PONTIFICAL CATHOLIC UNIVERSITY OF PARANÁ
POLYTECHNIC SCHOOL
INDUSTRIAL AND SYSTEMS ENGINEERING GRADUATE PROGRAM
(PPGEPS)

JOSÉ MARCELO ALMEIDA PRADO CESTARI

A CONTRIBUTION TO INTEROPERABILITY CAPABILITY DIAGNOSIS IN PUBLIC ADMINISTRATION DOMAIN

CURITIBA
2015

JOSÉ MARCELO ALMEIDA PRADO CESTARI

A CONTRIBUTION TO INTEROPERABILITY CAPABILITY DIAGNOSIS IN PUBLIC ADMINISTRATION DOMAIN

Thesis presented at the Industrial and Systems Engineering Graduate Program at the Pontifical Catholic University of Paraná, as a partial requirement to obtain the title of Doctor of Production Engineering and Systems.

Advisor:
Prof. Dr. Eduardo de Freitas Rocha Loures

Co-advisor:
Prof. Dr. Eduardo Alves Portela Santos

CURITIBA

2015

Dados da Catalogação na Publicação
Pontifícia Universidade Católica do Paraná
Sistema Integrado de Bibliotecas – SIBI/PUCPR
Biblioteca Central

Cestari, José Marcelo Almeida Prado
C422 A contribution to interoperability capability diagnosis in public administration
2015 domain / José Marcelo Almeida Prado Cestari ; advisor, Eduardo de Freitas Rocha Loures ; co-advisor, Eduardo Alves Portela Santos. – 2015.
356 f. : il. ; 30 cm

Tese (doutorado) – Pontifícia Universidade Católica do Paraná, Curitiba, 2015
Bibliografia: f. 325-345

1. Administração pública. 2. Relações interorganizacionais. 3. Framework (Arquivo de computador). 4. Engenharia de Produção. I. Loures, Eduardo de Freitas Rocha. II. Santos, Eduardo Alves Portela. III. Pontifícia Universidade Católica do Paraná. Programa de Pós-Graduação em Engenharia de Produção e Sistemas. VI. Título.

CDD 20. ed. – 670

"If you can look into the seeds of time, and say which grain will grow and which will not, speak then to me, who neither beg nor fear your favors nor your hate."

Macbeth: Act 1, Scene 3.

ACKNOWLEDGEMENTS

"It's a long way to the top if you wanna rock'n roll", and if by rock'n roll you mean getting a Ph.D., then it's a lonely way too. However, no man is an island and without a few good people, this could have never been accomplished.

To Dr. Eduardo de Freitas Rocha Loures and Dr. Eduardo Alves Portela Santos, respectively my advisor and co-advisor, which sometimes trusted me more than I did. Those two nice human exemplars guided me all along the way.

To other professors of PPGEPS, not only for the guidance, but mostly for the friendship and, in some cases, brotherhood. Especially to Dr. Edson Pinheiro de Lima, Dr. Sérgio E. Gouvea da Costa and Dr. Fernando Deschamps.

To PPGEPS and PUCPR, for giving me the opportunity to present papers at several conferences.

To fellow students, for the support and exchange of knowledge and experience, especially to Arthur Maria do Valle, who brought me into this in 2011.

To Roberto Clementi and Sofhar.

To Instituto Curitiba de Informática (ICI).

To all the organizations and their team that were objects of this research application cases, for opening their doors and allowing me to access their most dedicated staff.

To my family, for the unconditional love shown in so many different – or weird – ways and for believing me so much that their gigantic trust in me could even seem like they didn't even care. Deep down, I know they did in their own way.

To my parents, Isidoro and Maria, for the basis of all knowledge.

To my siblings and friends, for being there.

To my 4-year-old son (Arturo) and newborn baby girl (Annabel), who are the reason for all this.

To Marlisi, my wife, for everything that cannot be described in words.

To my in-laws, for the countless barbecues.

Ad Astra per Aspera.

RESUMO

A necessidade de colaboração entre as organizações é uma realidade com a qual sistemas, gerentes e outras partes interessadas devem lidar. Quando há troca de informações, comunicação, interação e integração, o progresso ocorre e, todos esses componentes trabalhando juntos podem melhorar o desempenho da empresa. Esta não é uma preocupação exclusiva das administrações privadas, uma vez que a crescente necessidade de troca de informações entre as agências governamentais, a oferta de serviços on-line aos cidadãos e a redução dos custos das operações demandam que as organizações governamentais devem estar prontas para fornecer uma interface adequada a seus *stakeholders*. A necessidade dessas "interoperações” é real e, dessa forma, a interoperabilidade está se tornando um fator-chave para que as organizações possam lidar com ambientes colaborativos e cooperativos. Diante deste cenário, realizar uma avaliação da interoperabilidade organizacional (do original em inglês, *Enterprise Interoperability Assessment*) fornece à organização a oportunidade de conhecer seus pontos fortes, pontos fracos, além de priorizar ações para melhorar seu desempenho e maturidade.

