processes		Few parts and few processes	x	3	3
- Strategic customer	yes	x	no		no		2	6
- Reference for new products	yes		no		no	x	2	2
- Industry/Market Development	yes	x	no		no		1	3

8.1.2 Case Study C – Small Project

Project Categorization			
Customer:		***Start Date:***	05.06.14
Project's Name:	Project C	***Finalization Date***	10.11.14
Project's Number:	0003	***Project Manager:***	Node 25
Country	Spain	***Language:***	Spanish
Short description:	Software actualization for an existing Warehouse locate in close proximity of Madrid- Spain. It concerns of an upgrade of the database and operating system of the existing Warehouse Control system under virtual basis.		

Categorization	**27**			**A - Project (Large-Scale Project)**				**up 60**
				B - Project (Standard Project)				**35 - 60**
				C - Project (Small Project)				**15 - 34**
Evaluation Criteria	**3 Points**		**2 Points**		**1 Point**		**Weights**	**Sums**
- Order Size	> 2,5 Mio €		1 Mio € - 2,5 Mio €		0,25 Mio€ -1 Mio €		5	1
- Estimated profit	<5%		<10%		>10%	x	1	1
- New Development / New product	substantial/ significant		negligible		none		3	1
- Estimated proportion of integration (with third party suppliers)	> 20%		5% bis 20%		< 5%		2	1
- Country / Industry risk	high		medium		low	x	2	2
- Credit / Currency / Payment risk	yes		no		none	x	1	1
- Critical project workflow	yes		no		none		2	1
- Deadline pressure / operational urgency	high		medium		low	x	2	2
- Mann hours	>10.000		< 10.000		<3000	x	2	2
- Strategic Importance	high		medium		low	x	1	1
- General Contractor	yes				no	x	3	3
- Complexity	Many parts and many processes		Many parts or many processes		Few parts and few processes	x	3	3
- Strategic customer	yes	x	no		no		2	6
- Reference for new products	yes		no		no		2	1
- Industry/Market Development	yes		no		no	x	1	1

8.2 Appendix 2: Code in R

In this appendix an example for the R code used in this research for the ERGMs is presented.

```
#Install the packages
install.packages("statnet")
install.packages("coda")
install.packages("foreign")

library(statnet)
library(coda)
library(foreign)

#Set my directory where all the files related to this project were saved
setwd("C:/Users/Doctoral_thesis/ERGM/Paguemenos/Modelling_directed/Modelling
directed")
getwd()

#Read intensity dataset intensity.net and create an R object called integration
intensity <- read.paj("intensity.net",verbose=TRUE)

#Obtain the main statistics of the network (density, degree, etc.)
summary(intensity)

#Obtain the attributes of the network
list.vertex.attributes(intensity)

#Identify the extraneous stuff
get.vertex.attribute(intensity, "vertex.names")
get.vertex.attribute(intensity, "x")
get.vertex.attribute(intensity, "y")
get.vertex.attribute(intensity, "na")
get.vertex.attribute(intensity, "z")

#Delete the extraneous stuff
delete.vertex.attribute(intensity, c("x","y", "z", "na"))

# Important -- don't delete the "vertex.names" attribute!
#Vertex names are the names of the organizations
intensity %v% "vertex.names"

#Now, save the .net file as an R object.
save(intensity, file="intensity.RData")

#Now, let's move on to the excel file
library(foreign)
```

demo_pred <- read.table ("attributes.csv", header=T, sep=";")
summary(demo_pred)

list.vertex.attributes(intensity)

#Now assign each predictor as an attribute
intensity %v% "Organization" <- as.vector(demo_pred$Organization)
intensity %v% "Organization"
intensity %v% "Division" <- as.vector(demo_pred$Division)
intensity %v% "Division"
intensity %v% "Level_of_Management" <- as.vector(demo_pred$Level_of_Management)
intensity %v% "Level_of_Management"
intensity %v% "Communication_Language" <- as.vector
(demo_pred$Communication_Language)
intensity %v% "Communication_Language"
intensity %v% "Native_Language" <- as.vector(demo_pred$Native_Language)
intensity %v% "Native_Language"
intensity %v% "Linguistic_Group" <- as.vector(demo_pred$Linguistic_Group)
intensity %v% "Linguistic_Group"
intensity %v% "Ethnic_Group" <- as.vector(demo_pred$Ethnic_Group)
intensity %v% "Ethnic_Group"
intensity %v% "Employ_seniority" <- as.vector(demo_pred$Employ_seniority)
intensity %v% "Employ_seniority"
intensity %v% "Frequency_of_Contact" <- as.vector(demo_pred$Contact)
intensity %v% "Frequency_of_Contact"
intensity %v% "Modularity_Class" <- as.vector(demo_pred$Modularity_Class)
intensity %v% "Modularity_Class"

