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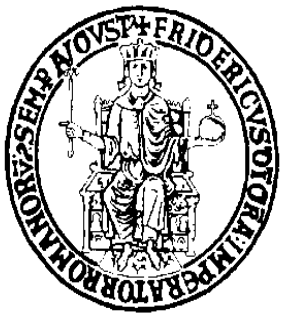

Department of Industrial Engineering

Ph.D Program in Science and Technology Management

XXVII Cycle

Ph.D Dissertation

The knowledge management in small and medium enterprises and the quality management approaches in service-oriented architecture

Ph.D Candidate: Maria Rosaria Spadaro

Ph.D Supervisor: Ch.mo Prof. Emilio Esposito

To my daughter Angelica

Contents

INTRODUCTION

The thesis is organized into two different sections: the first one deals with the knowledge management (KM) in small and medium enterprises (SMEs), a topic linked to the one of the research avenues carried out by the department of industrial engineering Federico II University of Naples; the second one deals with the quality management approaches in Service Oriented Architecture (SOA), this second topic has been set by an important telecommunications company supporting our Ph.D. program.

The first research topic arises from the awareness that knowledge fertilization is crucial for SMEs competitiveness and to improve network collaboration. Nevertheless, while there is an abundance of studies describing how large companies are successfully exploiting knowledge management practices, regarding SMEs the framework is still fragmented.

The Ph.D. program has been aimed at publishing two journal articles: the first one is a literature review, which provides the state of art of KM in small and medium enterprises and the second one is an empirical paper, which addresses the research questions emerging from the analysis of the literature review.

The research questions concern the barriers hindering the spread of KM practices in SMEs, the main knowledge management systems (KMSs) adopted by SMEs and the impact of the use of KM practices on SME performance; they were subsequently addressed through a field analysis conducted on a sample of SMEs. The empirical evidence highlights that although SMEs are generally characterized by poor financial and human resources, they are able to overcome the barriers preventing the spread of KM practices. The SMEs investigated perceive the strategic value of KM and consequently adopt a variety of KMSs. Nevertheless, such systems are generally outdated in comparison with cheaper, more recent, and user-friendly applications. This issue requires further and in-depth analysis concerning the degree of alignment between KMSs used by SMEs and the nature of knowledge as well as to evaluate the impact of KM by better exploiting the opportunities offered by the new ICTs. Furthermore due to the increasing importance of networks in the development of SMEs it seems important to investigate the ways through which knowledge is spread across networks populated by SMEs.

Finally, the analysis emphasizes that the use of KM practices can contribute to the overall growth of SMEs by simultaneously and significantly enhancing their performance.

Therefore the first section of this thesis is structured as a collection of these two published articles.

The second section deals with the quality management approaches in Service Oriented Architecture (SOA), this research topic arises from the needs to investigate services quality

techniques since there is a vast literature concerning the software quality metrics within an object-oriented environment, but this framework cannot be applied to SOA systems. This study attempted to fill these gaps presenting the results of a literature review on this topic; the outcomes of the review provide a valuable understanding of the best researched SOA topic, i.e. the quality attributes affecting SOA services, and the areas of SOA quality which are poorly investigated and that concern the link between the system level and the business level of an SOA architecture in terms of quality assessment, the application of SOA quality principles to real scenarios (case studies), the monitoring of services at runtime, and the need to exploit in-depth service quality attributes also using fuzzy set theory and a stochastic approach, and not just a deterministic approach. This review study has been aimed at editing a journal article which is going to be submitted to a journal indexed in Scopus and ISI Web of Science databases. In order to give an answer to one of the retrieved research questions, concerning the lack of case studies, an empirical analysis on SOA services performance has been carried out in an important telecommunications industry by an efficiency analysis.

We chose the performance as quality attributes to explore because performance evaluation is a typical issue in SOA environment, as highlighted by literature review.

The outcomes of the empirical analysis show the most critical services to improve in a quality control program and a preliminary analysis about the cause of not efficiency is introduced. This case study stresses the difficulty of storing, managing and analyzing big data from services so a monitoring framework is proposed. It is based on the introduction of an engine which automates service monitoring and logging phase and enforces the policies application. This approach stands for a future research avenue to develop for the company involved in the empirical investigation in order to overcome the limits of services inspection by human handling. Finally the work' conclusions are presented which sum up both the knowledge management prospect that the SOA prospect.

SECTION I: The knowledge management in small and medium enterprises

A literature review on knowledge management in SMEs

Roberto Cerchione, Emilio Esposito and Maria Rosaria Spadaro

Department of Industrial Engineering – University of Naples Federico II, Italy

Abstract: This paper provides a systematic review of the literature on knowledge management (KM) in small and medium enterprises (SMEs) and SME networks. The main objective is to highlight the state-of-the-art of KM from the management point of view in order to identify relevant research gaps. The review highlights that in recent years the trend of papers on the topic is growing and involves a variety of approaches, methodologies and models from different research areas. The vast majority of papers analysed focus on the topic of KM in the SME while there are only few papers analysing KM in networks populated by SMEs. The content analysis of the papers highlights six areas of investigation from which were derived ten research questions concerning three perspectives: the factors affecting KM; the impact of KM on firm's performance; the knowledge management systems.

Keywords: barriers; performance; knowledge management tools; knowledge management practice; knowledge management systems; SMEs

Introduction

A vast literature underlines that knowledge management (KM) is playing a crucial role in the global economy and is increasingly important for the competitiveness of large companies and small and medium enterprises (SMEs) (Esposito & Raffa, 1994; Esposito & Passaro, 1997; Dyer & Hatch, 2006; Gunasekaran & Ngai, 2007; Lakshman & Parente, 2008; Al-Mutawah et al, 2009; Esper et al, 2010; Lee et al, 2010; Samuel et al, 2011; Genovese et al, 2013).

However, while there are many studies that analyse the processes of dissemination of knowledge and highlight the adoption of KM in large companies, as regards SMEs the framework of knowledge is still fragmented. In particular, while the literature proposes a variety of models concerning KM in large companies, underlining the critical success factors (CSFs), the knowledge management systems (KMSs) used, the spread of practices of KM and their impact on performance, only in recent years literature has been focusing on KM in SMEs (Frey, 2001; McAdam & Reid, 2001; Sparrow, 2001; Wong, 2005; Wong & Aspinwall, 2005; Pillania, 2006; Pillania, 2008a, b).

Part of this literature focuses on the aspects relating to the epistemological and ontological dimensions of knowledge in SMEs. Concerning the epistemological perspective Egbu et al (2005) highlight that knowledge generated in SMEs is tacit in nature. Regarding the ontological perspective, Desouza & Awazu (2006) underline that in SMEs there is a sort of common knowledge known to all members of the organisation, and point out the dominance of the process of socialisation in the knowledge creating cycle. These contributions suggest that in SMEs the processes of acquisition and dissemination of knowledge should not prescind from the nature of knowledge that is human embedded. Moreover, even KMSs and the factors that affect the spread of KM practices should be in line with the nature of knowledge of SMEs.

With this in mind, this paper proposes a systematic review of the literature on KM that deals with the issues of SMEs and SME networks from three perspectives: the KMSs, the factors affecting the spread of KM practices, the impact of KM on firm's performance. This literature review is orthogonal to the interesting literature review of Durst & Edvardsson (2012) that focuses on the process of KM and is also orthogonal to the newsworthy contribution of Thorpe et al (2005) that provides a systematic review on how SMEs use and acquire knowledge. The main objective of this literature review is to highlight the state-of-the-art on KM in SMEs and SME networks, from a complementary outlook to those of Durst & Edvardsson (2012) and Thorpe et al (2005), in order to identify further research gaps to be investigated.

1. Literature review

The review was carried out using Scopus and Web of Science Academic databases, which include more than 8000 scientific journals that ensure a comprehensive coverage of the scientific production. According to Kolbe & Burnett (1991) and Li & Cavusgil (1995), the systematic study of existing body of knowledge on the above topic has been done through the three following phases: sampling; classification; content analysis.

1.1Sampling

This phase aims to identify all relevant scientific output covering the topic of KM in SMEs from 2000 to 2014. The search was performed using the keywords 'knowledge management', 'KM', 'knowledge creation', 'knowledge storage', 'knowledge transfer', 'knowledge sharing', in combination with 'SME*' or 'small firm*' or 'small business*'. This allows us to identify 428 papers included in the subject areas of the social sciences and humanities (i.e., business management and accounting, social sciences, decision sciences, computer science, engineering, multidisciplinary). In order to select only the papers concerning the aim of this section, two researchers read the abstract of each paper. The criterion of inclusion/exclusion was the focusing on the managerial aspects. In case of conflicting judgments a third researcher was involved in the selection process. The selection process allowed the exclusion of 334 papers. At the end of this stage 94 papers were selected and analysed.

Figure 1 shows that the trend of papers is growing. In fact the selected sample includes 5 articles from 2000 to 2004, 31 articles from 2005 to 2009, 58 articles from 2010 to 2014.

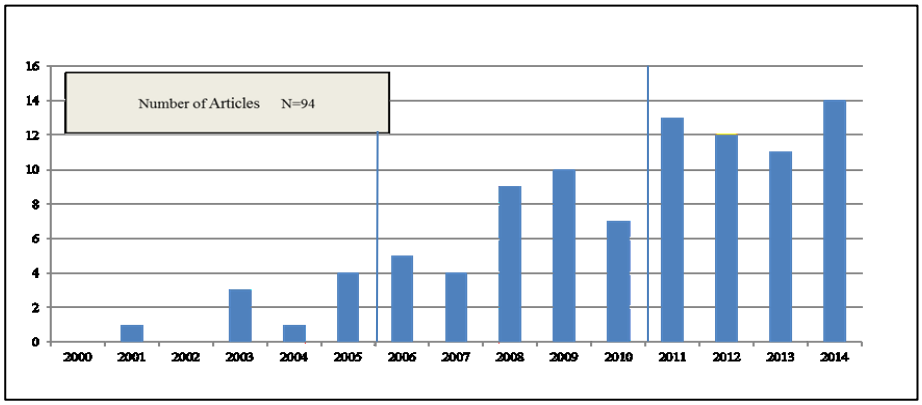

Figure 1 Papers over time

1.2 Classification

The papers selected were grouped into four macro areas (Table 1): Operations research and management science (60); Information systems and computer science (10); Engineering (8); Multidisciplinary (16). The distribution of papers by macro areas testifies that KM involves a variety of approaches, methodologies and models from different research areas.

Table 1 Papers by macro areas

Macro areas	Papers
Operations research and management science	60
Information systems and computer science	10
Engineering	8
Multidisciplinary	16
Total	94

1.3 Content analysis: characterisation of research areas

In line with the aim of this paper, the selected sample was analysed considering two outlooks. The first concerns three perspectives: the factors affecting KM; the impact of KM on firm's performance; the KMSs. The second that concerns the unit of analysis was divided into two groups: papers analysing the single SME; papers focusing on SME networks. This partition has identified six areas of analysis (Table 2):

Area 1: Factors affecting KM in SMEs (41 papers)

Area 2: Factors affecting KM in SME networks (1 paper)

Area 3: KM and SMEs performance (17 papers)

Area 4: KM and SME networks performance (2 papers)

Area 5: KMSs in SMEs (29 papers)

Area 6: KMSs in SME networks (4 papers).

Table 2 Papers by topic area

		Unit of analysis		Total
		SMEs	Network SMEs	
Perspective	Factors affecting KM	41	1	42
	KM and performance	17	2	19
	KMSs	29	4	33
	Total	87	7	94

1.3.1 Area 1: factors affecting KM in SMEs

Regarding the first area, the analysis of papers points out that it is possible to identify three sub-topics (Table 3):

- Contingency factors that are environmental and historical factors influencing the implementation of KM (9 papers);
- CSFs, namely factors that may influence the success of KM (28 papers);
- Barriers hindering KM diffusion (4 papers).

Table 3 Papers dealing with factors affecting KM

Factors affecting KM in SMEs	Authors	
Contingency factors	Cappellin (2003)	Moffett & McAdam (2006)
	Davenport (2005)	Purcarea et al (2013)
	Edwards (2007)	Roy & Therin (2008)
	Heavin and Adam (2014)	Soto-Acosta et al (2014)
	Hsu et al (2007)	
Critical success factors	Bocquet & Mothe (2010)	Montequín et al (2006)
	Boden et al (2012)	Mohannak (2014)
	Chen et al (2012)	Patalas-Maliszewska & Hochmeister (2011)
	Chen et al (2013)	Pillania (2008b)
	De Saá-Pérez et al (2012)	Pool et al (2014)
	Deng (2008)	Tan & Hung. (2006)
	Eze et al (2013)	Tseng et al (2012)
	Gholipour et al (2010)	Vajjhala & Baghurst (2014)
	Hussain et al (2011)	Valmohammadi (2010)
	Jones et al (2010)	Wee & Chua (2013)
	Lee & Lan (2011)	Wong (2005)
	Lin (2014)	Wong & Aspinwall (2005)
	Martinez-Costa & Jimenez-Jimenez (2009)	Zapata Cantù et al (2009)
	Migdadi (2008)	Zieba & Zieba (2014)
Barriers	Anand et al (2013)	Milosz & Milosz (2010)
	Joshi et al (2012)	Nunes et al (2006)

From the papers regarding the contingency factors, it clearly emerges that the KM processes are influenced by a variety of factors that may be grouped into three main sub-categories: Industrial organisation and industrial characteristics (Cappellin, 2003; Hsu et al, 2007; Purcarea et al, 2013; Heavin & Adam, 2014); Environmental and social factors (Davenport, 2005; Edwards, 2007; Roy & Therin, 2008; Soto-Acosta et al, 2014); Firm-specific factors (Davenport, 2005; Moffett & McAdam, 2006; Soto-Acosta et al, 2014).

The papers concerning CSFs may be classified into three main sub-categories: human and cultural factors (skill, motivation, training, education, trust and collaboration), technical factors (degree of IT applications, information system, infrastructure) and managerial factors (KM strategy management style, management leadership, organisational infrastructure, team-work and rewarding).

In particular 12 out of 28 papers deal with all three categories of factors, 7 contributions regard both managerial and human and cultural factors, 1 contribution focuses on both technical and managerial factors, 6 papers concern only human and cultural factors and 2 papers only managerial factors.

Finally, the four papers dealing with the barriers hindering KM diffusion point out two main issues. Anand et al (2013), Joshi et al (2012) and Milosz & Milosz (2010) identify the cultural issues, whereas Nunes et al (2006) highlight the financial issues. They do not consider the managerial issues, the role of human resources, the nature of the knowledge of SMEs that could represent potential barriers.

In summary, as far as the first topic there is a wide literature on the aspects concerning the factors that can influence the success of KM implementation. This literature has also identified a variety of contingency factors (industrial, environmental and firm-specific) and a substantial number of CSFs that may be attributed to three main categories (human and cultural, technical, managerial). By contrast, there are only four papers, which analyse the barriers preventing the adoption of KM practices. Even though these four papers pick out some cultural and financial factors, it seems evident that we need a more detailed analysis and more empirical evidence on this subject. The analysis of the first topic allows the formulation of the following research question:

Research Question 1: What are the barriers hindering the adoption of KM in SMEs?

1.3.2 Area 2: factors affecting KM in SME networks

The second area includes only the contribution of Chang et al (2012) that identify some important factors affecting the process of knowledge sharing in SME networks (relation-specific assets, knowledge-sharing routines, complementary resources and capabilities, and network position). Nevertheless, these conclusions are based on a desk analysis. Therefore, there is need of a more comprehensive investigation concerning factors and barriers that influence the adoption of KM practices in SME networks. Starting from this gap it is possible to identify a research question for future research tracks:

Research Question 2: What are the factors affecting the adoption of KM in SME networks?

According to the main aim of providing an overview on both factors (contingency and CSFs) and barriers, this latter has been subdivided in three research questions:

Research Question 2.1: What are the contingency factors affecting the adoption of KM in SME networks?

Research Question 2.2: What are the CSFs affecting the adoption of KM in SME networks?

Research Question 2.3: What are the barriers hindering the spread of KM in SME networks?

1.3.3 Area 3: KM and SMEs performance

As regards the third area, the analysis of the papers highlights that the KM may impact on the following performance (Table 4): economic and financial performance (sales growth, revenue growth, cost reduction, return to investment, profit), market performance (market share, service quality, market flexibility, reputation, customer satisfaction, services to clients), technical performance (innovation, product quality, competence, productivity, efficiency), human performance (creativity, entrepreneurial growth, staff satisfaction) and organisational performance (external relationships, diffusion of new ideas, work relationships, flexibility in resources utilisation).

In particular, 3 out of 17 papers indicate that KM supports all five performance, 4 contributions show that KM affects positively four performance, 1 paper points out that KM influences positively three performance, 2 papers highlight two performance and 7 papers only one performance. This seems highlight that KM contributes to an overall growth of SMEs by enhancing simultaneously more performance. Nevertheless, while it is strongly shared that KM strengthens the technical performance (12 out of 17 papers), it is not otherwise shared the impact on the organisational performance (6 out of 17 papers) and human performance (6 out of 17 papers). It seems evident that further empirical evidence could strengthen this conclusion and confirm that the impact of KM on SMEs performance is

extremely wide and affects simultaneously more performance. The above literature analysis allows us to formulate the following research question:

Research Question 3: What is the impact of KM on SMEs performance?

Table 4 Papers dealing with KM and SMEs performance

KM and SMEs performance	Authors	
Economic and financial performance	Bagnoli & Vedovato (2012) Daud & Yusoff (2011) Delen et al (2013) Gholami et al (2013) Hong et al (2014) Liu & Abdalla (2013)	Omerzel & Antončič (2008) Roxas et al (2014) Salojärvi et al (2005) Soon & Zainol (2011) Wei et al (2011)
Market performance	Beck & Schenker-Wicki (2014) Daud & Yusoff (2011) Delen et al (2013) Egbu et al (2005) Gholami et al (2013) Gupta et al (2014)	Hong et al (2014) Liu & Abdalla (2013) Soon & Zainol (2011) Talebi & Tajeddin (2011) Wei et al (2011)
Technical performance	Alegre et al (2011) Bagnoli & Vedovato (2012) Daud & Yusoff (2011) Delen et al (2013) Egbu et al (2005) Filippini et al (2012)	Gholami et al (2013) Hong et al (2014) Liu & Abdalla (2013) Soon & Zainol (2011) Talebi & Tajeddin (2011) Wei et al (2011)
Human performance	Egbu et al (2005) Gholami et al (2013) Liu & Abdalla (2013)	Soon & Zainol (2011) Talebi & Tajeddin (2011) Wei et al (2011)
Organisational performance	Daud & Yusoff (2011) Egbu et al (2005) Gholami et al (2013)	Hong et al (2014) Liu & Abdalla (2013) Wei et al (2011)

1.3.4 Area 4: KM and SME networks performance

The fourth area dealing with the relationship between KM and SME networks performance includes two articles. Briscoe et al (2001) analyse how knowledge sharing between networks affects SME networks performance. Saxena & Wadhwa (2009) show that knowledge sharing has crucial value for the networks of SMEs.

Although the interesting results, these two articles do not consider how the adoption of KM has an impact on different specific types of performance. Summarising, the analysis of this fourth area highlights that the impact of KM on SME networks requires a deeper investigation. This conclusion allows the formulation of the following research question:

Research Question 4: What is the impact of KM on SME networks performance?

1.3.5 Area 5: KMSs in SMEs

With reference to the fifth area, the papers were divided into two sub-topics (Table 5): Knowledge management practices (KM-Practices), defined as the set of methods and techniques to support the organisational processes of knowledge creation, storage, transfer/sharing and application (18 papers); and Knowledge management tools (KM-Tools), namely, the specific IT-based systems supporting KM methods and techniques (11 papers).

As far as the papers included in the first sub-topic (KM-Practices), they evidence the variety of methods and techniques of KM in relation to the nature of knowledge and/or the process of KM. All papers agree that knowledge in SMEs is mainly human embedded and there is the dominance of socialisation in the Socialization, Externalization, Combination, Internalization (SECI) cycle (Nonaka, 1994). Then it is not surprising that most of the practices are oriented towards the management of tacit knowledge. Some authors (Desouza & Awazu, 2006; du Plessis, 2008; Pillania 2008a; Spraggon & Bodolica, 2008; Navarro et al, 2010; Chong et al, 2011; Massa & Testa, 2011; Yao et al 2011; Lin et al, 2012; Noblet & Simon, 2012; Whyte & Classen, 2012) suggest a variety of people-centred practices such as: focus groups, formal meetings, seminars, communities of practice, communities of sharing, informal networks, project teams, storytelling, interactions with clients, interactions with suppliers, interactions with partners, job rotation, training. Moreover, even though Hutchinson & Quintas (2008) underline that small firms are more likely to adopt informal processes to manage knowledge, other authors (Levy et al, 2003; Ambrosini & Bowman, 2008; du Plessis, 2008; Fink & Ploder, 2009; Durst & Wilhelm, 2011, 2012) suggest also the importance of more formal techniques and methods (such as: casual mapping, knowledge map, balance scorecard, formal manual), while others suggest to establish a chief knowledge officer (Navarro et al, 2010) or a project team (Corso et al, 2003; Spraggon & Bodolica, 2008).