A maioria das contribuições neste tópico estão relacionadas com aspectos técnicos, e há uma ausência geral sobre o racional ou *framework* adotado, e sobre a exposição de como as medições foram extraídas e construídas a fim de realizar um diagnóstico sobre o grau de interoperabilidade de uma organização. A metodologia utilizada se baseia em uma revisão sistemática da literatura, *survey* com especialistas e um conjunto de ferramentas relacionadas à extração e modelagem do conhecimento extraído do domínio de administração pública, mapeados para artefatos teóricos, conceituais e práticos.

Esta tese apresenta um modelo de capacidade denominado Public Administration Interoperability Capability Model (PAICM) e um método de diagnóstico denominado Public Administration Interoperability Diagnosis Method (PAIDM). Tanto o modelo de capacidade quanto o método de diagnóstico são resultados do ciclo de desenvolvimento suportado pelo *framework* de pesquisa apresentado, sendo composto por fases, processos e atividades, propondo uma estrutura de extração e organização de atributos e diretrizes. A aplicação do PAICM e do PAIDM em organizações relacionadas à administração pública mostra os resultados em relação aos seus níveis de capacidade e podem ser usados como insumos para melhoria de processos de interoperabilidade.

Palavras-chave: interoperabilidade, diagnóstico, administração pública, modelos de maturidade e capacidade, *framework*.

ABSTRACT

The need for collaboration among organizations is a reality with which systems, managers, and other stakeholders must deal. When there is sharing of information, communication among entities, interaction and integration, progress occurs and, all these components working together can improve performance. Nevertheless, this is not an exclusive concern of private administrations, once the increasing need for information exchange among government agencies, the supply of online services to citizens, and the cost reduction of public operations demands that government organizations must be ready to provide an adequate interface to their stakeholders. The need of these 'interoperations' is real, and interoperability is becoming a critical factor for organizations facing with collaborative-cooperative environments. In addition, perform an enterprise interoperability assessment (EIA) provides to an organization the opportunity to know their strengths, weaknesses and prioritize actions to improve its performance and maturity.

Most of the contributions to this topic are related to technical aspects, and there is a lack of general rationale and/or framework of how the measurements items are extracted and how they are built to execute an assessment or a diagnosis of an interoperability degree within an organization. The methodology adopted in this research is based on a systematic literature review, a survey with experts and a set of tools related to the extraction and modeling of the extracted knowledge from the public administration domain mapped into theoretical, conceptual and practical outputs.

This thesis presents a capability model named as Public Administration Interoperability Capability Model (PAICM) and a diagnosis method named as Public Administration Interoperability Diagnosis Method (PAIDM). Both the capability model as the diagnosis method are results of the development cycle supported by a presented research framework, which is composed of phases, processes and activities, proposing a structure of how to extract and organize attributes and guidelines. The application of PAICM and PAIDM in public administration organizations shows results regarding their capability levels that can be used as inputs to interoperability processes improvements.

Keywords: interoperability, diagnosis, public administration, maturity and capability models, framework.