#Check the network to see if predictors are assigned as vertex attributes
list.vertex.attributes(intensity)

#Check the network to see if it is working
summary(intensity ~ edges + triangle)

 # model 1
model1 <- ergm(intensity ~ ostar(1)+istar(1), MCMC.samplesize =2e+5, MCMLE.maxit = 3, MCMC.burnin = 2e+4, verbose=TRUE, control=control.ergm(MCMLE.steplength= 1))
summary(model1)
model1$mle.lik
save(model1,file="model1.RData")

#Goodness of fit model 1
m1gof <-gof(model1, GOF=~espartners+distance+triadcensus+idegree+odegree, verbose=TRUE)
par(mfrow = c(3,2))
plot(m1gof, cex.lab=1.6, cex.axis=1.6, plotlogodds = TRUE)

 # model 2

```
Model2<- ergm(intensity ~ ostar(1)+istar(1)+mutual+nodematch("Organization", diff =
FALSE)+nodematch("Level_of_Management", diff = FALSE)+
nodematch("Native_Language", diff = FALSE)+nodematch("Ethnic_Group", diff =
FALSE)+nodematch("Communication_Language", diff = FALSE)+
nodematch("Employee_Seniority_Characterized", diff = FALSE)
+nodematch("Modularity_Class", diff = FALSE)+ nodeicov("Frequency_of_Contact")+
nodeocov("Frequency_of_Contact"),  MCMCsamplesize=1e+5, maxit = 3, burnin = 1e+5,
verbose=TRUE, control=control.ergm(steplength = 0.25))
summary(model2)
model2$mle.lik
save(model2,file="model5.RData")
```

#Goodness of fit model 2

```
M2gof <-gof(model3, GOF=~espartners+distance+triadcensus+idegree+odegree,
verbose=TRUE)
par(mfrow = c(3,2))
plot(m2gof, cex.lab=1.6, cex.axis=1.6, plotlogodds = TRUE)
```

 # model 3

```
Model3<- ergm(intensity ~ ostar(1)+istar(1)+mutual+nodematch("Organization", diff =
FALSE)+nodematch("Level_of_Management", diff = FALSE)+
nodematch("Native_Language", diff = FALSE)+nodematch("Ethnic_Group", diff =
FALSE)+nodematch("Communication_Language", diff = FALSE)+
nodematch("Employee_Seniority_Characterized", diff = FALSE)
+nodematch("Modularity_Class", diff = FALSE)+ nodeicov("Frequency_of_Contact")+
nodeocov("Frequency_of_Contact")+ gwidegree(0.5,fixed=TRUE)+
gwodegree(0.5,fixed=TRUE)+ gwesp(0.5, fixed=TRUE) + gwdsp(0.5,fixed=TRUE),
MCMCsamplesize=1e+5, maxit = 3, burnin = 1e+5, verbose=TRUE,
control=control.ergm(steplength = 0.25))
summary(model3)
model3$mle.lik
save(model3,file="model3.RData")
```

#Goodness of fit model 3

```
M3gof <-gof(model3, GOF=~espartners+distance+triadcensus+idegree+odegree,
verbose=TRUE)
par(mfrow = c(3,2))
plot(m3gof, cex.lab=1.6, cex.axis=1.6, plotlogodds = TRUE)
```

#model 4

```
Model4<- ergm(intensity ~ ostar(1)+nodematch("Native_Language", diff = TRUE, keep =
c(2,3,5))+nodematch("Ethnic_Group", diff = TRUE, keep =
c(2,3))+nodematch("Communication_Language", diff = TRUE, keep = c(1,2,3))+
nodeicov("Frequency_of_Contact")+nodeocov("Frequency_of_Contact")+nodematch("Mo
```

```
dularity_Class", diff = TRUE, keep = c(1,2))+ gwodegree(0.5,fixed=TRUE),
MCMCsamplesize=1e+5, maxit = 3, burnin = 1e+5, verbose=TRUE,
control=control.ergm(steplength = 0.25))
summary(model4)
model4$mle.lik
save(model4,file="model4.RData")

#Goodness of fit model   4
M4gof <-gof(model9b, GOF=~espartners+distance+triadcensus+idegree+odegree,
verbose=TRUE)
par(mfrow = c(3,2))
plot(m4gof, cex.lab=1.6, cex.axis=1.6, plotlogodds = TRUE)
```