As far as the second sub-topic (KM-Tools), Grace (2009), Razmerita & Kirchner (2011), Dotsika & Patrick (2013), Gresty (2013) show the opportunity offered by wikis as knowledge sharing tools. Lopez-Nicolas & Soto-Acosta (2010) identified intranet and webpages as KMSs to support organisational learning. Choudhary et al (2013) and Gresty (2013) analyse the use of communication and collaborative tools. Similarly, Dotsika & Patrick (2013) illustrate some specific communication tools (email, blog, content management system), collaborative tools (social media) and management tools (database, document management system, project management system). Edvardsson (2009) and Rosu et al (2009) suggest a knowledge-based applications architecture based on the use of enterprise resource planning, customer relationship management, document management system, data mining and data warehouse. Beylier et al (2009) analyse a prototype KM-Tool to improve knowledge creation and sharing. Finally, Lisanti & Luhukay (2014) and Zhou et al (2014) design two different models of SMEs KMS.

In summary, these 29 papers focus on specific KMSs but do not offer a comprehensive overview of the variety of KMSs used by SMEs. Then, there is a clear need for a more thorough investigation of KM-Tools and KM-Practices employed by SMEs. The above gap allows us to formulate the following research questions:

Research Question 5.1: What are the main KM-Tools adopted by SMEs?

Research Question 5.2: What are the main KM-Practices adopted by SMEs?

Table 5 Papers dealing with KMSs by authors

KMSs in SMEs	Authors	
KM-Practices	Ambrosini & Bowman (2008)	Levy et al (2003)
	Chong et al (2011)	Lin et al (2012)
	Corso et al (2003)	Massa & Testa (2011)
	Desouza & Awazu (2006)	Navarro et al (2010)
	du Plessis (2008)	Noblet & Simon (2012)
	Durst & Wilhelm (2011)	Pillania (2008a)
	Durst & Wilhelm (2012)	Spraggon & Bodolica (2008)
	Fink & Ploder (2009)	Whyte & Classen (2012)
	Hutchinson & Quintas (2008)	Yao et al (2011)
KM-Tools	Beylier et al (2009)	Lisanti & Luhukay (2014)
	Choudhary (2013)	Lopez-Nicolas & Soto-Acosta (2010)
	Dotsika & Patrick (2013)	Razmerita & Kirchner (2011)
	Edvardsson (2009)	Rosu et al (2009)
	Grace (2009)	Zhou et al (2014)
	Gresty (2013)	

Area 6: KMSs in SME networks

The sixth area includes four articles focusing on KM-Tools adoption in SME networks. Specifically, Al-Mutawah et al. (2009) analyse the use of a multi-agent system for tacit knowledge sharing among firms and perform some experiments to simulate the proposed approach.

Lockett et al (2009) examine the adoption of knowledge database to facilitate the process of knowledge transfer within SME networks co-located in a higher education institution considered as a centre of excellence for R&D. Perez-Araos et al (2007) illustrate the use of an innovative KM-Tool currently at the stage of validation. The adoption of this tool allows SMEs to facilitate the creation of virtual networks and manage efficiently and effectively the created knowledge.

Cagnazzo et al (2014) provide a methodology to establish a KMS in a SME network of 21 Italian firms through an action research approach.

Content analysis of this area shows the need of an integrated approach to analyse KMSs that are not analysed considering a set of tools and practices used by SME networks to improve the KM phases in terms of efficiency and effectiveness. The analysis of the sixth topic allows the formulation of the following research questions:

Research Question 6.1: What are the main KM-Tools adopted by SME networks?

Research Question 6.2: What are the main KM-Practices adopted by SME networks?

Conclusions

This paper has provided a systematic literature review on KM in SMEs and networks populated by SMEs. The review has been organised into three phases: sampling; classification; and content analysis.

The phase of sampling highlights that in recent years the trend of articles on the topic is growing.

The phase of classification underlines that the topic involves a variety of approaches, methodologies and models from different research areas. The content analysis was carried out considering two outlooks. The first was divided into three perspectives: the factors affecting KM; the impact of KM on firm's performance; and the KMSs. The second concerns the unit of analysis and was divided into two groups: papers analysing the single SME; and papers focusing on SME networks. This partition has allowed us to identify six areas of investigation. The vast majority of articles deals with the single SME compared with papers that focus on the analysis of SME networks. This aspect is important because it emphasizes that the knowledge management in networks of SME is still neglected. This gap is particularly relevant considering that in the global economy, networks of SMEs are crucial not only for the competitiveness of individual enterprise, but also for the economic system as a whole. Regarding the three perspectives, it emerges that 'factors affecting KM' is the most analysed perspective while 'KM and performance' is less studied. The content analysis highlights six main gaps in the literature from which were derived ten research questions. Four research questions regard the issue of KM in SMEs and six regard the topic of KM in SME networks.

As far as the KM in SMEs, the four research questions concern: the barriers hindering the adoption of KM in SMEs; the impact of KM on SMEs performance; the main KM-Tools adopted by SMEs; the main KM-Practices adopted by SMEs.

Regarding the issue of KM in networks of SMEs, the six research questions are about: the contingency factors affecting the adoption of KM practices in SME networks; the CSFs affecting the adoption of KM in SME networks; the barriers hindering the spread of KM in SME networks; the impact of KM on SME networks performance; the main KM-Tools adopted by SME networks; the main KM-Practices adopted by SME networks.

The variety of gaps that emerges from this literature review points out that the framework of knowledge in the field of KM in SMEs and KM in networks populated by SMEs is still fragmented and many areas are still unexplored. Nevertheless, while in the field of KM in SMEs in the last few years the number of papers is greatly increased and, although fragmented, the framework is in evolution, the issue of KM in SME networks is still

considerably unexplored. This finding is in line with what has already been highlighted by Durst & Edvardsson (2012) and Thorpe et al (2005). However, since this paper provides a complementary perspective to the two previous contributions, it offers opportunity to integrate their findings and draw a more comprehensive framework on the areas to be investigated in order to improve the body of knowledge in the field of KM in SMEs and in networks populated by SMEs.

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The Spread of Knowledge Management in SMEs: A Scenario in Evolution

Roberto Cerchione, Emilio Esposito and Maria Rosaria Spadaro

Department of Industrial Engineering – University of Naples Federico II, Italy

Abstract: This paper deals with knowledge management (KM) in small and medium enterprises (SMEs). Through a literature review, three research questions have been identified concerning the barriers hindering the spread of KM practices in SMEs, the main knowledge management systems (KMSs) adopted by SMEs and the impact of the use of KM practices on SME performance. The research questions were subsequently addressed through a field analysis conducted on a sample of SMEs. The empirical evidence highlights that the scenario has changed in the space of a few years. Although SMEs are generally characterized by poor financial and human resources, they are able to overcome the barriers preventing the spread of KM practices. The SMEs investigated perceive the strategic value of KM and consequently adopt a variety of KMSs. Nevertheless, such systems are generally outdated in comparison with cheaper, more recent, and user-friendly applications. Finally, the paper emphasizes that the use of KM practices can contribute to the overall growth of SMEs by simultaneously and significantly enhancing their performance.

Keywords: barriers; knowledge management systems; literature; performance

1. Introduction

The spread of organizational forms based on intensive collaborative relationships among small and medium enterprises (SMEs) (virtual enterprise, cluster, *etc.*) and between large companies and SMEs (vertical relationships, supply chain, *etc.*) has generated competitive and dynamic environments where knowledge fertilization in SMEs is increasingly crucial in supporting the network of collaboration and the competitiveness of the whole system (Al-Mutawah et al., 2009; Dyer and Hatch, 2006; Esper et al., 2010; Esposito and Passaro, 1997; Esposito and Raffa, 1994; Genovese et al., 2013; Gunasekaran and Ngai, 2007; Lakshman and Parente, 2008; Lee et al., 2010; Samuel et al., 2011). Nevertheless, there is an abundance of studies describing how large companies are successfully exploiting knowledge management (KM) practices, while SMEs show poor use KM practices, and the benefits of KM adoption are not fully exploited by these firms (Alavi and Leidner, 2001; Durst and Edvardsson, 2012; Marra et al., 2012; Thorpe et al., 2005). Although there are many studies that analyze the processes of dissemination of knowledge and highlight the adoption of KM in large companies, as regards SMEs, the framework of knowledge is still fragmented. Moreover, the degree of adoption of KM is not homogeneous and there are still profound differences among various industries (Hung et al., 2011).

Several researches highlight that the factors preventing the adoption of practices and strategies of knowledge management by SMEs are, directly or indirectly, connected to the following three aspects (Desouza and Awazu, 2006; Egbu et al., 2005; Frey, 2001; McAdam and Reid, 2001; Pillania, 2006 and 2008a; Sparrow, 2001; Wong, 2005; Wong and Aspinwall, 2005):

- In SMEs, the nature of knowledge is mainly human embedded;
- In SMEs, there is a sort of common knowledge, which is a knowledge shared by all members of the organization;
- The chronic shortage of human and financial resources that characterizes SMEs.

Even though these three aspects seem to explain the factors that have so far hindered the adoption of practices of KM in SMEs, it should be emphasized that Information and Communication Technologies (ICTs) are increasingly offering SMEs new tools that are (Antonelli et al., 2000; Esposito and Mastroianni, 1998 and 2001; Garrigos-Simon et al., 2012; Matlay and Westhead, 2005):

- low cost. This means knowledge management systems (KMSs) that do not require significant financial investments;
- ease-of-use. ICTs provide KMSs that do not need specific skills;
- more effective. Compared with traditional tools, new ones are able to support the processes of socialization among members of a group.

In summary, on the one hand, the literature highlights the factors that have prevented SMEs adopting KM practices. On the other hand, ICTs are weakening the weight of these factors, reducing the human and financial barriers that hinder their adoption.

This aspect emphasizes that the scenario is in an evolutionary phase, and although the number of papers regarding knowledge management in SMEs is increasing, further research efforts are still needed (Durst and Edvardsson, 2012).

With this in mind, the aim of this paper is to make a contribution to increasing the body of knowledge in the field of KM in SMEs by investigating three issues that emerge from the literature. The first regards the barriers hindering the spread of KM practices in SMEs, the second concerns the impact of KM practices on SMEs' performance, and the third looks at the adoption of knowledge management systems (KMSs) by SMEs. These three issues have been addressed through a field analysis conducted on a sample of SMEs operating in high-tech and/or complex industries.

The paper is organized into five sections. Following this introduction, the second section deals with the literature review on KM in SMEs. The third section describes the context of investigation and the methodology. The main findings emerging from the field analysis are presented and discussed in the fourth section. Finally, conclusions and implications are illustrated.

2. Literature Review

The main objective of this section is to analyze state-of-the-art of knowledge management in SMEs from the management perspective in order to identify research gaps. For this purpose, we adopt a systematic review approach adapted by Pittaway et al. (2004), Petticrew and Roberts (2006) and Easterby-Smith et al. (2012).

Pittaway et al. (2004) propose a systematic literature review organized into 10 steps: identification of key words; construction of search strings; initial search and identification of further key words; choosing the citation databases; review of the selected citation databases using the search strings; review of the citations identified based on inclusion and exclusion criteria; review of the citation abstracts and separation into different lists; encoding abstracts according to their content; reviewing significant articles; the addition of further articles, based on professional recommendation and references from reviewed articles.

Petticrew and Roberts (2006) define a systematic review process organized into 12 steps: define the question; consider drawing together a steering or advisory group; write a protocol and have it reviewed; carry out the literature search; screen the references; assess the remaining studies against the inclusion/exclusion criteria; data extraction; critical appraisal; synthesis of the primary studies; consider the effects of publication bias, and other internal and external biases; write up the report; wider dissemination.

Easterby-Smith et al. (2012) identify 5 steps in carrying out a systematic review: planning the review; identifying and evaluating studies; extracting and synthesizing data; reporting; utilizing the findings.

Summarizing the above contributions, a systematic study of the existing body of knowledge of the above topic has been carried out along the following the four main phases: (1) material comprehensive search; (2) selection of papers; (3) descriptive analysis; and (4) content analysis.

The review was carried out using Scopus and Web of Science Academic databases, which ensure a wide coverage of scientific output as they contain more than 8000 scientific journals, including the most important high-ranking journals.

2.1. Material Comprehensive Search

This phase aimed to identify all relevant scientific output covering the topic of knowledge management in SMEs. The literature review spans the years 1960–2014 and the search was conducted using the keywords “knowledge management”, “KM”, “knowledge adoption”, “knowledge development”, “knowledge acquisition”, “knowledge creation”, “knowledge storage”, “knowledge transfer”, “knowledge sharing”, “knowledge exchange”, “knowledge application”, “knowledge reuse”, “knowledge re-use”, in combination with “SME *” or “small firm *” or “small business *”. This allowed us to identify 428 papers included in the subject areas of the social sciences and humanities (*i.e.*, business management and accounting, social sciences, decision sciences, computer science, engineering, multidisciplinary).

2.2. Selection of Papers

In order to select only the papers concerning the aim of this section, two criteria for the inclusion/exclusion of research products were defined. The first criterion follows the approach proposed by Pittaway et al. (2004). It allowed us to select only those articles whose abstracts focus on knowledge management SMEs. In order to achieve this objective, abstracts of the 428 articles were read in parallel by two different researchers, plus a third one in case of uncertainty.

The second criterion is related to the focus of the article. For this purpose articles were read in full by two researchers. In the case of conflicting judgements, a third researcher was involved in the selection process. The selection process allowed 341 papers to be excluded. At the end of this stage, 87 papers were selected and studied in detail.

2.3. Descriptive Analysis

The descriptive analysis of the papers aims to give an overview of the papers that deal with the topic of knowledge management in SMEs. For the evaluation of the 87 selected articles, two descriptive perspectives were identified:

(1) Papers over time;

(2) Papers by journal subject areas.

According to the distribution of papers over time (Figure 1), thirteen of the selected papers were published in 2011 and 2014. Then a significant percentage of papers belongs to the years 2012 and 2013 with 11 papers. Specifically, there are 13 papers written between 2003 and 2006, 26 papers from 2007 to 2010, and 48 papers from 2011 to 2014.

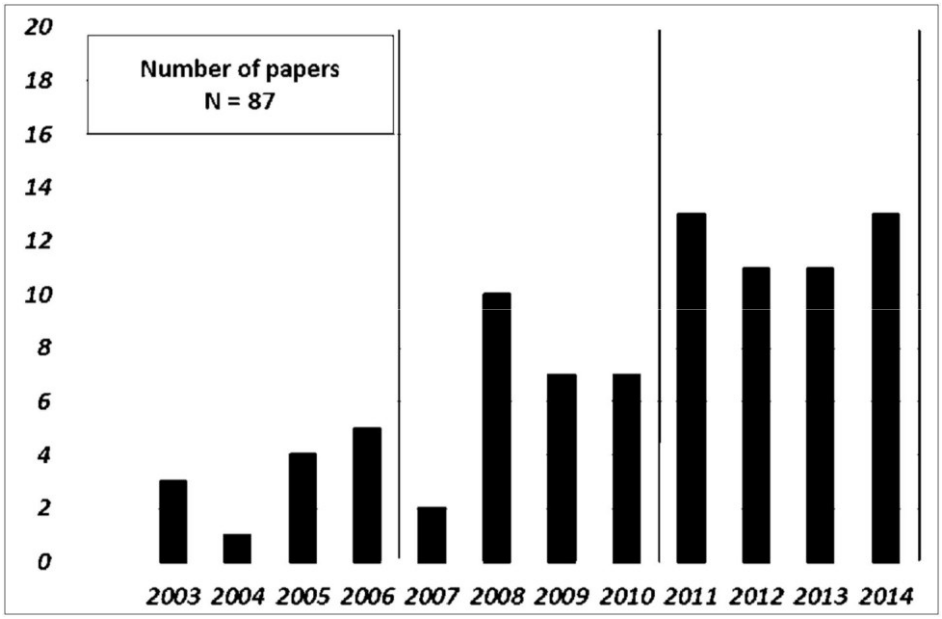

Figure 1 Article distribution over time.

The trend of articles on this topic has thus seen growth over recent years. This conclusion is in line with Serenko (2013), who shows how KM research has progressed through three distinct phases: Initiation (1997–2001), Early Development (2002–2006), and Rigor and Consolidation (2007–2012).

Regarding paper distribution by journal subject areas, the papers identified were grouped into the following four areas: (a) Engineering (6 papers); (b) Computer science and information systems (8 papers); (c) Operations research and business science (59 papers); and (d) Multidisciplinary (14 papers). The distribution of papers by journal subject area testifies that knowledge management involves a variety of approaches, methodologies and models from different research areas.

2.4. Content Analysis

In this phase, the papers selected were studied in detail, and the following three main topics were identified (Table 1):

(1) *Factors affecting KM*, *i.e.*, the set of factors that positively or negatively influence the implementation of KM in SMEs (41 papers—47.1%);

(2) *Systems supporting KM*; this topic encompasses all the papers included in the sample that highlight how KM is implemented in terms of practices and tools (29 papers—33.3%);

(3) *KM and performance*; this topic includes papers dealing with the impact of KM on firm performance (17 papers—19.6%).

In the following paragraphs, the three main topics will be analyzed in detail.

2.4.1. Factors Affecting Knowledge Management

As far as the first topic is concerned, analysis of the 41 papers shows that it is possible to identify three sub-topics:

- *Contingency Factors*, *i.e.*, environmental and historical factors influencing the implementation of KM in SMEs (9 papers);
- *Critical Success Factors* (CSFs), namely factors that may influence the success of KM implementation (28 papers);
- *Barriers hindering KM*; factors hindering KM diffusion (4 papers).

From the nine papers regarding the *Contingency Factors*, it clearly emerges that KM processes are influenced by a variety of factors that may be grouped into three main categories: *Industrial organization,* which includes the agglomeration economies (Cappellin, 2003, Heavin and Adam, 2014; Purcarea, 2013) and industrial characteristics (Hsu et al.,

2007); *Environmental factors, i.e.*, social context (Edwards, 2007; Soto-Acosta et al., 2014), environmental commitment (Roy and Therin, 2008), geographic proximity to the knowledge sources (Davenport, 2005), *and Firm specific factors,* namely international interactions and organizational proximity (Davenport, 2005; Soto-Acosta et al., 2014), and organization size (Moffett and McAdam, 2006).

Table 1 Papers by topic and sub-topic.

Topic 1: Factors Affecting KM (41 Papers)	Topic 2: Systems Supporting KM (29 Papers)	Topic 3: KM and Performance (17 Papers)
Contingency factors (9 papers)	**KM-Practices (18 papers)**	
Cappellin (2003)	Ambrosini and Bowman (2008)	Alegre *et al.* (2011)
Davenport (2005)	Chong *et al.* (2011)	Bagnoli and Vedovato (2012)
Edwards (2007)	Corso *et al.* (2003)	Beck and Schenker-Wicki (2014)
Heavin and Adam (2014)	Desouza and Awazu (2006)	Daud and Yusoff (2011)
Hsu *et al.* (2007)	du Plessis (2008)	Delen *et al.* (2013)
Moffett and McAdam (2006)	Durst and Wilhelm (2011)	Egbu *et al.* (2005)
Purcarea (2013)	Durst and Wilhelm (2012)	Filippini *et al.* (2012)
Roy and Therin (2008)	Fink and Ploder (2009)	Gholami *et al.* (2013)
Soto-Acosta *et al.* (2014)	Hutchinson and Quintas (2008)	Gupta *et al.* (2014)
Critical success factors (28 papers)	Levy *et al.* (2003)	Hong *et al.* (2014)
Bocquet and Mothe (2010)	Lin *et al.* (2012)	Liu and Abdalla (2013)
Boden *et al.* (2012)	Massa and Testa (2011)	Omerzel and Antončič (2008)
Chen *et al.* (2012)	Navarro *et al.* (2010)	Roxas *et al.* (2014)
Chen *et al.* (2013)	Noblet and Simon (2012)	Salojärvi *et al.* (2004)
De Saá-Pérez (2012)	Pillania (2008a)	Soon and Zainol (2011)
Deng (2008)	Spraggon and Bodolica (2008)	Talebi and Tajeddin (2011)
Eze (2013)	Whyte and Classen (2012)	Wei *et al.* (2011)
Gholipour *et al.* (2010)	Yao *et al.* (2011)	
Hussain *et al.* (2011)	**KM-Tools (11 papers)**	
Jones *et al.* (2010)	Beylier *et al.* (2009)	
Lee and Lan (2011)	Choudhary (2013)	
Lin (2014)	Dotsika and Patrick (2013)	
Martinez-Costa and Jimenez-Jimenez, (2009)	Edvardsson (2009)	
Migdadi (2008)	Grace (2009)	
Mohannak (2014)	Gresty (2013)	
Montequin *et al.* (2006)	Lisanti and Luhukay (2014)	
Patalas-Maliszewska and Hochmeister (2011)	Lopez-Nicolas and Soto-Acosta (2010)	
Pillania (2008 b)	Razmerita and Kirchner (2011)	
Pool *et al.* (2014)	Rosu *et al.* (2009)	
Tan and Hung (2006)	Zhou (2014)	
Tseng *et al.* (2012)		
Vajjhala and Baghurst (2014)		
Valmohammadi (2010)		
Wee and Chua (2013)		
Wong (2005)		
Wong and Aspinwall (2005)		
Zapata Cantù *et al.* (2009)		
Zieba and Zieba (2014)		
Barriers to KMSs adoption (4 papers)		
Anand (2013)		
Joshi (2012)		
Milosz and Milosz (2010)		
Nunes *et al.* (2006)		

The 28 papers concerning *Critical Success Factors* offer a comprehensive framework of the factors that affect KM adoption and show that they may be classified into three main categories: *Human and cultural factors,* which includes human resources, people skill, motivation, training and education, a culture of collaboration and trust (Boden et al., 2012; Chen et al., 2012; Deng, 2008; De Saá-Pérez, 2012; Eze, 2013; Gholipour et al., 2010; Hussain et al., 2011; Lee and Lan, 2011; Migdadi, 2008; Montequin et al., 2006; Patalas-Maliszewska and Hochmeister, 2011; Tan and Hung., 2006; Vajjhala and Baghurst, 2014; Valmohammadi, 2010; Wee and Chua, 2013; Wong, 2005; Wong and Aspinwall, 2005; Zapata Cantù et al., 2009), *Technical factors,* namely the degree of IT applications, the information system, infrastructure, degree of KM adoption, Total Quality Management practices (Eze, 2013; Hussain et al., 2011; Lee and Lan, 2011; Lin, 2014; Migdadi, 2008; Montequin et al., 2006; Tan and Hung., 2006; Valmohammadi, 2010; Wong, 2005; Wong and Aspinwall, 2005) and Managerial factors*, i.e.*, cultivating trust, KM strategy, integrating KMS with staff, management style, management leadership, internal and external network relationships, organizational infrastructure, physical networks, teamwork, and rewarding (Bocquet and Mothe, 2010; Chen et al., 2012; Chen et al., 2013; Deng, 2008; Eze, 2013; Hussain et al., 2011; Jones et al., 2010; Lee and Lan, 2011; Lin, 2014; Martinez-Costa and Jimenez-Jimenez, 2009; Migdadi, 2008; Mohannak, 2014; Montequin et al., 2006; Patalas-Maliszewska and Hochmeister, 2011; Pillania, 2008b; Pool et al. 2014; Tan and Hung, 2006; Tseng et al., 2012; Valmohammadi, 2010; Wee and Chua, 2013; Wong, 200; Wong and Aspinwall , 2005; Zieba and Zieba, 2014).