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

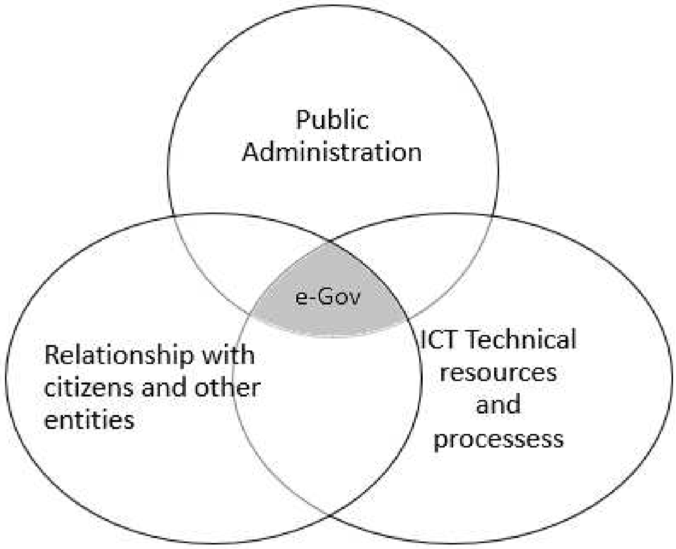
INDEX

1 INTRODUCTION AND CONTEXTUALIZATION

Since the middle 90s, companies are facing a competitive marketplace and, in order to survive, enterprises must, among other things, develop partnerships and work in an integrated way with other competitors, once a company rarely conducts meaningful transactions alone. As the need of these ‘interoperations’ is real, interoperability is becoming a critical success factor for enterprises facing with collaborative-cooperative environments in a globalized marketplace. Interoperability can be described as the ability of Information and Communication Technology (ICT) systems – and the business processes they support – to exchange data, to enable the sharing of information and knowledge and, use these data (European Commission, 2004). Interoperability takes into account dimensions such as concerns, barriers, degrees of maturity and types of assessment. When put together and analyzed, this set of views and perspectives can help to increase the level and quality of collaboration, interaction and transactions between organizations (public or private) and between areas (agencies) inside the same organization.

However, this is not an exclusive concern of private administrations, once the increasing need for information exchange among government agencies, the supply of online services to citizens, and the cost reduction of public operations and transactions demands that government organizations must be ready to provide an adequate interface to their users. With the increasing use and importance of ICT in government institutions, a concept, known as eGovernment, rose in the late 1990s (Camargo, 2009). The term eGovernment, e-gov, eGov and similar are an abbreviation of “electronic government” and refers to the use of ICT to support the government business, providing or enhancing public services or managing internal government operations and the relation with citizens, businesses and other government entities technology (Novakouski & Lewis, 2012). The eGovernment can be viewed as a tactical and operational implementation of strategic aspects (defined by a public administration) regarding the use of ICT and the relation with the citizen and other entities (Figure 1).

Figure 1: e-Gov composition and as a subset of public administration.



Source: The author (2015), based on Castro et al. (2015).

Considering the application of interoperability and eGovernment concepts in an integrated way in public administration domain, the eGovernment interoperability arises, as the ability of constituencies or public agencies to work together attempting to meet interoperability requirements (Charalabidis et al., 2008) and this is one of the focus of this research.

This scenario imposes not only the development of external interfaces but also the improvement of its internal environment and dimensions, such as business, processes, knowledge and ICT systems. Therefore, it is important a complementary focus on the internal aspects of the organization, that is, the intrinsic ability of the organization on interoperating. This implies the possibility of measuring the relation between human, technological and organizational entities (e.g., resources, systems, and departments) within interoperability assessment concepts. Knowing that the relations among organizations are relevant for their survival and competitiveness, important questions are identified: how to measure and assess interoperability? Which assessment model use? How to define maturity levels? Which dimensions must be taken into account? Which are the impact (financial, operational, strategic, legal and political) of the non-interoperability compliance? Which government entities assess?

Another important aspect of interoperability is the assessment of the adherence regarding some particular model or maturity degree, that is, the evaluation of how adherent (or how mature) is an organization in comparison with a baseline model. In this sense, EIA provides an organization the opportunity to diagnosis their strengths, weaknesses and prioritize actions to improve its performance and maturity.

Bring the concepts regarding Enterprise Interoperability (EI) and Enterprise Interoperability Assessment (EIA) to a public administration domain is not an easy task, once the complexity, barriers and variables of a government organization may differ from those found in the private companies. The application and use of EI models and frameworks are well defined and approached in several different works, especially considering the technological dimension. Protocols, semantic models, ontologies, system integration and data exchange are also treated in multiple proposed models.

However, as the entire interoperability problem consists of more than technical aspects (Pardo & Burke, 2008a), this research intends to create specific attributes and guidelines for increasing the interoperability aspects of public administration entities and providing a method to assess the adherence of that entity to the defined attributes and guidelines, considering not only the technical aspects. It is important to mention that IT aspects related to concerns and barriers are some of the influence factors.

1.1 RELEVANCE

In the modern context, organizations need to rethink and adjust their systems, processes and methods in order to better operate, cooperate and integrate with the environment and their stakeholders. One way to achieve this and increase the degree of the relationship between the organizations is through modeling, implementation, execution and measurement of an interoperable business. In comparison with private companies, which aspects such as profit and competition are strongly applied, government organizations, by nature, do not have this kind of concerns. The issues may be similar, but government focus is on the welfare of citizens, reduction of costs, integration with other agencies and political aspects.