Finally, the four papers dealing with the barriers hindering KM diffusion highlight just two main issues. Some authors identify the *cultural issues* (knowledge transfer, knowledge sharing, and intellectual property) Anand et al., (2013), Joshi et al., (2012) and Milosz and Milosz (2010), whereas others highlight the *financial issues* (return on investment and long term investments always have lower priority than short term investment) Nunes et al. (2006). It is important to stress that these two papers do not consider the managerial issues, the role of human resources, or the nature of the knowledge that SMEs possess that could represent potential barriers to the spread of KM practices.

In summary, as far as the first topic is concerned, there is a wide literature on the aspects concerning the factors that can influence the success of KM implementation. This literature has also identified a variety of contingency factors (industrial, environmental and firm specific) and a substantial number of CSFs that may be attributed to three main categories (human and cultural, technical, managerial). In contrast, there are only four papers which analyze the barriers preventing the adoption of KM practices. Even though these four papers

pick out some cultural and financial factors, it seems evident that we need a more detailed analysis and more empirical evidence on this subject. Analysis of the first topic allows the formulation of the following research question:

- **RQ1**: What are the major barriers hindering the spread of knowledge management practices in SMEs?

2.4.2. Systems Supporting Knowledge Management in SMEs

With reference to the second topic (systems supporting KM), the 29 papers were divided into two sub-topics (see Table 1): *Knowledge management practices*, that may be defined as the set of methods and techniques to support and enhance the organizational processes of knowledge creation, storage, transfer/sharing, and application (18 papers), and *Knowledge management tools*, that may be defined as the specific IT-based systems supporting KM methods and techniques (11 papers).

As for the 18 papers included in the first sub-topic (knowledge management practices), these evidence the variety of KM methods and techniques relating to the nature of knowledge (tacit or explicit) and/or the process of knowledge management (e.g., identification, capture, storage, mapping, dissemination and creation). All papers converge towards the fact that knowledge in SMEs is mainly embedded in the human resource and that socialization is dominant in the SECI cycle (Nonaka, 1994). Thus, it is not surprising that most of the practices are oriented toward the management of tacit knowledge. Some authors (Chong et al., 2011; Desouza and Awazu, 2006; du Plessis, 2008; Lin et al., 2012; Massa and Testa, 2011; Navarro et al., 2010; Noblet and Simon, 2012; Pillania 2008a; Spraggon and Bodolica, 2008; Whyte and Classen, 2012; Yao et al. 2011) suggest a variety of people-centered practices such as: focus groups, formal meetings, communities of sharing, virtual communities, informal networks, project teams, interactions with clients, interactions with suppliers, interactions with partners, communities of practices, job rotation, training. Moreover, even though Hutchinson and Quintas (2008) underline that small firms are more likely to adopt informal processes to manage knowledge, other authors (Ambrosini and Bowman, 2008; Durst and Wilhelm, 2011, 2012; Fink and Ploder, 2009; Levy et al., 2003) also suggest the importance of more formal techniques and methods (such as: casual mapping, knowledge maps, balance scorecards, formal manuals), while others suggest establishing a chief knowledge officer (Navarro et al., 2010) or a project team (Corso et al. 2003; Spraggon and Bodolica, 2008).

As far as the second sub-topic (KM-Tools) is concerned, Grace (2009), Dotsika and Patrick (2013), Gresty (2013), and Razmerita and Kirchner (2011) show the opportunities offered by wikis. Lopez-Nicolas and Soto-Acosta (2010) identified intranet and webpages as KMSs to support organizational learning. Choundary et al. (2013) and Gresty (2013) analyze the use of communication and collaborative tools. Similarly, Dotsika and Patrick (2013) illustrate some specific communication tools (email, blog, content management systems), collaborative tools (social media) and management tools (database, document management systems, project management systems). Edvardsson (2009) and Rosu et al. (2009) suggest a knowledge-based

applications architecture centered on the use of enterprise resource planning, customer relationship management, a document management system, data mining and the use of data warehouses. Beylier et al. (2009) analyze a prototype KM-Tool to improve knowledge creation and sharing. Finally, Lisanti and Luhukay (2014) and Zhou et al. (2014) design two different models of SME knowledge management system. In summary, these 29 papers focus on specific KMSs, but do not offer a comprehensive overview of the variety of KMSs used by SMEs. Thus, there is a clear need for a deeper analysis of the KMSs used by SMEs. The above allows us to formulate the following research question:

- **RQ2**: What are the main knowledge management systems adopted by SMEs?

2.4.3. Knowledge Management and Performance

As regards the third topic, analysis of the papers highlights that the implementation process of KM in SMEs may impact on the following performance (Table 2): *economic and financial performance* (profit, sales growth, revenue growth, cost reduction, financial performance, return to investment, profitability), *market performance* (market share increase, service quality, market flexibility, reputation, customer satisfaction, services to clients), *technical performance* (innovation, product quality, growth in core competence, productivity, efficiency, flexibility technical), *human performance* (creativity, entrepreneurial growth, staff performance, staff satisfaction) and *organizational performance* (external partner and relationships, diffusion of new ideas, organizational agility, work relationships, learning curve, flexibility in the use of resources).

In detail: three out of 17 papers (Gholami et al., 2013; Liu and Abdalla, 2013; Wei et al., 2011) indicate that KM supports all five performances; four contributions show that KM positively affects four performance types (Daud and Yusoff, 2011; Egbu et al., 2005; Hong et al., 2014; Soon and Zainol, 2011), two papers point out that KM positively influences three performances (Delen et al., 2013; Talebi and Tajeddin, 2011), whereas one paper highlights two performances (Bagnoli and Vedovato, 2012), and seven papers show only one performance (Alegre et al., 2011; Beck and Schenker-Wicki, 2014; Filippini et al., 2012; Gupta et al. 2014; Omerzel and Antončič, 2008; Roxas et al., 2014; Salojärvi et al., 2005). This seems to highlight that KM contributes to an overall growth of SMEs by simultaneously enhancing more performance. Nevertheless, while it is strongly agreed that KM strengthens economic and financial performance (12 out of 17 papers) as well as technical performance (12 out of 17 papers), the impact on the human and organizational performance (both with 6 out of 17) papers is not shared.

It seems evident that further empirical evidence could strengthen this conclusion and confirm that the impact of KM on SME performance is extremely wide and simultaneously affects more performance. The above literature analysis allows us to formulate the following research question:

- **RQ3**: What is the impact of the use of knowledge management practices on SME performance?

In order to provide answers to the three research questions above, a field analysis was carried out on a sample of SMEs. The following section provides an overview of the research context in which the field analysis was conducted.

Table 2. The impact of knowledge management on small and medium enterprises (SME) performance (by author)

Author/Performance	Economic and Financial	Market	Technical and Innovative	Human	Organizational	Performance Number
Alegre et al. (2011)			x			**1**
Bagnoli and Vedovato (2012)	x		x			**2**
Beck and Schenker-Wicki (2014)	x					**1**
Daud and Yusoff (2011)	x	x	x		x	**4**
Delen et al. (2013)	x	x	x			**3**
Egbu et al. (2005)		x	x	x	x	**4**
Filippini et al. (2012)			x			**1**
Gholami et al. (2013)	x	x	x	x	x	**5**
Gupta et al. (2014)		x				**1**
Hong et al. (2014)	x	x	x	x		**4**
Liu and Abdalla (2013)	x	x	x	x	x	**5**
Omerzel and Antončič (2008)	x					**1**
Roxas et al. (2014)	x					**1**
Salojärvi et al. (2004)	x					**1**
Soon and Zainol (2011)	x	x	x	x		**4**
Talebi and Tajeddin (2011)		x	x	x		**3**
Wei et al. (2011)	x	x	x	x	x	**5**
Total	**12**	**10**	**12**	**6**	**6**	**46**

3. The Context of the Investigation and Methodology

The field analysis was carried out on a sample of 22 SMEs in 2013. The sample mainly consists of firms with 10–49 employees (63.7%), as shown in Table 3. In the table, the latest EU definition of SMEs proposed by the EU Commission was used (European Commission, 2005).

Table 4 shows that most of the SMEs operate in high-tech industries also characterized by a high level of complexity, such as aerospace, ICT and transport (systems and services); namely, industries in which knowledge management is crucial for firm competitiveness.

The SMEs investigated are part of important SME networks that have a critical impact on the territorial development of an Italian region that is a long-established leader in producing complex components for aerospace and railway industries. The investigation methodology is based on semi-structured interviews. The semi-structured interviews approach has the advantage that does not limit the interview to a set of predetermined responses, but at the same time the use of predetermined questions provides uniformity to investigation (Qu and Dumay, 2011). The investigation has been organized into the following five steps:

(1) *Definition of basic objectives and preparation of the draft semi-structured questionnaire*. In this phase, starting from the basic objectives of the investigation, a draft version of the semi-structured questionnaire was prepared.

(2) *Establishment of a focus group*. In this phase, a focus group involving experts with different competences and professional backgrounds was established. Specifically, the focus group encompassed researchers, entrepreneurs/managers of SMEs, and consultants operating in the field of KM. The focus group was set up in three different phases. Firstly, the topic investigated was presented in order to make focus group participants familiar with it. Secondly, the draft semi-structured questionnaire was submitted to the panelists in order to receive their useful feedback and comments. Finally, panelists' remarks were discussed in a plenary session.

(3) *Re-focusing the objectives and the semi-structured questionnaire.* On the basis of the feedback received during the focus group discussion, objectives were re-focused and the semi-structured questionnaire was revised and finalized.

(4) *Testing the semi-structured interview*. In this step, the final version of the semi-structured questionnaire was tested by means of 3 pilot interviews.

(5) *Field analysis implementation*. The semi-structured questionnaire was submitted during face-to-face interviews involving at least two managers with different skills

and roles (e.g., a manager involved in the firm's strategic decision-making process and a manager involved in operations management). This made it possible to obtain both strategic and operational perspectives.

In order to gain a more comprehensive picture of the sample investigated, information from complementary sources (e.g., company websites, company reports and industry magazines) were collected and analyzed.

Table 3 SMEs, breakdown by employees.

Employees Bands	Number of SMEs	%
Micro 0–9	5	22.7
Small 10–49	14	63.7
Medium 50–249	3	13.6
Total	**22**	**100.0**

Table 4 SMEs by industries

Overall Economic Industry	Specific Industry	Number of SMEs	%
Manufacturing	Aerospace	5	22.7
	Engineering	5	22.7
Service	Aerospace (R&D)	1	4.6
	ICT	5	22.7
	Management training and consulting	1	4.6
	Transport (system and services)	5	22.7
Total		**22**	**100.0**

4. Results and Discussion

This section describes the preliminary findings emerging from the semi-structured interviews. It is divided into three sub-sections. The first presents the findings related to the major barriers hindering the adoption of practices of knowledge management, the second describes the variety of KMSs used by SMEs, the third highlights the impact of using knowledge management practices on SME performance.

4.1. Barriers Hindering Knowledge Management Practices

On the basis of the feedback received during the focus group meetings (step 3 of the methodology) and from the pilot interviews carried out in three SMEs of the sample (step 4 of the methodology), the following 11 barriers hindering the implementation of KM practices have been identified: business culture, financial barriers, integration with existing processing, lack of shared language, lack of confidence in benefits, lack of managerial support, lack of staff skills, lack of time and resources, protection of critical information, tacit and non-formalized knowledge, and technological barriers.

To evaluate the importance of each barrier, a fuzzy set-based approach was used (Watanabe, 1979; Zadeh, 1965). Fuzzy logic gives us the possibility to use the rigor of logic to model natural language and common-sense reasoning (Michellone and Zollo, 2000; Zimmermann, 2001). Furthermore, it is an appropriate methodology to aggregate approximate judgements expressed by managers during the semi-structured interviews (through linguistic variables such as *very poor, poor, medium, important, very important*). In particular, the importance of each barrier was calculated as follows:

(1) The level of importance was defined as a linguistic variable: very poor, poor, medium, important and very important;
(2) Each level was associated with a fuzzy number;
(3) During face-to face meetings, managers of the 22 SMEs were asked to provide a judgement on the level of importance of each barrier;
(4) Each judgement was translated into the corresponding fuzzy number (Figure 2);
(5) The fuzzy mean was calculated for each barrier;
(6) The fuzzy mean of each barrier was de-fuzzified using the well-known mean-of-maxima (MeOM) method (Saletic et al. 2002). The result is a number that ranges from zero to ten representing the level of importance of the barrier (Figure 3).

Figure 3 highlights that the level of importance of barriers hindering the adoption of KM methods and techniques is very low (scores less than 5 out of 10). In fact, they range from 2.2 (lack of managerial support) to 4.8 (protection of critical information), where the mean equals 3.48, variance 0.87, and coefficient of variation 27%. Although SMEs are usually characterized by scarce financial and human resources, the low value of the mean and the coefficient of variation indicate that relevant barriers to the implementation of KM practices do not exist. Moreover, the level of importance attributed by the investigated SMEs to the "protection of critical information" barrier (score 4.8 out of 10) shows that there are still concerns about preserving intellectual assets from opportunistic behavior. Moreover, the very low score (2.2) attributed to barriers such as "lack of managerial support", "technological barriers" (2.4), and "lack of confidence in the benefits" (2.5) highlights that there are no significant technical and managerial obstacles to the spread of KM. These findings, despite coming from a sample of SMEs operating in high/tech or complex industries, highlight that both the results of Nunes et al. (2006), concerning the financial barriers that hinder the implementation of KM in SMEs, and the conclusions of Milosz and Milosz (2010) that identify the cultural barriers that SMEs have to face, are no longer true. This aspect emphasizes that in the space of a just few years the context has changed. SMEs are proving able to overcome the barriers that hampered the implementation of KM practices yesterday. In summary, with regard to RQ1, this section shows that we are witnessing an evolving scenario. Today, SMEs are able to overcome the barriers that prevent the spread of KM practices. Within this new scenario, there are new opportunities for SMEs and new frontiers to explore in the field of KM.

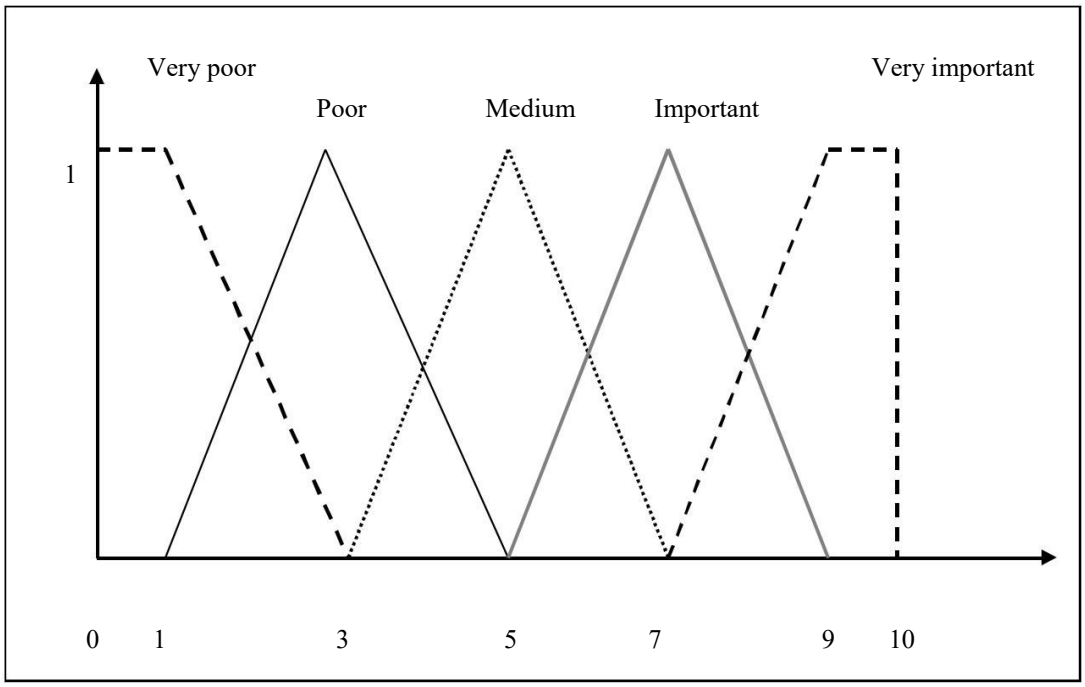

Figure 2 Fuzzy numbers associated to five qualitative levels.

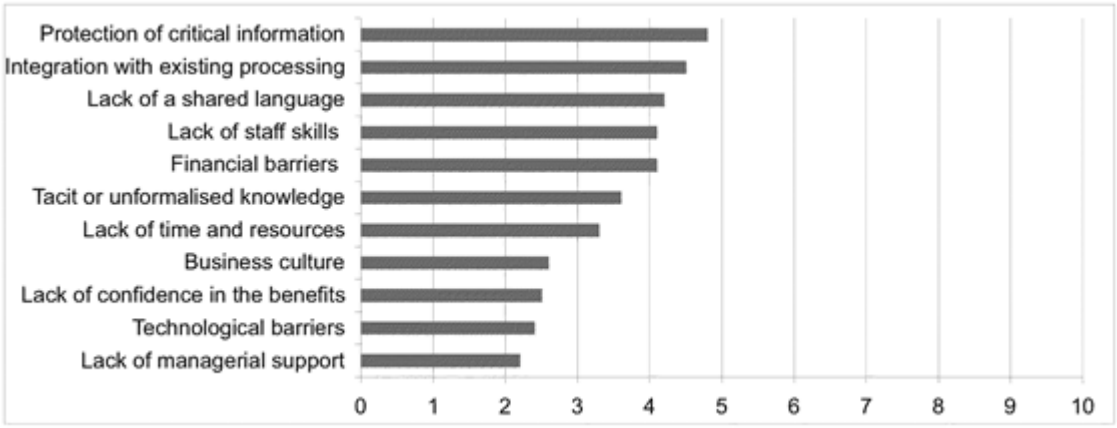

Figure 3 Barriers hindering KMS adoption—Level of importance (from 0 to 10)

4.2. The Adoption of Knowledge Management Systems

On the basis of the definition of KMSs used in this paper (IT-based systems to support methods and techniques of KM) that reflects that provided by Alavi and Leidner (2001), an investigation was carried out to ascertain whether SMEs were using knowledge management systems.

Figure 4 shows the KMSs used by SMEs. The classification of KMSs included in the figure was obtained following a three-step process. In the first step, a draft list of KMSs was obtained adapting those proposed by Alavi and Leidner (2001), Fink and Ploder (2009) and Massa and Testa (2011). Subsequently, this list was submitted to a number of experts in the field of information systems management. The feedback received was used to set up a further list of KMSs that was lastly scrutinised by managers of SMEs in the context of focus group discussion. The final list of KMSs obtained was used during the semi-structured interviews. The field analysis shows that the KMSs used by most of the SMEs investigated are the *database* (95.5%), *document management system* (86.4%), *e-mail and newsletter* (77.3%), *data mining* (72.7%) and *configuration management system* (59.1%). A second group of applications used by 50% of the SMEs includes *data warehouse*, *social media*, *video-conference,* and *content management system*. A third group used by 18%-27% of SMEs includes *podcasting* (27.3%), a *learning management system* (22.7%), and *peer-to-peer* (18.2%). Finally, a fourth group of KMSs with the lower level of usage includes *wiki* (9.1%), *collaborative filtering* (4.5%), *cloud computing* (4.5%) and a *crowd-sourcing system* (4.5%). These results complement and extend the findings of both Lopez-Nicolas and Soto-Acosta (2010), that identified Intranet and webpages as KMSs to support the process of organizational learning, and Rosu et al. (2009), that suggest a knowledge-based applications architecture based on the use of enterprise resource planning, customer relationship management, a document management system, data mining, and a data warehouse. The field analysis highlights that the SMEs investigated do not exploit the opportunities offered by wiki as a tool to share information and knowledge, as suggested, however, by Beylier et al. (2009), Grace (2009), and Razmerita and Kirchner (2011). This latter point seems to highlight that the SMEs are prone to using older KMSs such as a database and email instead of the newer KMSs, e.g., cloud computing, crowd-sourcing systems, and collaborative filtering.

A similar result emerges when considering KMSs associated with different phases of the KM process. In fact, for the creation phase, 72.7% of the sample firms use data mining and only 4.5% of the firms investigated use collaborative filtering and crowd-sourcing that are newer, cheaper and more user friendly. In the storage phase, a preference emerges for the older database (95.5%) instead of newer content management systems (50.0%). In the distribution phase, SMEs seem to prefer email (87.3%) rather than web 2.0 tools. This aspect is even more

significant when considering that the SMEs analyzed operate in high-tech and/or complex industries such as aerospace, telecommunications, transport, *etc.* where large companies adopt the most updated KMSs.

In summary, as far as the RQ2 is concerned, this paper highlights that the majority of SMEs investigated adopt a variety of KMSs. This finding seems to show that SMEs have a perception of the strategic value of knowledge management and consequently adopt IT systems to support methods and techniques to enhance the organizational processes of knowledge creation, storage, transfer/sharing, and application. Nevertheless, it also emerges that SMEs adopt more traditional KMSs instead of new and more updated tools that are generally cheaper and easier to use. During the interviews, interviewees have underlined that this gap is a consequence of two factors. On the one hand, SMEs typically do not have dedicated resources to monitor the evolution of the ICT market and are not even able to follow the technological dynamic. This forces them to remain in a backward position. On the other hand, ICT vendors generally prefer to deal with large companies rather than SMEs for financial and cultural reasons. Therefore, this gap highlights the difficulties in following rapid technological changes and the lack of support from the system's suppliers (Evangelista et al. 2013).

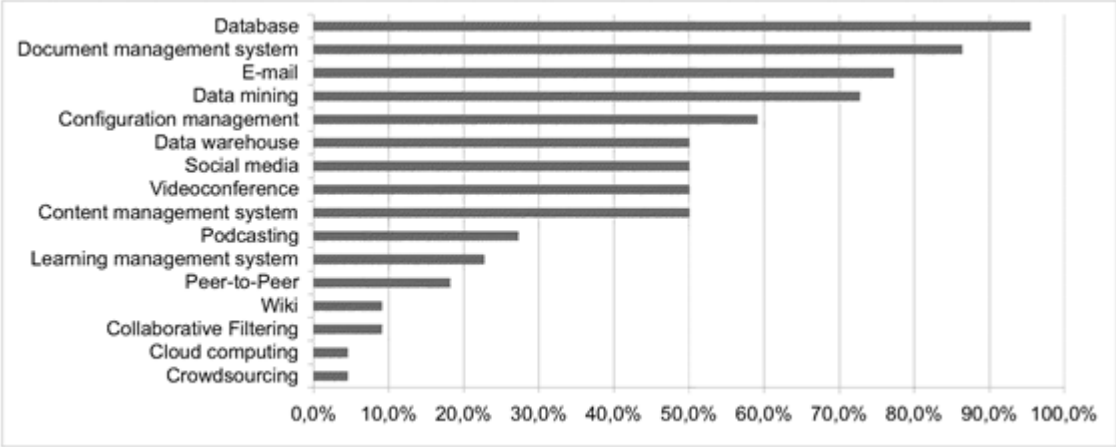

Figure 4 KMSs used by SMEs (%).

4.3. Knowledge Management and Performance

The literature analysis shows how the implementation of KM influences a variety of firm performance types, namely: economic and financial performance, market performance, technical performance, human performance, and organizational performance. Starting from these five kinds of performance, during face-to-face meetings, managers were asked to provide a judgement on the impact of KM practices for each type of performance using linguistic variables organized into five qualitative levels (very poor, poor, medium, significant, and very significant). The judgements were aggregated using a fuzzy mean and then de-fuzzified following the six steps illustrated previously. The results are shown in Figure 5.

Figure 5 points out that the impact of KM practices on firm performance ranges from 6.9 (human performance) to 8.1 (organizational performance), with a mean of 7.4, variance 0.21, and coefficient of variation at 6.2%. The values of mean, variance and coefficient of variation underline that the impact of KM practices is very significant and involves all five performance types simultaneously. This conclusion, on the one hand, confirms the results of Gholami et al. (2013), Liu and Abdalla (2013) and Wei et al. (2011) who had already stressed that KM improves all five performances. On the other hand, it reveals that the impact of KM on the performance of SMEs is extremely important.

In summary, regarding RQ3, the empirical evidence of this section highlights that the use of KM practices can contribute to an overall growth of SMEs by enhancing several firm performance types simultaneously and significantly.

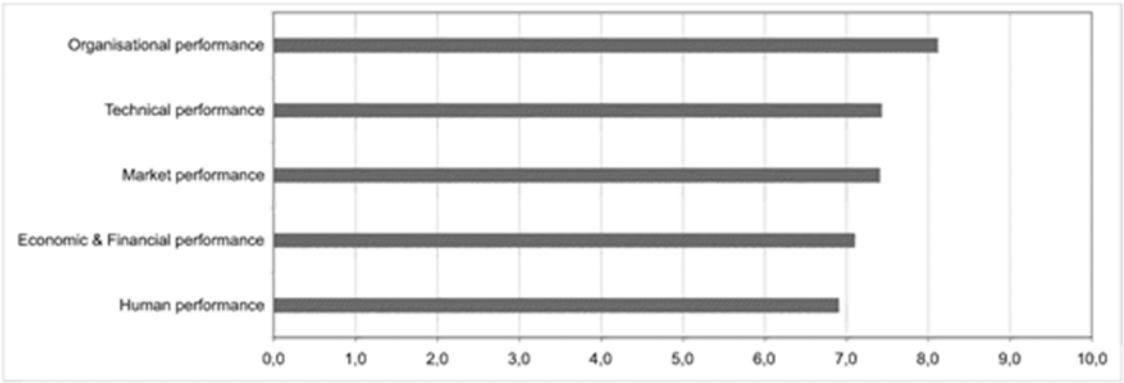

Figure 5 The impact of KM on firm performance—Level of importance (from 0 to 10).

5. Conclusions and Implications

The main aim of this paper was to give a contribution to increase the body of knowledge in the field of KM in SMEs. Through a literature review, three research questions were identified:

- RQ1: What are the major barriers hindering the spread of knowledge management practices in SMEs?
- RQ2: What are the main knowledge management systems adopted by SMEs?
- RQ3: What is the impact of the use of knowledge management practices on SMEs'performance?

These three RQs were addressed through a field analysis carried out on a sample of SMEs operating in high-tech and/or complex industries.

In relation to the first research question, the field analysis results indicate that although SMEs are usually characterized by scarce human and financial resources, they are able to overcome the barriers preventing the spread of KM practices. Thanks to technological innovation in the field of ICTs, cheaper and very easy to use KMSs are available posing reduced financial, technical and cultural barriers. This aspect stresses that the scenario is evolving and is offering SMEs new opportunities and new frontiers to explore in the field of KM.

As for the second research question, empirical evidence shows that the SMEs investigated have perceived the strategic value of KM and consequently adopt a variety of KMSs. Nevertheless, it emerged that they are generally prone to using outdated KMSs rather than the newer ones, which are also cheaper and user friendly. This gap shows the difficulties that SMEs usually have in following rapid technological changes, as well as the lack of support from ICT vendors in the decision-making process regarding the choice of appropriate KM tools and systems.

With regards to the third research question, empirical evidence points out that the impact of the use of practices of KM on firm performance can be extremely significant and at the same time improves a variety of performance. In particular, it emerges that KM contributes positively to the overall growth of SMEs by enhancing financial, market, technical, human and organizational performance.

These results show that we are witnessing an evolving process. Today, SMEs increasingly have access to new knowledge management systems, which do not need significant human and financial investments. This has allowed the reduction of the barriers that have hindered the spread of knowledge management practices in SMEs. Nevertheless, even today, SMEs do not exploit all the opportunities offered by new technologies. In the coming years, overcoming this gap could reduce the distance between SMEs and large companies in the field of knowledge management.

5.1. Future Research

The paper provides guidance for future research. The first research implication derives from the fact that SMEs generally use outdated KMSs rather than newer ones. This issue requires further and in-depth analysis concerning the degree of alignment between KMSs used by SMEs and the nature of knowledge from both the ontological and epistemological perspectives. Secondly, due to the increasing importance of firm networks in the development of SMEs, it seems important to investigate the ways through which knowledge is spread across networks populated by SMEs.

5.2. Implications

From the SME point of view, this paper has highlighted that KM contributes to overall growth by enhancing their performance simultaneously and significantly. However, SMEs could further increase the impact of KM by better exploiting the opportunities offered by the new ICTs (such as cloud computing, crowd-sourcing, collaborative filtering, wiki, etc.).

From the point of view of KMS providers, this paper has stressed that SMEs typically do not have dedicated resources to monitor the innovation process in the field of KMS. Nevertheless, they could represent a significant market. To seize this opportunity, it is necessary create a new market segment dedicated to SMEs, reducing the cultural distance between demand and supply by developing direct channels of communication (including virtual means) between SMEs and KMS providers.

5.3. Limitations

The results highlighted in this paper can be broadly applied to SMEs operating in high-tech end/or complex industries. Future studies will extend these results, expanding the sample and taking care to include SMEs representing different industries.

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SECTION II: The quality management approaches in service-oriented architecture

Introduction

In the field of information technology, Service-Oriented Architecture (SOA) is an approach to creating an architecture based on the use of “services”. This architectural style provides benefits such as increased organizational agility and reduced implementation costs, so it is very popular in modern industries.

The concepts introduced by service orientation are realized through the introduction of the concept of “service”, which is a software functionality performing a business task such as producing data, validating a client and so on.

Each service is marked by a description and communicates with another service via messages; this forms a basic architecture.

Service oriented architecture can be considered as an evolution of middleware systems, which integrates applications of different enterprise environments. According to the SOA approach, the services have to be loose coupled if the system is to be agile.

As far as back as 1993 in the study by Kendrick the importance of experimentation with distributed computing systems is stressed as a future research avenue to explore in the field of computational science.

Although the concept of SOA has been described in research and industry literature, the scenario concerning SOA quality metrics is still fragmented; there is a vast literature concerning software quality metric models following an object-oriented approach (Dubey et Sharma, 2012; Dubey et Rana, 2010), but these studies cannot be applied to an SOA system. As argued in the literature, the main problem with object-oriented quality metrics in service orientation is that they focus on “classes” which are implementation level concepts, while SOA solutions are based on the concept of “service”, which is a business concept marked by an interface and an implementation level, decoupled so that the service stands for an extra level of abstraction. Nevertheless, quality management in SOA applications is an important goal in assessing the compliance of the system with standard requirements and discovering problems that need to be solved as well as avoiding wasted resources in the advanced stages of process implementation. This study thus arises from the need to assess quality management approaches for SOA services. The importance of this research topic is underlined by three works which provide an overview of the major issues concerning quality measurement in Service Oriented Architecture.

Hasan et al. 2014 propose a literature review concerning SOA quality, adopting the service quality lifecycle perspective, in which they review sixty articles dealing with quality of service monitoring, but they focus on a particular aspect concerning the little evidence found in the literature on monitoring the vague quality of service specifications of an SOA. The

review highlights the need to treat SOA quality attribute values also as vague parameters, adopting certain approaches such as the fuzzy set theory rather than the more widespread deterministic approaches, due to the uncertain nature of web services.

Daud and Kadir (2012) investigate the state of the art in quality attribute measurement in service-oriented architecture by focusing on the most widespread quality attributes, the techniques applied in order to measure them, and the level of granularity adopted. It is a good starting point for a general overview of the topic, but defining quality attributes is also a key phase in the service quality lifecycle.

Later, Daud and Kadir (2015) propose a review of structural properties metrics in SOA design in which they review seventeen papers dealing with these properties, analyzed from both static and dynamic perspectives.

The review highlights the lack of studies on the dynamic perspectives of SOA application due to the intrinsic complexity of services at runtime. These studies highlight an increasing interest in measuring the quality of services in an SOA, but there is a need for an assessment, complementary to the previous works, that can consider two perspectives simultaneously: quality attributes and the service quality life cycle. Furthermore there is a lack of case studies in literature concerning SOA quality management approaches.

This work attempts to fill these gaps presenting the results of a literature research on this topic and describing the findings collected through an empirical analysis carried out in an important telecommunications company. After the introduction, the review methodology is illustrated, the selection of papers is shown in the second section, while the descriptive phase is presented in the third section and the content analysis of papers and main results are shown in the fourth section.

Lastly, the literature review's conclusions are presented. The sixth section shows the context of investigation, methodology and the main findings emerging from the empirical analysis.

Methodology

1. Literature review

This chapter presents the approach adopted in order to describe the state of the art in quality management in an SOA.

This approach aims to review the studies described in the literature using an explicit and reproducible method (Greenhalgh, 1997).

The contributions of Pittaway et al. (2004), Petticrew and Roberts (2006), Schneider and Wallenburg (2013) were taken into consideration when developing the review strategy.

Pittaway et al. (2004) propose a review strategy organized into several stages, which can be summed up as follows, the identification of key words thanks to brainstorming carried out by experts, the construction of search strings adopting Boolean operators, the exploitation of additional key words, choosing the citation databases, review of the selected citation databases using search strings, review of the citations identified according to the inclusion and exclusion criteria which involve the analysis of both the titles and the abstracts of the articles, classification of the articles into different lists using inclusion and exclusion criteria, supplementing with additional papers upon professional recommendation and references from reviewed papers, the evaluation of the significant papers and retrieved references, and a review of the final sample of articles according to relevant subject topic.

Petticrew and Roberts (2006) propose a review process organized into 12 steps: define the question that the review aims to answer, consider forming a strategic group to consult on the review protocol, write a protocol and have it reviewed, carry out the literature search, screen the references, assess the remaining studies in terms of the inclusion/exclusion criteria, data extraction, critical appraisal, synthesis of the primary studies by tabulating, reporting and graphic representation of the quantitative data, consider the effects of publication bias and other internal and external biases, writing up the report in order to avoid any loss of details of the full search, and wider dissemination.

Schneider and Wallenburg (2013) focus on two main processes of a systematic review.

The first is a descriptive analysis which gives us an overall view of the topic in terms of article distribution over time, methodology adopted, and identification of research areas; the second one is a content analysis which divides the identified research areas into topic areas.

Taking inspiration from the contributions in the literature, we designed the review process according to two main phases that, in turn, are divided into two steps:

1. Paper selection phase:

a. Comprehensive material search. This step aims to identify the key words and subsequent search string, to select the database to be investigated (Scopus, ISI Web of Science), and to review the database using research strings;

b. Selection of papers to be analyzed in detail, establishing the definition of criteria for inclusion/exclusion and the selection process according to these criteria.

2. Descriptive and content analysis phase for the selected papers:

a. Descriptive analysis. This phase provides an overview of the topic by tabulating and reporting on quantitative data;

b. Content analysis. Papers are reviewed and studied in depth. The analysis of the papers highlights the strengths and weaknesses in the literature; it serves to highlight research gaps leading to research questions for investigation.

2. Paper selection phase

2.1 Comprehensive material search

The first phase of the literature review is the selection phase; it aims to identify all relevant papers covering the topic of service quality measurement in service-oriented architecture.

As highlighted by Daud and Kadir (2012), selecting the correct terms for a search string provides the keywords establishing the boundaries of the research.

In this case, the keyword is “quality measurement” as the subject of the study, with “service-oriented architecture” as its domain. We also identified close terms and synonyms using some online business dictionaries which helped us identify changes in the language used to describe the subject area, enabling us to choose the most suitable keywords.

The terms are combined using the Boolean operators “AND” and “OR”.

The chosen keywords were put together into the following search string: (“service oriented architecture” OR “SOA”) AND (“measurement” OR “metrics” OR “monitoring”) AND (“quality attributes” OR “quality service” OR “quality”).

The chosen keyword string was inserted into the search engines, which allowed us to identify suitable references.

We chose the online databases Scopus and ISI Web of Science, including the most important high-ranking journals from 1960 until 2015, although attention towards this topic in research dates from 2005.

Our research yielded 660 documents, as shown in table 1.

Table 1 Material search

Keywords used	(“service oriented architecture” OR “SOA”) AND (“measurement” OR “metrics” OR “monitoring”) AND (“quality attributes” OR “quality service” OR “quality”)
Date range	Published from 2005 to present
Scopus database	588 hits
Web of Science database	159 hits
Total hits retrieved from two databases	747
Duplicates	87
Number of hits excluding duplicates	**660**

2.2 Selection of papers

The purpose of this phase is to only select papers dealing with the subject research area; three steps were identified which established the criteria for inclusion/exclusion as shown in table2.

Table 2 Criteria for inclusion/exclusion

First criterion: focus of the abstracts	Abstracts focusing on quality measurement and service-oriented architecture are included
Second criterion: focus of the papers	Papers focusing on quality measurement and service-oriented architecture are included
Third criterion: cited references	Additional papers, upon professional recommendation and references from reviewed papers or not included in Scopus and Web of Science on quality measurement in SOA are included

The first criterion follows the approach proposed by Pittaway et al. (2004), and it allows us to select only those papers whose abstracts focus on quality measurement in SOA. In order to

achieve this objective, abstracts of the 660 documents were read in parallel by two different researchers, plus a third one in case of uncertainty.
Following Petticrew and Roberts (2006), and Pittaway et al. (2004) the papers were categorized into the following three lists as shown in table 3:

1. List A includes papers with a focus on both quality measurement and service-oriented architecture;
2. List B includes papers with a prevalent focus on quality measurement, but scarce or insignificant reference to SOA;
3. List C includes papers with a predominant focus on service-oriented architecture but scarce or inconsiderable reference to quality measurement.

Table 3 First step selection

List	**Description**	**Number of papers**
C	papers with a predominant focus on service-oriented architecture, but scarce or inconsiderable reference to quality measurement	478
B	papers with a prevalent focus on quality measurement, but scarce or insignificant reference to SOA	29
A	papers with a focus on both quality measurement and service-oriented architecture	153
Total		**660**

The papers contained in List C (478) and list B (29) were excluded as they are beyond the scope of the research. The 153 papers contained in List A, selected on the basis of the abstracts, were considered in full and subjected to the second criterion to be analyzed in detail. The second criterion regards the focus of the paper and to ascertain it the papers were read in full by two researchers. The in-depth reading phase allowed us to exclude 83 papers (out of 153) not focused on the research topic.
The third criterion concerns references cited in the literature analyzed or not included in Scopus and Web of Science and additional papers on the basis of professional recommendation. Six additional papers were identified. Therefore the papers selected for the subsequent phase of descriptive analysis are 76 in number.

3. Descriptive analysis phase

We conducted a descriptive analysis of the 76 papers chosen before studying their contents in more depth.

The descriptive analysis of the papers aims to give an overall analysis of the papers that deal with the topic of quality management in the context of service-oriented architecture. For evaluation of the 76 selected papers, five perspectives were identified:

1. Papers through time;
2. Papers by research area;
3. Papers by methodology;
4. Papers by level of analysis;
5. Papers by topic area.

3.1Papers through time

Concerning the first perspective, it needs to be stressed that the kind of papers retrieved in the literature are mostly proceedings (57 papers), and only 19 papers are journal articles.

To focus the distribution of the selected papers over time we first examined the distribution of the selected proceedings. Descriptive analysis covers the distribution of the selected documents over time as shown in figure1. It appears that the number of studies reaches its peak in 2009-2010 and drops towards 2013, rising again more recently.

Some of the proceedings (11) have been published in series of books, and table 4 shows the papers' references and the books they appear in.

Most of the conferences were held in Asia, as can be seen from figure 2.

The proceedings come from three kinds of meetings: workshops, symposia, congresses and conferences.

Most proceedings are from conferences, as shown in figure 3.

The distribution of journal articles over time reaches its peak in the period 2014-2015, see figure 4. This point highlights an increased awareness of this topic among researchers in recent years; in fact the only two reviews on SOA quality found in the literature are from the period 2014-2015.

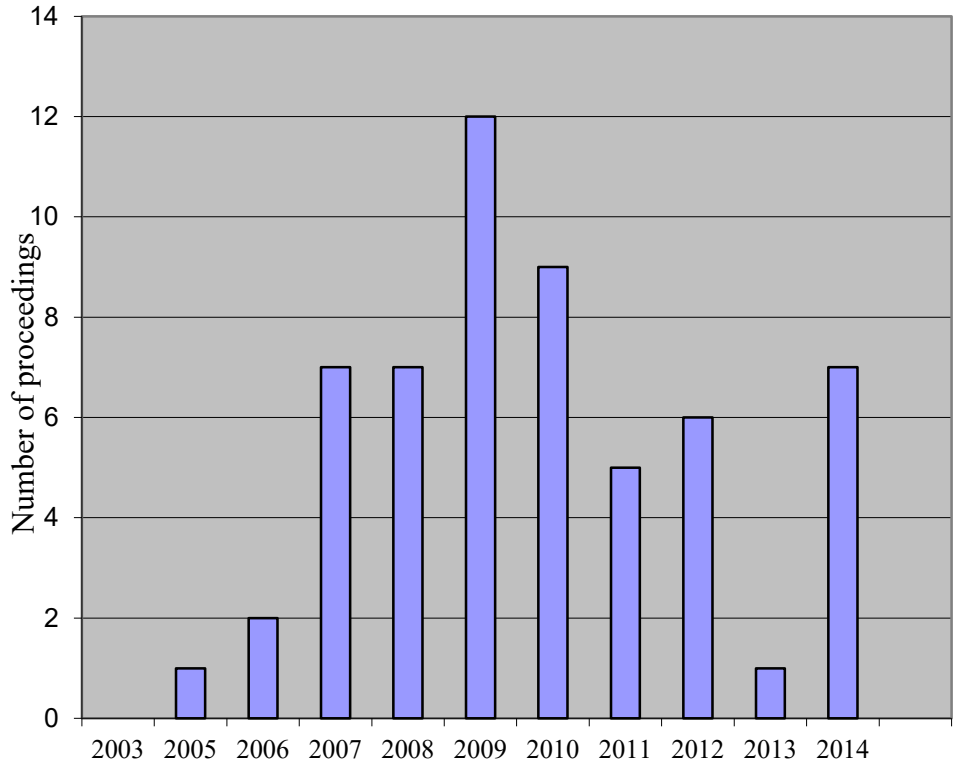

Figure 1 Proceedings over time

Table 4 Published proceedings

Proceedings authors	Library series	Chapter	Volume
Hirzalla et al. (2008)	Lecture notes in computer science	Service-Oriented Computing ICSOC 2008 Workshops	5472
Sindhgatta et al.(2009)	Lecture notes in computer science	Service-Oriented Computing ICSOC/ServiceWave 2009	5900
Baresi et al. (2005)	Lecture notes in computer science	Technologies for E-Services	3811
Souza et al. (2011)	Lecture notes in computer science	On the Move to Meaningful Internet Systems: OTM 2011	7045
Lee (2010)	Lecture notes in electrical engineering	Future Intelligent Information Systems	86
Comuzzi et al. (2009)	Lecture notes in computer science	Service-Oriented Computing ICSOC/ServiceWave 2009 Workshops	6275
Zeng et al. (2007)	Lecture notes in computer science	Service-Oriented Computing ICSOC 2007	4749
Zhao et al. (2006)	Lecture notes in computer science	Service-Oriented Computing ICSOC 2006	4294
Losavio et al. (2008)	Lecture notes in computer science	Software Architecture	5292
Robinson and Kotonya (2008)	Lecture notes in computer science	Service-Oriented Computing ICSOC 2008	5364
Feuerlicht (2010)	Lecture notes in computer science	Service-Oriented Computing ICSOC 2010 Workshops	6568

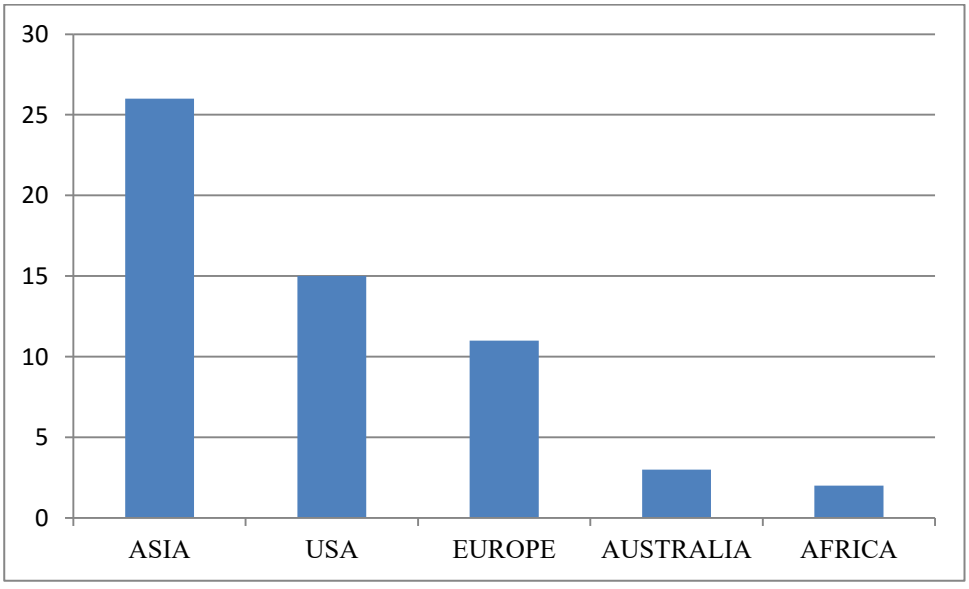

Figure 2 Conference locations

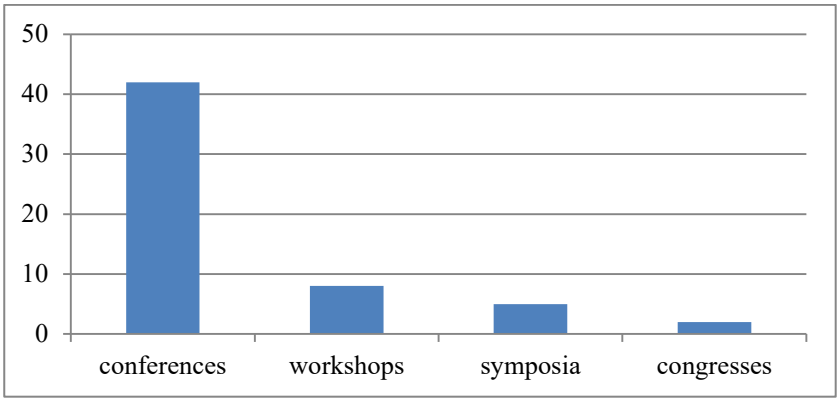

Figure 3 Kinds of scientific SOA meetings

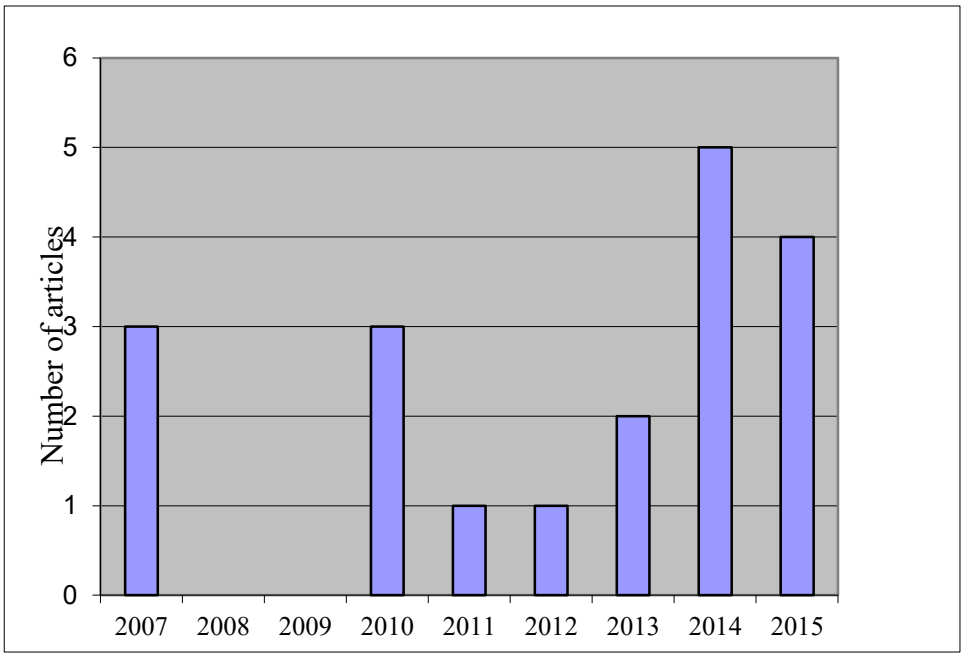

Figure 4 Journal articles over time

3.2Papers by research areas and methodologies

The functionalities provided by the SCImago Journal Rank platform were adopted to classify the subject area of the retrieved journal articles.

The following subject areas were identified (table 5): “Earth and Planetary Sciences”, “Social Sciences”, “Arts and Humanities”, “Biochemistry, Genetics and Biology”, “Business, Management and Accounting”, “Decision Sciences”, “Engineering”, “Computer Science”, “Medicine”, “Economics, Econometrics and Finance”, “Environmental Science”, “Mathematics”, “Multidisciplinary”.

Table 5 Papers distribution by journals

Journal		**Journal subject area**												
Number of articles	**Journal Name**	**Earth and planetary sciences**	**Social sciences**	**Arts and humanities**	**Biochemistry, Genetics and Biology**	**Business, Management and Accounting**	**Decision Sciences**	**Engineering**	**Computer Science**	**Medicine**	**Economics, Econometrics and Finance**	**Environmental Science**	**Mathematics**	**Multidisciplinary**
1	The Scientific World Journal				x					x		x		
1	American Journal of Applied Sciences													x
1	Artificial intelligence review		x	x					x					
1	CrossTalk								x					
2	Performance Evaluation								x				x	
1	Future Generation Computer Systems								x					
2	Expert Systems with Applications							x	x					
1	The Journal of Systems and Software								x					
1	Journal of software							x	x					
1	Journal of computers								x					
1	Transactions in GIS	x												
1	IEEE Transactions on Parallel and Distributed Systems								x					
2	IEEE Transactions on Services Computing						x		x					
1	Science of Computer Programming								x					
1	ACM Transactions on the Web								x					
1	Jurnal Teknologi							x						

Table 5 highlights that most of the articles focusing on quality measurement in service-oriented architecture are from journals whose subject area comes under the “Computer Science” category, with a lack of journals focusing on business and management or economic issues.

As for conference proceedings - the most formal kind of meeting - the subject areas were identified as illustrated in table 6.

This table highlights that most of the conferences focused on computing issues with less attention on business process management issues.

Table 6 Conferences by subject areas

Conferences		Subject areas				
Number of proceedings	**Conference name**	**Information management**	**Engineering**	**Computer Science**	**Business process management**	**Multidisciplinary**
3	International Conference on Services Computing			x	x	
	International Conference on Information Management and Engineering	x	x			
	International Conference on Research Challenges in Information Science	x				
	International Conference on e-Business Engineering		x	x	x	
	Asia-Pacific Services Computing Conference			x	x	
	International Conference on Information Science and Digital Content Technology	x		x		
	Australian Software Engineering Conference	x	x	x		
	International Conference on Recent Advances in Computing and Software Systems			x		
	International Conference on Computer Engineering and Applications		x	x		
	International Conference on Grid and Cooperative Computing	x	x	x		
	International Conference on Computer Science and Network Technology	x	x	x		
	International Enterprise Distributed Object Computing Conference			x		
	International Conference on Information Engineering and Computer Science	x	x	x	x	x
	International Conference on Advanced Communication Control and Computing Technologies	x	x	x		
	Conference on information and knowledge technology	x		x		x
	International Conference on Data and Software Engineering	x		x	x	
4	International conference on web services	x	x	x		
	International conference on service oriented computing and applications			x	x	
4	International conference on service oriented computing		x	x	x	
	International conference on Systems, Man and Cybernetics,		x	x		x
	International Conference on Software Engineering Advances	x	x	x		
	International conference broadband network and multimedia technology			x		x
	Confederated international conferences: On the Move to Meaningful Internet Systems			x		
	International conference on computer sciences and convergence information technology	x	x	x		x
	International Conference on Knowledge and Systems Engineering	x	x	x		
	International CSI Computer Conference		x	x		x
	Conference: National days of network security and systems	x	x	x		x
	Asia-Pacific Software Engineering Conference		x	x		
	International Conference on High Performance Computing and Communications	x		x		

	International Conference on Current Trends in Engineering and Technology		x	x		x
	International conference on service operations and logistics and informatics		x	x		x
	European Conference on software architecture			x		
	International Conference on e-Commerce in Developing Countries: with focus on e-Trust	x		x		
	International Conference on Next Generation Web Services Practices	x		x		

In relation to the research methodology adopted, the most widespread approach for measurement is modelling techniques (33 documents), the second is a theoretical approach (22 documents) involving frameworks, conceptual works such as dissertations and classifications of quality metrics, with only two literature reviews, and a few articles using case studies (10 documents), while others (11 documents) make reference to both mixed method (quali-quantitative) and measurement techniques (adoption of tool) to measure quality attributes, figure 5.

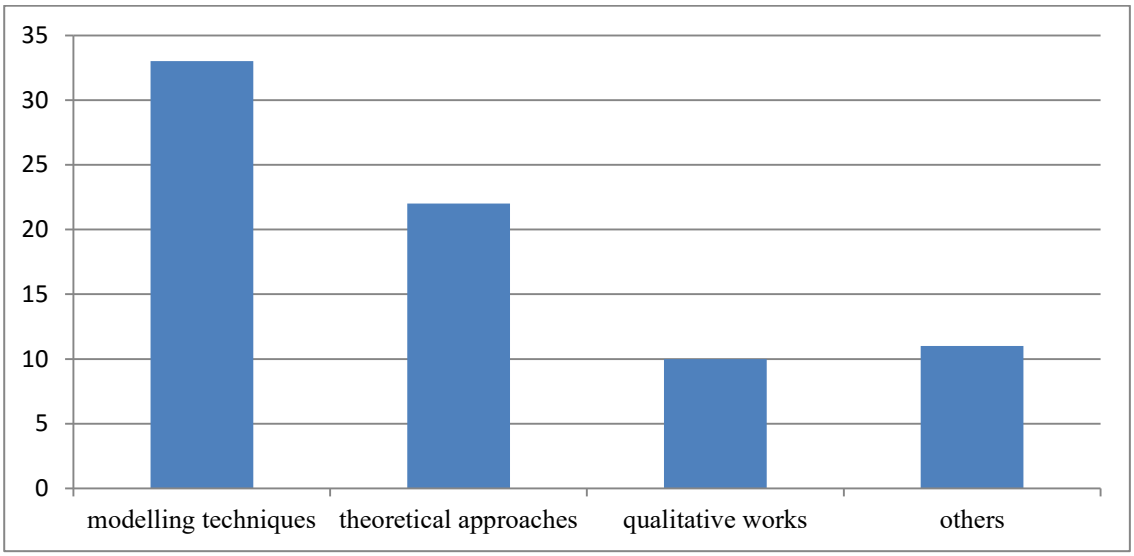

Figure 5 Documents by methodology

The thirty-three documents based on modelling techniques are divided into computational models, including 12 mathematics models, 4 statistics models, 3 artificial intelligence models (fuzzy set theory, neural network), and descriptive models involving both architectural models (9 documents) and quality models (5 documents), figure 6.

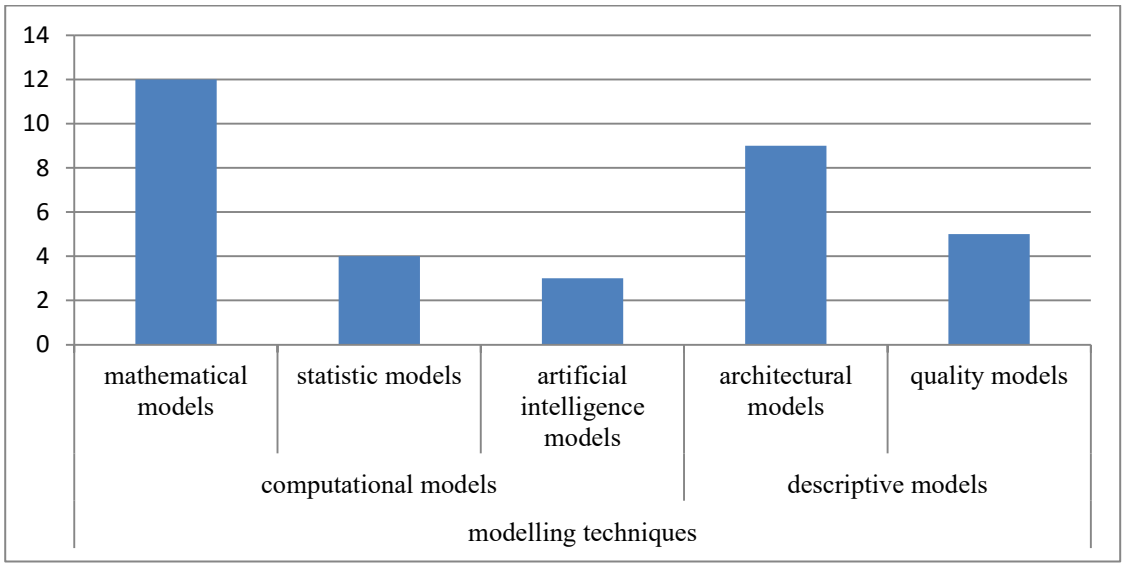

Figure 6 The division of modelling technique approaches into sub-categories

The theoretical works can then be subdivided into the following sub-categories: frameworks, literature review, and conceptual works, figure 7.

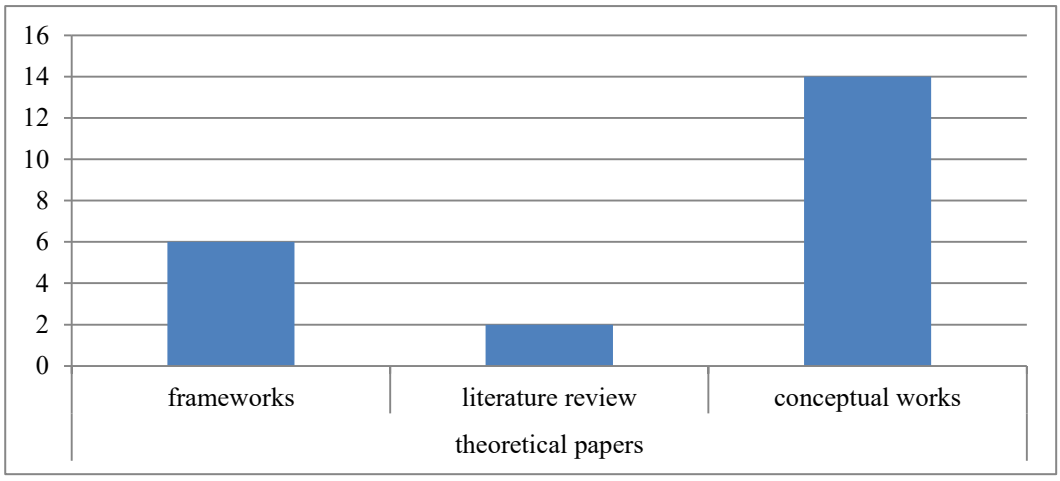

Figure 7 Division of the theoretical approach into sub-categories

3.3 Articles by level of analysis

In an enterprise adopting an SOA paradigm, it is possible to identify a business domain supported by a set of business processes and a system domain, which involves a set of services designed to perform the process tasks. In turn, a service provides a set of operations, each of which involves a set of messages which encapsulate data. It is therefore possible to identify three levels: business process, service layer, and application landscape. It is possible to classify quality approaches to services by SOA domain level. Yeom et al. (2006) classify the levels of an SOA architecture into three categories: service-level view, system-level view and business-level view. The service level makes reference to service behavior and its quality attributes; system level refers to services quality' requirements considering the operations of the services and their knowledge transfer, while the business view refers to the qualities of services considering business values in terms of service charge, the cost involved in requesting the service, compensation rate, and penalty rate. The classification of papers by service quality metrics/approaches based on domain level is shown in figure 8.

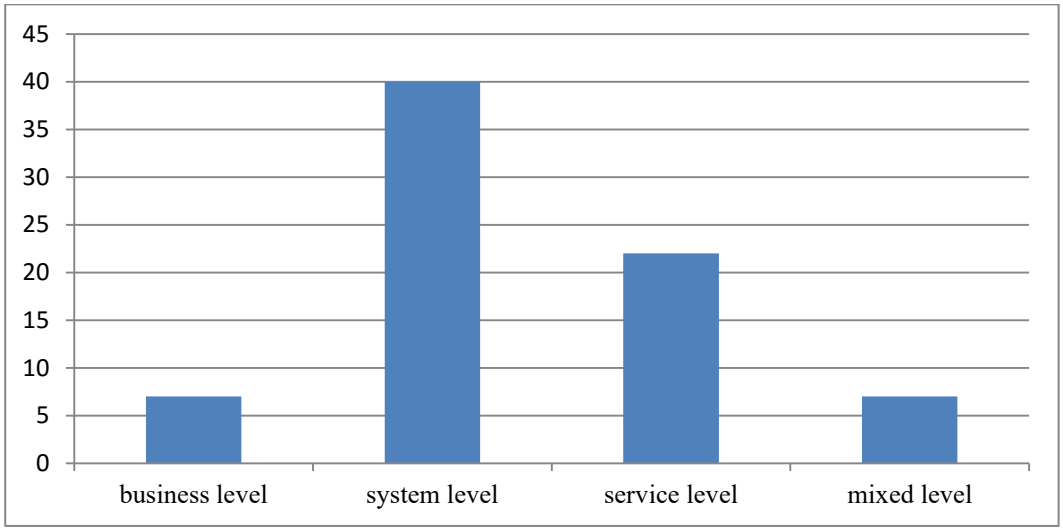

Figure 8 Papers by domain level

As shown in figure 8, most of the papers face the problem of SOA quality measurement at system level, focusing on the properties which embody the relationship between services in the domain, while very few works deal with service quality from a business point of view. From a business perspective, there is only one article dealing with SOA quality measurement from a financial point of view, evaluating the service as a "cost center" and calculating the revenue for the enterprise (Wang and Fan 2011). In the literature, the most widespread approach splits the business system from the IT system and relative quality measurement issues. In the yielded documents, only Liu and Fan (2007) propose a quality attributes model, merging the performance of workflow and quality of service through an AHP analysis.

3.4 Articles by topic area

In the literature, authors have tried to address software product quality issues by breaking down the concept of quality into a number of quality factors, which mirror the software characteristics. Once the software characteristics have been defined, they have to be connected to indicators and metrics. The first to propose this approach were McCall, Richards, and Walters (1977). Reinforcing this idea are the contributions of the International Organization for Standardization (ISO) and the International Electro-technical Commission (IEC), which have defined a standard set of quality characteristics referencing internal and external metrics. The guidelines are ISO/IEC 9126 (2001) which have been revised by ISO/IEC 25010 (2011); this set reflects a big step towards consensus in the software industry and thereby addresses the general notion of software quality. Taking inspiration from these guidelines, which prescribes the general notion of software quality and criteria for quality measurement, scholars have addressed the topic of SOA quality by first identifying all the quality attributes in order to derive quality metrics for services. The research focuses on two classes of quality attributes for measurement in SOA, namely, structural/internal quality attributes and external quality attributes. This leads to identifying the first macro topic area: quality attributes which affect the quality measurement of SOA services, that can be split into two sub-topic areas: structural quality factors and external quality factors.

3.4.1 An overview of the first topic area: quality attributes

Concerning the first sub-topic area, the structural properties of services are: granularity, coupling, cohesion, and complexity, which are designed by the developers, Perepletchikov et al., (2007). They only address the aspects of a system that are available exclusively for system architects. The external quality properties on the other hand make reference to a service's behavior within the system of which it is a part from the perspective of the service consumer or provider, e.g.: performance, security, availability, and reliability, Choi et al. (2007a, b).

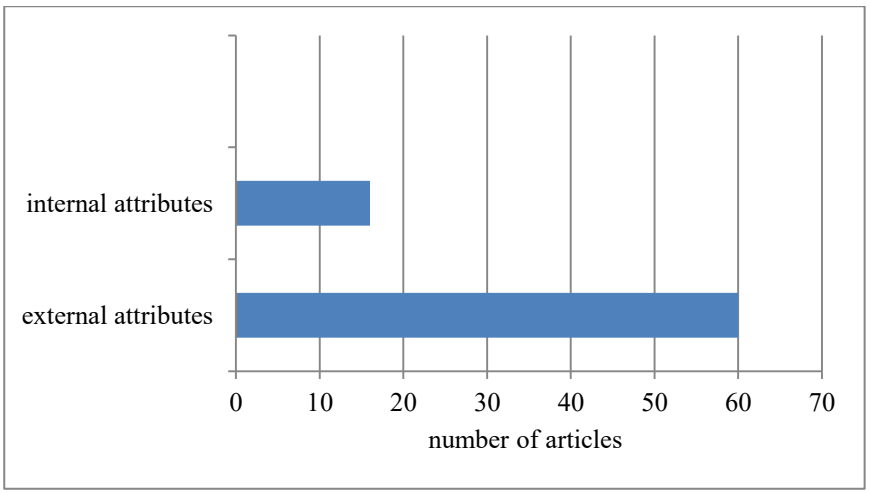

Figure 9 Papers by first topic area

Table 7 Papers by first topic area

Topic area: service quality attributes	
Structural/internal quality attributes	**External/non- functional quality attributes**
Alahmari et al.(2011)	Akzhalova and Poernomo (2010)
Daud and Kadir (2015)	Alamelu and Zubair (2014)
Deepiga et al.(2014)	Baghermousavi et al. (2014)
Feuerlicht (2010)	Balfagih and Hassan (2009)
Hirzalla et al.(2008)	Balfagih and Hassan (2010)
Hock-koon and Oussalah (2010)	Baresi et al.(2005)
Hofmeister and Wirtz (2008)	Bouasker and Langar (2014)
Karhikeyan and Geetha (2012)	Brosig et al. (2014)
Ma et al. (2009)	Bruneo et al. (2013)
Perepletchikov et al.(2007)	Cabrera and Franch (2012)
Sindhgatta et al. (2009)	Cardellini et al. (2009)
Singh and Singh (2010)	Choi et al. (2007a)
Thi et al. (2009)	Choi et al. (2007b)
Wang(2009)	Comuzzi et al. (2009)
Zhang and Li (2009)	Daud and Kadir (2012)
Zhao et al. (2006)	Dubey and Menascè (2010)
	Estrella et al. (2010)
	Fei et al. (2008)
	Fei et al.(2010)
	Golshan and Barforoush (2009)
	Gomathy and Rajalakshmi (2014)
	Guo et al. (2008)

	Hasan et al. (2014) Her et al. (2007) Kassou and Kjiri (2012) Lau (2007) Lee (2010) Liu and Fan (2007) Liu et al. (2011) Losavio et al. (2008) Menasce et al. (2007) Menascè et al. (2010) Mezghani and Halima(2012) Muller et al. (2014) Musavi et al. (2014) Nematzadeh et al. (2014) Newman and Kotonya (2012) Nuraini and Widyani (2014) Oriol et al. (2015) Owrak et al. (2012) Potena (2013) Psiuk et al. (2012) Punitha and Babu (2008) Robinson and Kotonya (2008) Rud et al. (2007) Safy et al. (2013) Seip and Bill (2015) Schuller et al. (2014) Shim et al. (2008) Souza et al (2011) Teixeira et al. (2009) Ukor and Carpenter (2009) Villegas et al. (2011) Vinek et al. (2011) Wang and Fan (2011) Yeom et al.(2006) Yoo et al. (2010) Yu et al. (2007) Zeng et al. (2007) Zheng et al. (2010)

Figure 9 and table 7 show that “external quality attributes” is the sub-topic area with the highest number of documents (60), and the “internal quality attributes” sub-topic area includes 16 documents. The quality attributes are the characteristics of the service/software; once the quality attributes have been defined, they have to be measured, so it is possible to identify the second perspective to analyze the problem of the second topic area: the service quality life-cycle process.

3.4.2 An overview of the second topic area: the service quality life cycle

The second sub-topic area, the "service quality life cycle" process is categorized into 3 different phases: definition, monitoring and selection (Fei et al. 2008).

The definition phase specifies the QoS attributes and related metrics, the monitoring phase obtains the values for the quality metrics, and the selection phase selects services according to specific requirements based on collected quality metric values.

As shown in table 8, the majority (47 documents) of retrieved papers focuses on the monitoring phase.

Table 8 The phases in the QoS lifecycle process

QoS lifecycle process		
definition	monitoring	selection
22	47	7

Table 9 shows the categorization of papers belonging to the sub-topic areas of quality attributes by QoS lifecycle process phase and the methodology adopted to analyze these phases.

Table 9 Quality of Service life cycle process by methodology

External quality attributes		QoS lifecycle process			
		methodology sub-categories		definition	monitoring	selection
methodology	theoretical approaches	literature reviews		1	1	
		frameworks		1	5	
		conceptual works		12	2	
	computational models	mathematical			6	6
		statistical			3	1
		artificial intelligence	fuzzy		2	
			neural network		1	
	descriptive models	architectural models			9	
		quality models		5		
	qualitative approaches	case studies		2	7	
	others	measurement tool			4	
		quanti/quali approaches		1	7	

Intersecting the two “phases of QoS lifecycle” and “methodology” perspectives, it emerges that for the definition phase, which provides the quality metrics as the input for monitoring strategies and includes 22 documents, the most widespread approach is the theoretical approach and in particular the conceptual perspective, with few empirical validation studies through case study (qualitative approach). The monitoring phase includes 47 papers in which the most widespread approaches are the quantitative models involving mathematical, artificial intelligence and statistical models: a computational model is given and some experimental results are shown, with few works adopting a qualitative approach. Only two recent literature reviews have been retrieved. The selection phase follows monitoring phase approaches in terms of methodology.

4. Content analysis: the characteristics of the research areas

A contents analysis of the 76 documents gives us a detailed overview of the aspects covered by research on quality measurement within an SOA.

Two content perspectives are identified: the quality attributes topic area (internal and external quality attributes) and the topic area concerning the phases in the service quality life cycle process, namely, definition, monitoring and selection.

These two contents perspectives are analyzed in depth in the following paragraphs.

4.1 The characteristics of the first topic area

Concerning the first topic area, that of quality attributes, the research focused on two classes of quality attributes to be measured in an SOA, i.e., the internal/structural attributes and the external quality attributes.

The internal quality attributes include complexity, cohesion, coupling and granularity.

Zhang and Li. (2009) present a set of metrics to assess the complexity of compound services and service-oriented systems.

This refers to an attempt to know the implementation of a service; it can be quantified as the number of services in a composite service or by the size of service operations, for example, so it is coupled to service granularity, as shown in the study by Alahmari et al. (2011).

The service granularity metric, whose value is based on interface properties, refers to both data granularity, the type and size of the data elements used in a service operation, and to the granularity of the functionality, and to the logic encapsulated within an operation or operations in a service or, otherwise, the functions which the service offers. Another important factor to be included is the relative coupling of services, the degree to which one service depends on another's interface or otherwise, and the more the number of requested services increases, the more complex the system is, (Zhang and Li 2009). It is clear that if a service has a high relative coupling index, the design of the service is "bad" and a redesign is needed.

Concerning internal attributes, also service cohesion has to be measured.

This refers to service operations similar in terms of exchanged message type or operation type.

However, analysis of the papers on internal quality attributes highlights that in several occasions they are the starting point for the calculation of external quality attributes, which are those most emphasised in the literature, see figure 9.

Concerning external QoS attributes there is no common consensus in the literature on which and in what way they should be monitored in a quality assessment program, though the most popular are: reliability, availability, reusability and maintainability, and performance.

Reliability involves the ability of a service to operate with specified quality requirements over time. It can be measured keeping in mind both the service failure ratio and the mean time between service failures (Choi et al. 2007a, b).

Reliability plays an important role in service composition, which involves several services operating in heterogeneous environments because the reliability of one service can affect the reliability of the whole service composition.

Service availability refers to the ratio of time in which a service runs normally and provides the required business operations for specific customers (Lee 2010).

Service maintainability concerns the effort needed to modify the software product, including corrections and improvements, as shown in the study by Perepletchikov et al. (2007). Coupling and cohesion in isolation can predict external quality of service such as maintainability.

The attributes of coupling and cohesion also allow predictions regarding reusability. In fact, as argued by Sindhgatta (2009), a service whose operations are cohesive and have fewer external dependencies will be more easily reusable.

Furthermore, Feuerlicht (2010) proposes a simple design metric to estimate the level of coupling between services in order to evaluate the reusability of services.

Performance in SOA governance can be defined as the time required for a service to complete a specific task; in a dynamic context, as argued by Villegas et al. (2011), this involves network latency (including transmission time, propagation time, internet protocol delay, and congestion) which refers to the time required by a service to respond to an event, throughput, capacity, and efficiency. The performance efficiency concept is established by ISO 25010 and involves three sub-concepts: time behaviour, the use of resources, and capacity.

In particular, the evaluation of SOA service performance is a typical issue because the nature of SOA architecture is complex due to the heterogeneity of service platforms and the deployment of services in a distributed environment.

The contributions found in literature are not always able to apply performance analysis in a practical way taking into account the dynamism of an SOA (Her et al. 2007).

In the literature, the response time is stressed as the most effective performance indicator in an SOA implementation.

On the other hand, there are several approaches to the performance topic, the most widespread of which is the introduction of models.

As argued by Brosig et al. (2014) the existing performance modelling approaches can be classified into predictive performance models and architecture level performance models. The former adopt prediction techniques such as queuing networks, queuing Petri nets, stochastic process algebras, and statistical regression models: these approaches aim to establish the system's behaviour over time, in order to achieve performance prediction by analytical techniques. Otherwise, the architecture level performance models are descriptive in nature and adopt UML standard modelling language for software architectures to depict service domain or service-oriented applications using graphical diagrams. Other approaches concern the adoption of mathematics models which deal with performance issues together with other quality attributes in order to solve an optimization model whose results show the best combination of quality attribute values for a specific SOA domain (Potena 2013).

Table 10 Service performance documents per QoS lifecycle and methodology

performance attribute		methodology sub-categories		QoS lifecycle process		
				definition	monitoring	selection
methodology	theoretical approaches	literature reviews				
		frameworks		1		
		conceptual works		2		
	computational models	mathematical			1	1
		statistic			1	
		artificial intelligence	fuzzy			
			neural network			
	descriptive models	architectural models			4	
		quality models				
	qualitative approaches	case studies				
	others	measurement tool				
		quanti/quali approaches			3	

Table 10 shows the categorization of papers dealing with service performance from the points of view of the QoS lifecycle process phases and the adopted methodology. The lack of qualitative approaches to this topic is evident. In summary, this study highlights the need for a more comprehensive analysis of service performance among the external service quality attributes using a qualitative approach.

4.2 The characteristics of the second topic area

As for the second topic area, i.e., exploring the QoS life cycle process, the first phase of a QoS life cycle is to establish a definition; it is important to stress that although it marks external quality attributes, external attributes are often calculated in a roundabout way using internal attributes as a starting point, as shown above. Thus, the definition phase can also involve the definition of the internal quality attributes.

As shown in table 9, the most widespread approach to the definition phase, which involves the description of both quality attributes and metrics, is the theoretical approach; in fact as argued by Perepletchikov et al. (2007), the service quality attributes metrics proposed in the literature are mostly validated in either a subjective or an axiomatic manner.

Quantitative adherence to quality principles is somewhat ambiguous, partly due to the fact that service-oriented principles are subject to interpretation and also to the fact that often the design metrics found in the literature can hardly be applied to the SOA applications domain, which is complex because, like the evolution of middleware systems, it is intended to link applications from different organizations, thus involving overlapping messages and the requirements of a wide range of users.

Furthermore, service-oriented systems quality metrics/approaches are often proposed in the literature as a solution for specific scenarios.

The definition of quality attributes is the starting point for designing monitoring strategies, which verify the compliance of software properties with quality standards. They regard the data collection phase and the QoS metric computation phase. On the other hand, the monitoring phase is closer to the selection phase; the latter addresses the aim of selecting services which match QoS constraints, verified in monitoring steps, in order to put together services for an application or to produce a quality assessment.

The monitoring phase is proposed from a theoretical point of view mostly by the introduction of frameworks, table 9.

They describe the different actor-relationship structures in an SOA monitoring environment in order to provide guidelines for the development of theories and models.

Fei et al. (2008) propose a policy-driven monitoring framework for collecting QoS information focusing on cross-domain service interaction, unlike the most widespread approaches which focus on monitoring service interaction in a single domain. This framework involves a data collector, metric generator and feedback controller covered by user-defined policies.

However the definition of the policy, deduced from SLA documents, is put together manually by monitor users.

Baresi and Guinea (2005) propose a uniform framework, which involves both WS Policy and WS-CoL (Web Service Constraint Language) in order to fulfil both functional and non-functional constraints even though the paper only addresses non-functional requirements: in particular, it focuses on security as a quality attribute. This framework turns monitoring directives into policies by means of supervision rules, but these rules are static and they cannot be changed dynamically.

Furthermore, model approaches can be considered when evaluating monitoring strategies. They start from frameworks, but they lend themselves more readily to testing.

Zeng et al. (2007) implement a kind of descriptive model to compute QoS metrics and associate evaluation formulas through a monitoring framework able to identify systematic detection and routing of operational service events. A metrics computation engine has been implemented to test the system throughput. These are the first to propose the idea of metric value collection through monitoring, as argued by Fei et al. (2008); nevertheless they address the topic of monitoring only focusing on QoS collection, without following through with the handling of QoS exceptions.

Souza et al. (2011) stress the lack of flexibility on the reconfiguration of QoS monitoring scenarios and data analysis in the literature, so they propose a dynamic event-driven monitoring mechanism for observable QoS attributes validating it in an SOA scenario, but they do not adopt an autonomic management infrastructure.

Muller et al. (2014) have recently presented a platform called “SALMONonADA”, whose architectural model can be considered as an instantiation of a more general conceptual reference model for SLA violations, which is presented in their paper. This platform involves a monitor engine, responsible for monitoring the services, an ESB, Enterprise Services Bus, which intercepts all requests and responses and feeds the measuring instrument, and a QoS repository, which stores the measured metrics. To carry out the detection and explanation of SLA non-fulfilment, a solver was adopted, analysing SLAs using a problem-based constraint satisfaction technique.

This platform performs an automated monitoring configuration, but the issues concern integration with different monitor systems as well as supporting different SLAs and the inevitable overheads which affect service quality parameters, such as response time. This can be mitigated using “SALMonADA” in alternative locations.

As well as the above-mentioned descriptive models, which focus on system architectures, computational models are also mentioned in the literature as monitoring and selection strategies, mainly to try and solve the quality attributes trade-off problem.

As shown in table 9, the most widespread approach among the computational models is a mathematical approach concerning the adoption of optimization techniques to model the service selection problem as a constraint satisfaction optimization problem. According to this approach, a conformance parameter is defined which expresses whether the requirements of the QoS metrics were satisfied by the provider.

Yu et al. (2007) address the problem of service selection by optimizing an application-specific utility function under end-to-end QoS constraints. Both optimal and efficient heuristic algorithms are presented. The algorithms are used to solve the problem for two flow structures: for service processes with a sequential flow structure and for service processes with a general flow structure, including loops, conditionals, and parallel operations.

Menascè et al. (2010) propose an optimized algorithm to solve the problem of finding the set of service providers that minimizes the total execution time of a business process given specific constraints.

This is a good approach for problems of moderate size.

Nevertheless, as the dimensions of the problem increase, heuristic modelling techniques have to be adopted, which attempt to find sub-optimal solutions within a reduced computation time (Potena 2013).

As argued by Robinson and Kotonya (2008), until 2008 the service quality management schemes proposed in the literature concerned the static properties of the system, but the dynamic nature of a system requires a dynamic runtime monitoring approach able to identify problems that arise in the service execution environment as a result of service composition, for example. In order to reach this goal, recovery strategies have to be implemented.

As Newman and Kotonya (2012) argue, there are attempts in the literature to try to study ways of managing the runtime quality of service-oriented systems using QoS policies, but they are based on static quality properties.

Another important monitoring issue concerns the placement of monitoring activity, such as the provider side, the client side and third parties, like the Enterprise Service Bus and the inevitable overheads linked to the topology which can affect service quality attributes.

Furthermore, concerning the selection phase, the research focuses mainly on achieving operational (Ukor et al. 2009) rather than strategic goals. Future research should address how

to align strategic goals with service selection in order to improve performance analysis in a business process.

Concerning the methods of addressing both the monitoring and selection phases studied in the literature, most of the studies use a deterministic approach to measuring service quality attributes (Schuller et al. 2014), calculating the value of a quality attribute as an exact parameter value, but as argued by Hasan et al. (2014), it is not realistic to specify the exact QoS due to the uncertain nature of web services and the network. Karhikeyan and Geetha (2012) propose a fuzzy model for measuring the degree of coupling in service-oriented architecture based on the concept of dependency among services, but this model needs to be validated using a monitoring tool.

Musavi et al. 2014 propose a Fuzzy Model for the Evaluation of External Service Quality Parameters in order to select the best web service, implementing a case study.

Similarly, research in the area of stochastic QoS attributes, however, is rather fragmented, (Schuller et al. 2014). The few works proposing a statistics method can be divided into parametric and non-parametric approaches, and they try to estimate quality attributes from statistical distributions.

As simulation results in Zheng et al. (2010) show, estimating QoS in order to obtain a selection for web service composition can be accurately achieved using QoWS probability density function representation thanks to the non-parametric statistical method, which is better able to reflect the real QoWS distribution than standard statistical distributions can.

This study highlights that research avenues are moving towards the study of an automated monitoring configuration, which adapts to the runtime environment, and is able to automatically extract and interpret the services information needed to detect violations, policies, and logging tracks, in order to reduce topology-linked monitoring overheads.

There is also a need to examine SOA quality attributes values in depth using both fuzzy set theory and stochastic approaches.

5. Literature review implications

This work has presented the state of the art in quality management approaches in service-oriented architecture, allowing us to identify some gaps in the literature from which to derive future research implications.

This descriptive analysis offers a helicopter view analysis of the papers included in the review process. It has allowed us to provide a summary outlook of the papers on the topic of quality measurement in the context of service-oriented architecture. In particular, the descriptive analysis has highlighted that the topic of quality in service-oriented architecture involves a research area focusing on the computer science category. The descriptive analysis has also shown that the vast majority of documents are based on modelling techniques as their methodology, with few papers using qualitative methodologies such as case studies.

Sometimes the application of model measurement to a real SOA domain is presented as a future research avenue.

Starting from this gap related to the need to exploit firms' practices in the field of SOA quality, it is possible to formulate the following research question:

RQ1: *"In practice, how can a quality monitoring program be applied to an SOA platform?"*

Concerning the level of analysis, it is important to stress that the topic of SOA quality measurement has been addressed mainly at system level rather than at business process level, little attention is given to the relationship between IT level and business level in terms of quality assessment. This gap allows us to formulate the following research question:

RQ2: *"How can an SOA program deliver support to both IT and business in terms of a quality assessment plan in order to improve performance analysis for the entire enterprise?"*

Regarding the topic areas, two perspectives have been identified: attributes which affect quality measurement in an SOA architecture, and the phases of the QoS life-cycle.

The most important service quality attribute which needs greater analysis using case studies is service performance.

This gap allows us to identify a research avenue for the implementation of SOA performance case studies.

Another field requiring more in-depth study is the way quality attributes are defined. In the literature, deterministic approaches are most common, but they are not always realistic.

This gap allows us to formulate the following research question:

RQ3: "*What are the possible approaches to defining quality of service attributes?"*

Monitoring is the key phase in the quality of service lifecycle; in fact it regards the output in the definition phase and the input in the selection phase.

In order to meet environmental changes, service monitoring has to be automated and carried out at runtime. There have been some attempts to study this issue in recent years, but they are still few and too closely linked to SLA specifications and system topology, so this is a rich avenue of research for the future.

In order to give an answer to one of the retrieved research questions, concerning the lack of case studies, an empirical analysis on SOA services performance has been carried out in an important telecommunications company. We chose the performance as quality attributes to explore because performance evaluation is a typical issue in SOA environment, as highlighted by literature review.

The following section provides an overview of the research context in which the empirical analysis has been conducted.

The context of investigation

6. Introduction

In this chapter the empirical study carried out in a large company operating in telecommunications industry is presented, this phase is aimed at exploring performance features for the services in a SOA platform, as software technology, in order to identify the most critical services to monitor in a quality control program. We propose a framework for quality assessment in a SOA architecture, which involves the following phases: Define, Measure, Analysis.

6.1 Define

In this phase the services and their critical quality issues are presented. This work adopts service provider perspective focusing on system environment rather than business environment, operating at design time, these project boundaries were set by the telecommunications company which is involved in our research work. The involved telecommunications company implemented 150 SOA services. We make reference to a sample of nineteen SOA services, each one is invoked by a single client. For each service we are going to investigate the related performance. In order to get this aim we process the following daily data since July 2015 up to September 2015 for every service: begins, average response times and related standard deviations, errors; so for every service' variable a sample of ninety-two elements can be defined taking in account the entire period of observation.

6.1.1 Environment Description and network topology

The SOA system core of the company involved in the case study is the enterprise service bus, ESB, which is a functional intermediary between consumer and provider. The enterprise service bus topology involves that message transformation and routing are executed by an engine which is distributed to the application adapters rather than centralized into a single ''hub'' like in the hub and spoke topology. In the last one the "hub" acts as a single centralized broker system which routes the data but this design pattern depends on the hardware/volumetric capabilities of the hub a lot. The concept of ESB has been arisen from the need to move away from point-to-point integration, which becomes hard to manage over time due to no central way to monitor. The core concept of the ESB architecture is that you integrate different applications by putting a communication bus between them and then enable each application to talk to the bus. This decouples systems from each other, allowing them to

communicate without dependency on or knowledge of other systems on the bus. Internal mechanism of the SOA service system is as following: (a) a client sends a request message, (b) the message is transferred into ESB, (c) ESB routes the message to the business process engine, (d) business process engine executes its activities and invokes external web services through ESB, and (e) the external web service executes the request and return the result to ESB.

The enterprise service bus ESB' roles are:

1. Service composition;
2. Content based routing;
3. Protocol switching / adapter;
4. Reliability;
5. Transformation and semantic reconciliation.

In the context of our company, the measurement values (daily average response times, set limits, policy violations, begins) have been developed manually by enterprise programmers, responsible for enterprise service bus management, extracting manually services' raw data, so providing us the inputs for the calculation of the performance efficiency indicator. This approach depends on programmer competence a lot, leading to extend the processing data time, it is less timely. The SOA scenario of company is reported in figure 10.

In our case study it is possible to mark two buses: the first one executes mobile services and the other one executes corporate services.

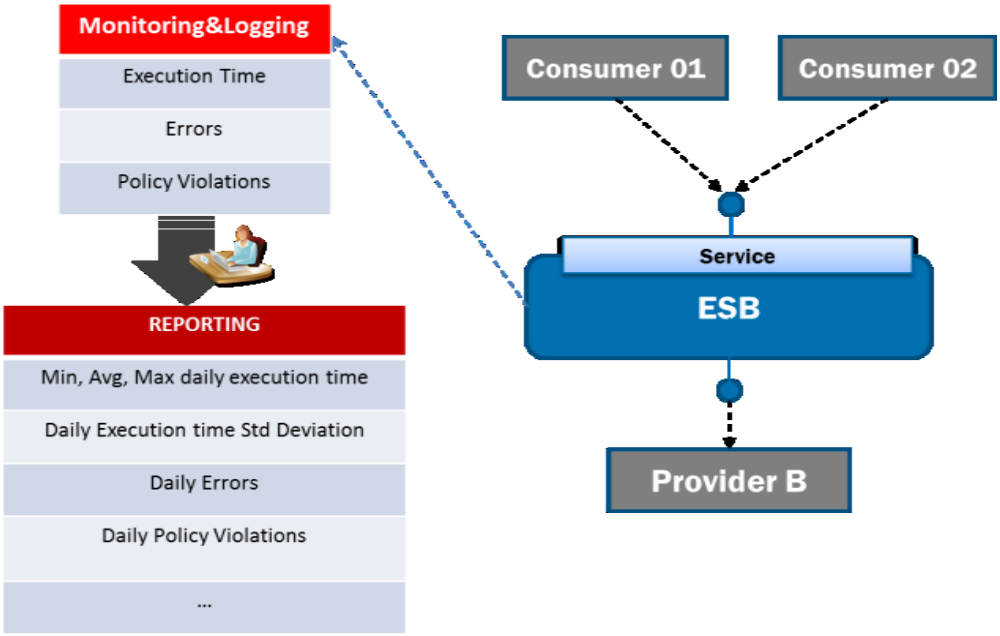

Figure 10 Current scenario in the company

6.2Measure

The measurements concern the number of daily begins, the number of daily errors, daily average response times and related standard deviations, average response times set limit, and errors set limit for every service during three months: July, August and September 2015.

Notice that the measured metrics related to time are defined in milliseconds.

The services performance efficiency is the goal which this empirical analysis tries to investigate. The performance efficiency concept is established by ISO/IEC 25010 (2011), which breaks down it in three sub-concepts: time behaviour, resource utilization and capacity. The time behaviour is the service variable, explored in this analysis. It is the degree to which the response time of a service when performing its function meets requirements. The service response time requirement is set to zero value, implying that the fastest service is the best one; the aim of our quality monitoring approach is about to verify whether the service meets this requirement or at least it does not exceed the set limit, with respect to selected measures and to identify possible exceptions. The following table 11 sums up the variable size data for every service, which are employed in the following measure phase, pointing at the entire period of observation for the aggregate measures. In the measure phase at first the services have been classified in function of the bus to which they relate, and then they have been sorted by two scores: the importance score and the performance-efficiency score. The importance score for every service is designed summing the ninety-two partial factors, obtained multiplying the daily begins for the corresponding daily average times and standardizing the total value of every service by the max value among all services, see table12 and table 13.

The part of table 12 highlighted in red requires special attention because it stresses the most critical importance values.

Table 11 Services' features

service	set limit time (ms)	total errors	max begins	total begins
G	300	1	17946	129745
P	500	3	132	5367
H	1000	34	690	15095
L	300	1	966	44620
D	500	5934	7094	264280
U	10000	154	30	1019
S	2000	25	1062	67332
F	300	8	3759	214804
I	1000	70	491	12996
O	2000	14	158	2177
Q	2000	5	32	828
E	500	10	12909	506922
N	1000	3	99	4003
B	500	5478	16593	851808
R	1000	0	99	1303
A	2000	5514	9807	606756
M	1000	0	609	23619
C	500	611	10539	345713
T	200	0	143	4879

service by BUS1	$\sum_{i=1}^{92}(begins * times\ average)$	importance scores
A	728569193	1
B	465750063,4	0,639266754
C	190123411	0,260954502
D	159890465,7	0,219458175
E	132240416,1	0,18150701
F	59588624,86	0,08178856
G	32900913,5	0,045158255
H	16755902,66	0,022998368
I	15960593,05	0,021906764
L	14267386,15	0,019582747
M	12070667,27	0,016567633
N	3704506,099	0,005084632
O	3152170,33	0,004326522
P	2228350,851	0,00305853
Q	1359886,12	0,001866516
R	1221764,78	0,001676937

Table 12 Service importance score design for BUS 1

service by BUS 2	$\sum_{i=1}^{92}(begins * times\ average)$	importance scores
S	149393908,9	1
U	1365908,837	0,0091
T	640067,0381	0,004

Table 13 Service importance score design for BUS 2

As shown in table 12 and table 13 the services have been clustered by the related enterprise services buses, which executes them, as shown in the table below the most part of services belongs to BUS 1, so they are mobile services as previously specified.

Table 14 Services by buses

service	BUS 1	BUS 2
A	X	
B	X	
C	X	
D	X	
E	X	
F	X	
G	X	
H	X	
I	X	
L	X	
M	X	
N	X	
O	X	
P	X	
Q	X	
R	X	
S		X
T		X
U		X

The efficiency score for every service is designed by loss function which makes reference to Taguchi approach. Genichi Taguchi believes that the customer becomes increasingly dissatisfied as performance departs farther away from the target and when it does, there is a loss incurred by society. This loss may involve delay, waste scrap or rework. He suggests a quadratic curve to represent a customer's dissatisfaction with a product/service performance (Quality Characteristic / Metric / KPI). The quadratic curve target is set equal to zero. The curve is centered on the target value, which provides the best performance in the eyes of the customer. The Taguchi Loss Function (TLF) uses both the process average and the variation as critical measures of quality. In essence, the Taguchi Loss Function measure quality. The vertical (y) axis of figure 11 represents the amount Loss ($) due to the service.

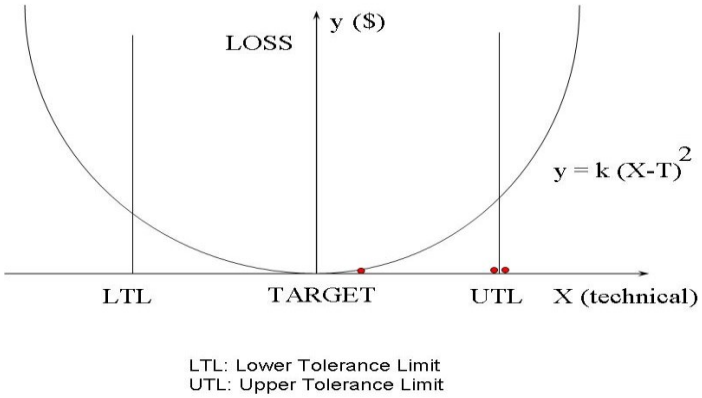

Figure 11 Taguchi'loss function

In our case study our technical variable (X) is the service response time, metric for the service performance efficiency, whose target value X_0 is set to zero, it is marked by both a mean and deviation standard, the related loss function is L(x), figure 11, which express the economic loss due to the gap $(X\text{-}X_0)$

$$L(x) = L(x_0) + \frac{L'(X_0)}{1!}(X - X_0) + \frac{L''(X_0)}{2!}(X - X_0)\text{^}2 + \cdots, \qquad 0 \le x \le \infty$$

It can be considered that $L(x_0) = 0$ and $L'(x_0) = 0$; and neglecting the terms of the third order, L(x) becomes:

$$L(x) \cong \frac{L''(X_0)}{2!}(X - X_0)^2; \quad L(x) \cong k(X - X_0)^2$$

The variable X can be divided in two share the mean of X, named signal μ and noise z (with medium equal to zero and variance σ^2).

In our case $(x_0) = 0$ and the average value of loss function can be expressed as follows:

$$E\big(L(x)\big) = k(\mu 2 + \sigma 2)$$

Keeping in mind this approach the total average loss, namely E(L(x)) function, has been calculated for every service. It is our key service efficiency indicator and considering k=1, E(L(x)) becomes:

$$E\big(L(x)\big) = ((x^*)\text{^}2 + (\sigma^*)\text{^}2)$$

with:

$$x^{*} = \frac{\sum_{i=1}^{m} \frac{x_i}{(t\ limit)} * n_i}{\sum_{i=1}^{m} n_i} \; ; \; \sigma^{*} = \left(\frac{\sum_{i=1}^{m} \left(\frac{\sigma_i}{t\ limit}\right)\text{^}2 * (n_i - 1)}{\sum_{i=1}^{m} (n_i - 1)}\right)\text{^}\left(\frac{1}{2}\right)$$

Where x^{*} is the weighted average of the x_i, which are the response times day by day of the sample, the sample size is m, where m is the observation period (m=92 days) and n_i are the daily begins, σ_i are the standard deviations, t limit is the service response time set limit, that varies from service to service.

The results concerning E(L(x)) are reported in the table below, the values have been standardized for the mobile services by the max value among all services for services processed by bus 1; otherwise for the services processed by bus 2.

Table 15 The sorting of services by loss scores

service by bus 1	**loss values**	**loss scores**	**service by bus 2**	**loss values**
E	0,950879782	0,008835736	U	0,054471575
O	1,455199352	0,013521959	T	6,962861787
G	1,527391585	0,014192782	S	11,62557272
Q	1,668967206	0,015508326		
H	2,352963147	0,021864132		
P	4,161931637	0,038673374		
R	7,398349231	0,068746715		
C	9,425689796	0,087585108		
F	9,666002491	0,089818134		
L	10,8412027	0,100738294		
D	17,43484149	0,162007503		
A	29,49477566	0,274070456		
M	40,24660215	0,37397825		
I	49,39049681	0,45894487		
B	58,64034391	0,544896017		
N	107,6174941	1		

The services are sorted by the loss scores from the smallest to the largest one.

The part of table 15 highlighted in yellow and red requires special attention because it stresses the most critical loss values.

6.3 Analysis

Nevertheless not all the efficient services are important, maybe a service can be important but not efficient so it is critic; in order to focus on critical services for every services both the loss score and importance score have been reported for the services executed by BUS 1 in a diagram, see figure12, adapting the values to plot format (table 16a).

Notice that our analysis has been aimed at calculating the global efficiency for every service. See the charts reported in Appendix A for more explanation of the average loss values and local loss values for every service. Concerning the services routed by bus 2, both the loss and importance values have been reported in table16b. In this case the critical analysis is easy because the value set is small. It is clear that for the bus 2 the most critical service is the service S, which shows the biggest values for loss and importance.

Services by BUS 1	Loss scores	Importance scores
A	2,740704559	10
B	5,448960173	6,392667544
C	0,875851076	2,609545021
D	1,620075029	2,194581753
E	0,088357361	1,815070104
F	0,898181339	0,817885596
G	0,141927816	0,451582551
H	0,218641325	0,229983683
I	4,589448699	0,219067636
L	1,007382935	0,19582747
M	3,739782505	0,165676334
N	10	0,050846318
O	0,135219591	0,043265216
P	0,386733744	0,030585302
Q	0,155083262	0,018665161
R	0,687467153	0,016769372

Table 16a Services by loss scores and importance scores

Services by BUS 2	Loss values	Importance values
U	0,054471575	1365908,837
T	6,962861787	640067,0381
S	11,62557272	149393908,9

Table 16b Services by loss scores and importance scores

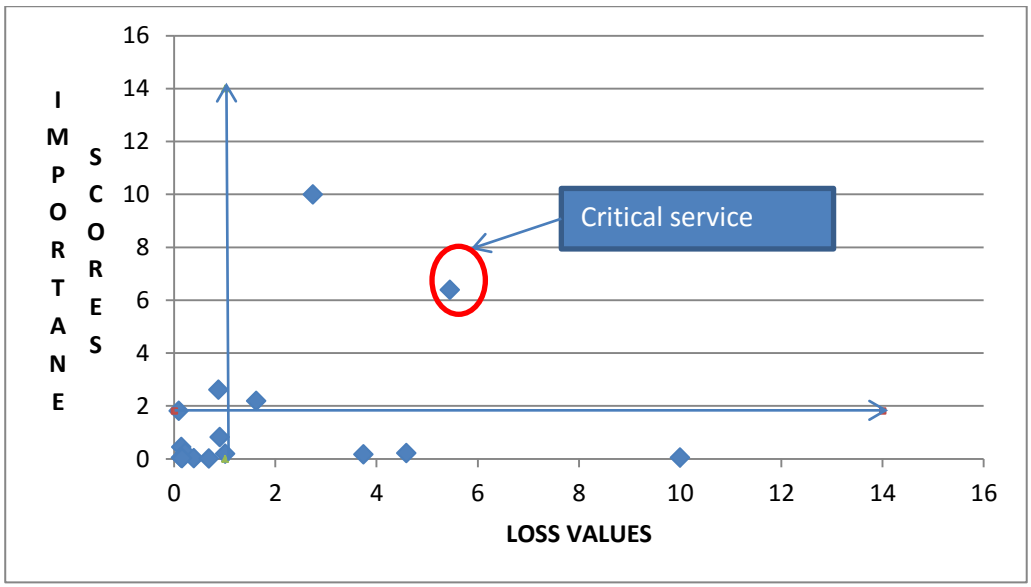

Figure 12 Analysis of SOA services by importance score and loss values

The diagram (figure 12) identifies a values domain; the service E importance score (1,81) identifies the value limit for the services importance values, the services values with a fewer importance score than service E are not very important. The service L loss score (1,007) identifies the value limit for the services loss values, the services values with a fewer loss score than service L are enough efficient so they are not taken into account to critical services. The analysis of the diagram shows that the service B, red circled, is the most critical service because it presents a great importance score and at the same time a great loss value so it has to be studied more in depth. The figure 13 reports the local loss values compared to the average loss for the service B; about twelfth loss values overcome the average loss, in that days the service is particularly not efficient. Concerning these critical days with higher loss values, the response time and deviation standard have been focused in order to calculate variation index, see table17; the maximum variation index makes reference to the third point (day), bold in the table, which means that in that day there are few response times values which overcome the response time set limit a lot, so among the critical points it is the most critical one. In order to identify possible cause of critic loss values, a correlation diagram between loss values and begins has been reported (figure 15), taking into account service begins values (figure 14). The correlation coefficient, like the covariance, is a measure of the extent to which two measurement variables "vary together." The value of any correlation coefficient must be between -1 and +1 inclusive; the correlation analysis allows us to determine whether the two measurement variables tend to move together. The analysis of diagram shows that there is not a correlation between loss values and begins so the high loss score related to the service B, linked to local average response times, maybe is not due to a congestion problem but more

probably to a design problem concerning local service processing time as the correlation index between loss values and standard deviations suggests (table 18). Another critical point, concerning service B, it arises from errors diagram analysis (figure 16) and focuses on the sixth point.

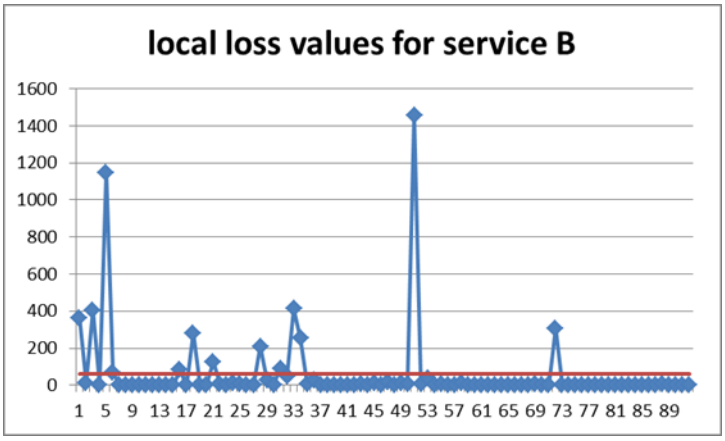

Figure 13 Service B' local loss values compared to service B'average loss

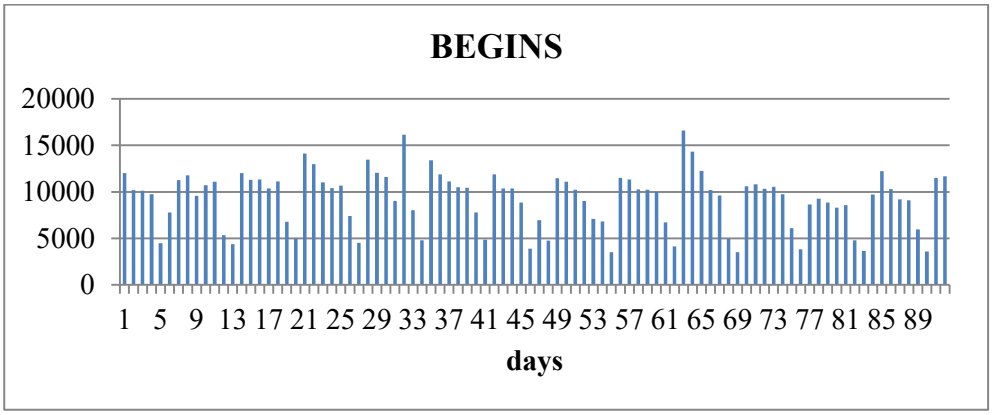

Figure 14 Service B' begins by three months

Table 17 Service B' most critical days

days	average response times	standard deviations	variation indexes
1	653,279	9509,98	14,5573
3	**586,254**	**10038,5**	**17,12312**
5	1768,12	16851,3	9,530631
16	443,115	4531,75	10,22703
18	640,965	8377,96	13,07085
21	396,603	5601,48	14,12365
28	883,184	7186,85	8,137432
31	362,67	4727,11	13,03419
33	1056,21	10094,8	9,557569
34	619,25	7923,14	12,79474
51	2398,58	18943,9	7,897965
72	929,58	8704,38	9,363777

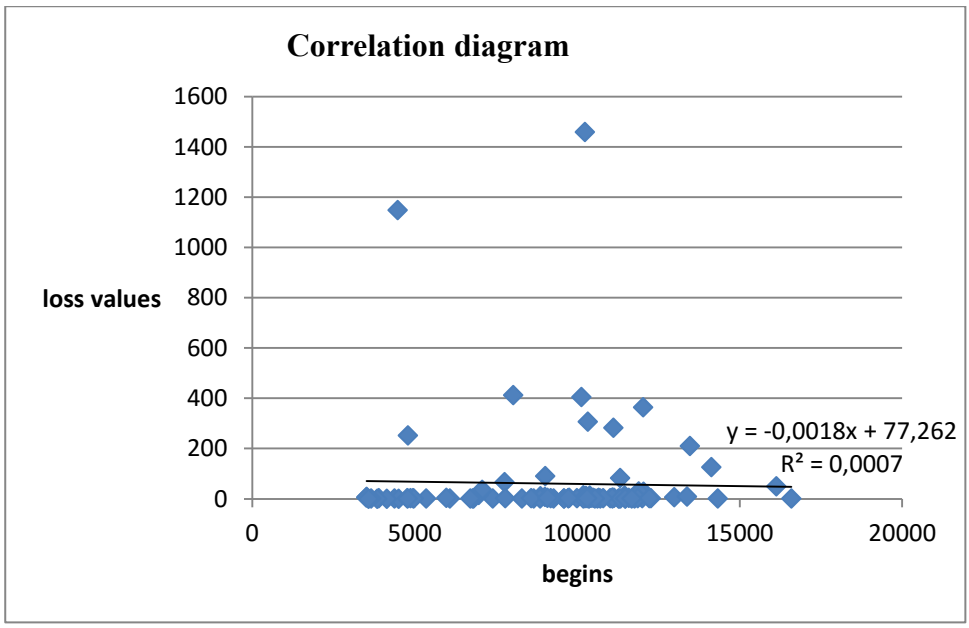

Figure 15 Service B correlation diagram

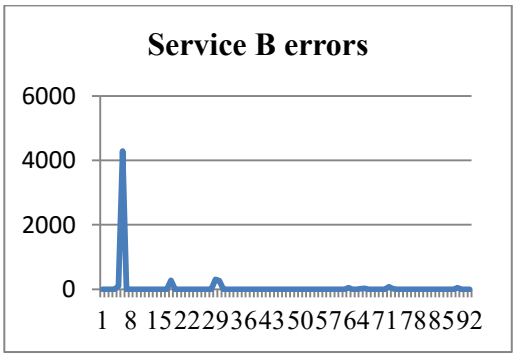

Figure 16 Service B errors

Table 18 Correlation diagrams for service B

Correlation errors and loss values	Correlation loss values and standard deviations	Correlation response times and begins
0.02	0,93	-0.04

Furthermore a local efficiency analysis has been carried out for services executed by BUS 1. A local efficiency score has been assigned to every service in function of the number of local loss values which exceeds the average loss value for every service. The results are reported in the table below (table 19).

Table 19 local efficiency scores

service	local efficiency	score	
F	0,03	1	
Q	0,03	1	
N	0,03	1	
R	0,03	1	
L	0,05	0,98	
D	0,05	0,98	
P	0,06	0,97	
H	0,06	0,97	
O	0,07	0,96	
A	0,07	0,96	
M	0,12	0,91	
I	0,15	0,88	
B	0,15	0,88	
G	0,2	0,83	
C	0,25	0,78	
E	0,27	0,76	

The analysis of the table shows that the service E, red highlighted, is the most critical service because it shows the smallest efficiency score so it has to be studied more in depth (figure 17). In order to identify the causes of not local efficiency a correlation analysis has been carried out. As the table concerned the correlation index shows (table 20), the local loss values are strongly related to deviations standards but not begins. The criticality of the service can be due strongly to design problems but not to a congestion problem. In particular it is important to stress that the biggest loss value makes reference to the day in which the biggest error value occurs, see figure 18 and table 20.

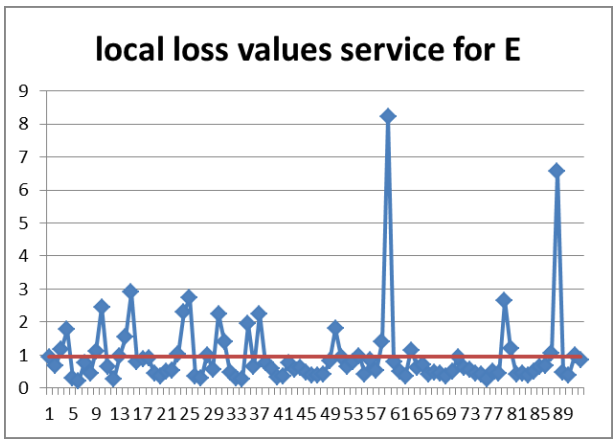

Figure 17 local loss values for service E

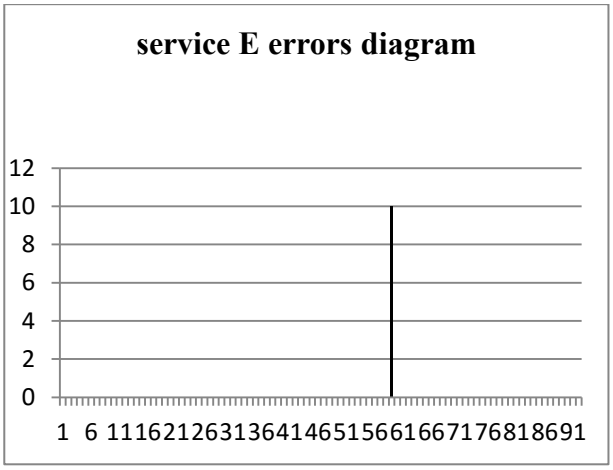

Figure 18 service E errors

Table 20 Correlation indexes for service E

Correlation errors and loss values	Correlation loss values and standard deviations	Correlation loss values and begins
0.67	0.95	-0.042

6.4Discussion

The service oriented computing is aimed at ensuring a great interoperability among software programs delivered as services by a good understanding of data exchange between services and their consumers. SOA adoption benefits are services reusability, loose coupling between services, reduction of time to market, reduction of operating cost; in order to get this aims an effective SOA governance is basic. SOA governance operates by policy implementation, where policy stands for a set of constraints in a common general sense, applied at services. In our case study such policies as well as monitoring phase rely on manual processes, carried out by humans, which ensure enforcement. Manual policies enforcement can be prone to human erring, it can introduce risk with potential financial and operational ramifications. Therefore the company is moving towards ways to automate policy enforcement by the introduction of a technical intermediary between service and consumer called Policy Enforcer, which is able to apply three kinds of runtime policies:

- ✓ Security;
- ✓ Restriction of usage;
- ✓ Monitoring.

The working flow of a service request owing to the policy enforcer introduction can be depicts as follows: a client send a request message, the message is transferred to policy enforcer which applies the policy and carries on monitoring phase, the message is transferred to ESB, which applies functional intermediary actions, ESB routes the message to the business process, (d) business process executes its activities and invokes external web services through ESB, and (e) the external web service executes the request and return the result to ESB. In the meantime policy enforcer tracks service execution data (processing time, errors, begins, policy violations and so on). Figure 19 shows the solution to get a runtime monitoring approach towards the enterprise is moving.

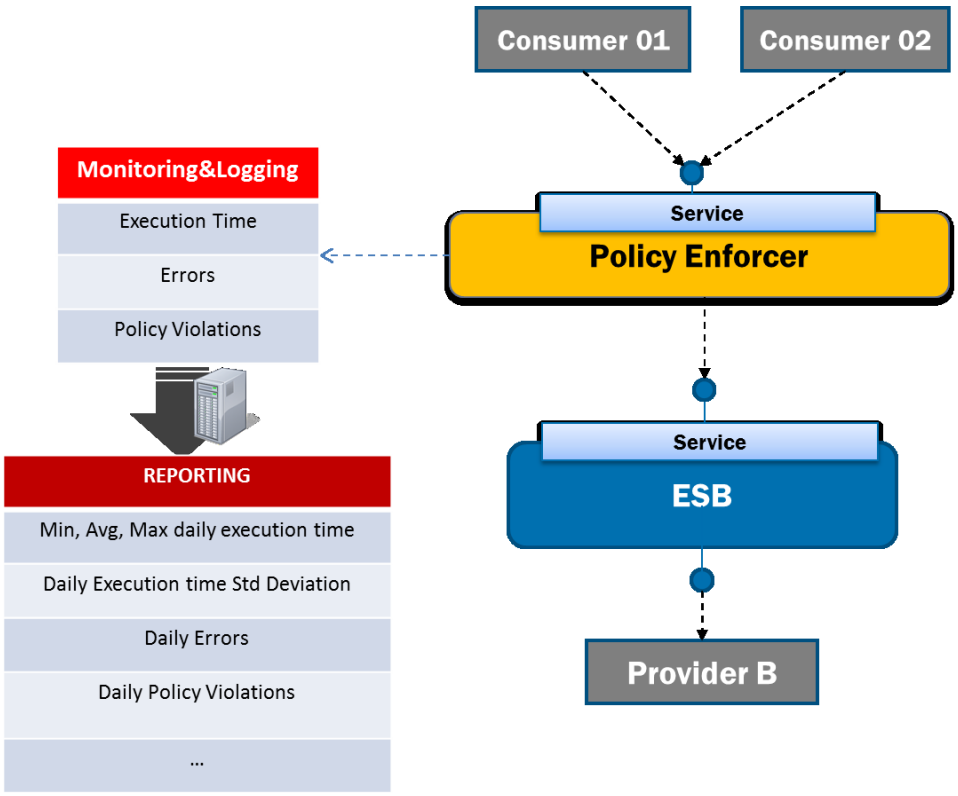

Figure 19 Policy enforcer' introduction

6.5 Conclusions and implications

There are evidences of several gaps in literature concerning the management of quality in SOA environment. In particular there are also little empirical investigations exploring quality management practices and factors affecting their usage. This work attempted to fill these gaps presenting the preliminary results of a literature search on this topic and describing the findings collected through an empirical analysis carried out in a telecommunications company and concerning SOA services performance, in order to improve the SOA performance evaluation knowledge, since performance evaluation is a typical issue in SOA environment.

An empirical analysis on nineteen SOA services data has been carried out. The raw data are retrieved at design time and concern the daily service response times, related standard deviations, errors and begins for every service; the reporting period covers three months. Furthermore for every service the average response time limit is set. The study reflects the service provider perspective and focuses on the system environment rather than business environment, these project boundaries were set by the company involved in our case study. The data have been extracted manually and developed by the programmers responsible for enterprise service bus, the last one is the core of the investigated SOA system, which executes all service data. The developed data are the inputs for the calculation of both an importance score and an efficiency indicator for every service. The last one is defined for every service as a quadratic function of overall weighted average response times and related variance, taking inspiration from Taguchi loss function. Therefore the efficiency concept is introduced by loss function, the most efficient service shows the fewest loss score. This elaboration leads to the identification of the most critical service among the observed ones, which is the service with both the biggest importance score and loss value. The outcomes of the empirical analysis show the most critical services to improve in a quality control program and a preliminary analysis about the cause of not efficiency is introduced. The analysis is linked to the network topology adopted in the industry scenarios based on the adoption of enterprise service bus (ESB) and to competence of programmers which handle the raw data.

Finally a framework is proposed to automate services monitoring and logging phase, which is based on the introduction of a machine which enforces the policies application.

This approach stands for a future research avenue to develop for the company in order to overcome the limits of services inspection by human handling.

6.5.1 Limitations

However, despite the general agreement about the value of the approach and the important role of context information, the contextual conditions of SOA environment are generally assumed as static observations in future to improve this work can be useful to adopt a dynamic monitoring approach to retrieve services data, the empirical analysis adopts only averages response times as input parameters it could be interesting to exploit all service response times for the critical days at least. Other issues not covered here have to do with the cost constraints on the system, the hardware technology and the load constraints of the services access points in the network. Therefore it can be consider a first preliminary step of the analysis concerning SOA services performance evaluation.

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CONCLUSIONS OF THESIS AND RESEARCH IMPLICATIONS

The SOA case study stresses the difficulty of storing, managing and analyzing big data from services so an automated monitoring framework is proposed.

Nowadays with the prevalence of service oriented computing and its evolution towards cloud computing, more and more services provide Big Data making reference to huge volume of information (data), trace logs, services relationships and so on.

The use of big data will become a key basis of competition and growth for individual firms. From the standpoint of competitiveness and the potential capture of value, all companies need to take big data seriously.

Therefore how to store, manage, and analyze the knowledge from the big data becomes an important research avenue which needs to be exploited more in depth in future.

Furthermore this thesis stresses how knowledge management is an important means to improve enterprise performance. The enterprise implementing knowledge management has to adopt specific systems to support knowledge management phases.

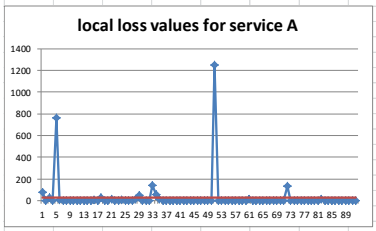
The knowledge management systems have to be flexible in order to meet market changes.

They can be best realized through multiple agents cooperating with each other to perform business tasks in order to overcome the limits of monolithic systems.

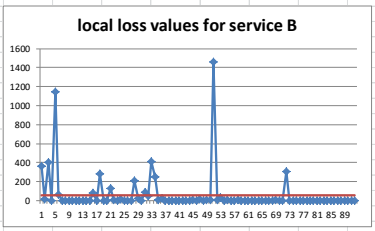
Therefore a knowledge management system can be best designed by a distributed system and distributed systems can be designed by SOA, where the agents act as service providers which in turn can be consumed by clients in different applications of different enterprises environment.

According to this view the Service Oriented Architecture could be a challenge for the small and medium enterprises which could get value from using distributed resources overcoming their financial limits.

APPENDIX A



	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio A	29,49477566	2000	9807



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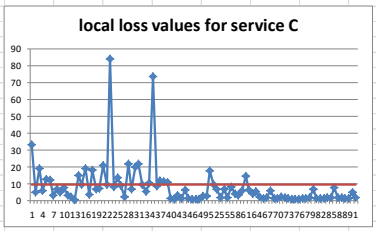
servizio B	58,64	500	16593



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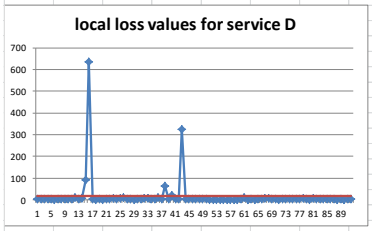

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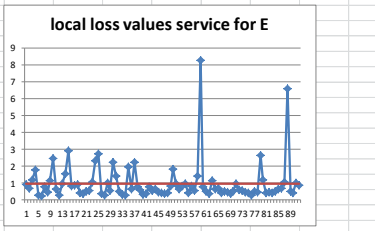

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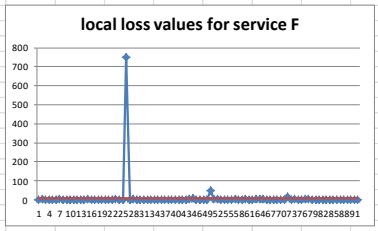

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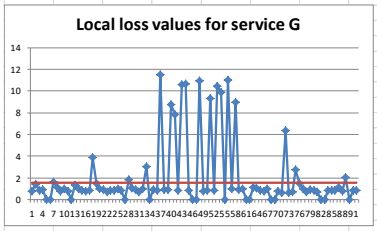

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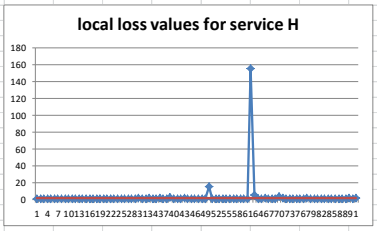
servizio G	1,527391585	300	17946



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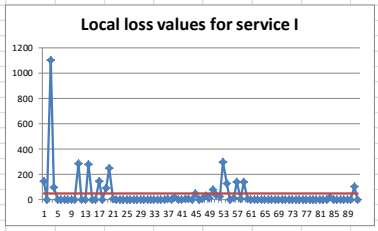
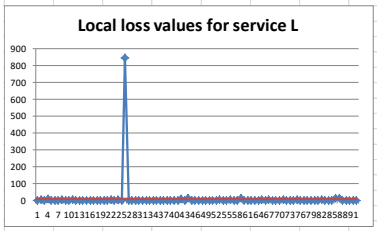
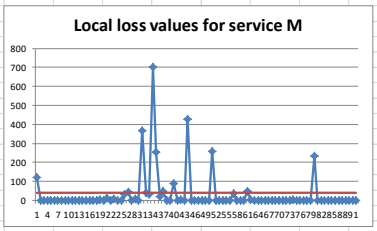


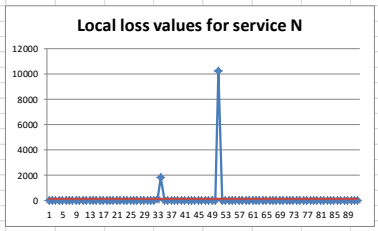
	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio I	49,39049681	1000	491



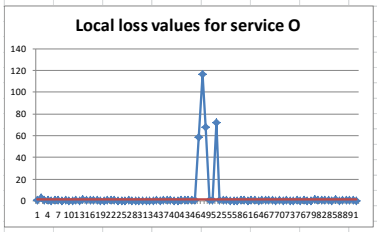
	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio L	10,8412027	300	966



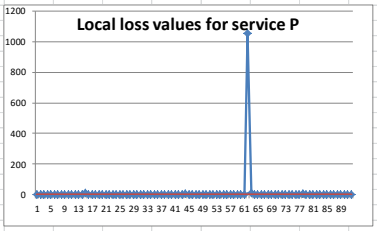
	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio M	40,24660215	1000	609



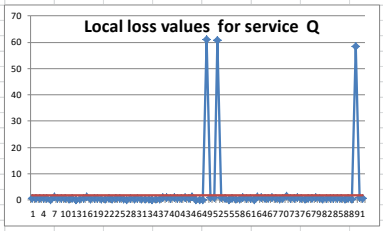
	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio N	107,6174941	1000	99



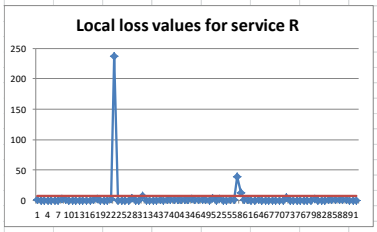
	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio O	1,455199352	2000	158



	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio P	4,161931637	500	132



	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio Q	1,668967206	2000	32



	AVERAGE LOSS	T LIMIT (ms)	max BEGINS
servizio R	7,398349231	1000	99