One important common characteristic for all modern organizations, whether they're public or not, is the use of ICT to improve their process performance, increase profit, productivity and reduce their costs. Since the year 2000, government agencies began to address, more formally, aspects of ICT in their operations and relationships with citizens and other agencies, creating the notion of an “electronic government”. In other words, according to Bettahar et al., (2009), eGovernment is the utilization of ICT in serving the priorities of a government in meeting specific social, economic and political endeavors of the state. To Guédria (2012), progress occurs when entities communicate and share information in order to achieve, together, something that they could not achieve alone. Therefore, in spite of public or private organizations, machines, systems, people, business and political interoperability is becoming a key success factor in all areas. Characterization and measurement of different degrees of interoperability allow an organization to know its “as is” stage and plan the ways to achieve higher degrees (“to be”) of organizational performance regarding interoperability.

This scenario highlights the scientific relevance of the subject in which it is possible to mention:

- Public administration interoperability leads to a better decision-making, allows better coordination of government agency services, have a foundation on a citizen-centric delivery of services and leads to cost savings and/or avoidance. In other words, eGovernment interoperability contributes to good governance (UNDP, 2007).
- The official Brazilian interoperability framework (e-Ping) deals mainly with technical aspects (Ministério do Planejamento, 2012).
- Interoperability will allow data compiled by different agencies to be used together to make faster and better decisions (UNDP, 2008).
- Interoperability allows governments to manage better their internal operations (UNDP, 2008).
- Interoperability increases transparency and accountability. Governments are better able to justify their programs and citizens are better informed, both prerequisites for a vibrant democracy (UNDP, 2008).
- According to the UNDP (2007), e-Government interoperability is becoming an increasingly crucial issue, especially in developing countries.

- Public administration and eGovernment interoperability are perhaps the most important issue of eGovernment today (Goldkuhl, 2008).
- The government services in Brazil were questioned (e.g., riots in June/July 2013) (Watts, 2013), generating an opportunity to achieve better quality, time and cost (Cestari et al., 2013) performance in public administration.
- There are (and were) some important Brazilian influencing factors, such as the World Cup 2014, Olympics 2016 and Curitiba as the most digital city of Brazil according to Brazilian Index of Digital Cities, 2012 (CPqD & Wireless Mundi, 2012).

1.2 ORIGINALITY

The complexity presented in the public administration/eGovernment context requires additional effort regarding influencing factors in public administration such as legal, political, sociocultural and other issues. This scenario is particularly prominent in some emergent countries as Brazil, providing a broad field for research in the eGovernment interoperability domain, once eGovernment interoperability frameworks focus almost entirely (90%) in the technical domain (CSTRANSFORM, 2010).

The literature analysis, presented in section 2, reveals that there are many papers regarding interoperability models and government initiatives of eGov models and frameworks. Nevertheless, it was not possible to identify frameworks, assessment models or models organizing and dealing with influence factors other than the technical ones. Another issue detected is that the Brazilian initiative in the area is almost entirely focused on the e-Ping framework (Ministério do Planejamento, 2012). The literature review and analysis supports the originality of this research, considering, in the first moment, documents since 1986. Afterward, the interval was applied considering documents since 2000. In this period (2000 to 2013) it was not possible to identify specific models, frameworks or assessment procedures regarding the evaluation of public administration entities not related to (almost entirely) technical issues.

Another originality aspect is the fact that it was not found, in the literature review, papers describing the methodology behind the interoperability assessment or diagnosis methods and frameworks proposals. The documents usually present and exposes the ideas as “take this as a fact”, not exposing a rational (“how to”) and/or the construction behind it. That is, it was not found papers describing the rules, rationale or procedures regarding the knowledge discovering steps of interoperability aspects in public administration domain (Ray et al., 2011), (Solli-Sather, 2011) and (Gottschalk, 2009).

1.3 COMPLEXITY OF THE RESEARCH

In general, the complexity of the subject is associated with the quantity and complexity of influence factors and government specific potential barriers (e.g., political, language, culture, government structure). Some of the complex items of the domain, and approached in this research, are:

- Identification and evaluation of the qualifying attributes (measurement aspects) regarding the public administration and government domain (considering the interoperability aspects);
- Identification and evaluation of the barriers related to interoperability;
- Comprehension of the influence and causality relationship of those attributes that difficult an adequate diagnosis of the organizational barriers.
- High tacit knowledge and subjectivity in assessing the qualifying attributes.

Other complex aspects of the research itself are:

- Conduction of a systematic literature review of eGovernment interoperability in order to identify concepts, barriers, distribution around the world and across the years, preliminary guidelines and other information;
- Identify the existent models and frameworks related to the subject and the approaches adopted;
- Extract the attributes from the literature review, using qualitative, quantitative and some Natural Language Processing (NLP) analysis.

- Compose a diagnosis method, including guidelines and attributes and execute a diagnosis case in order to improve the proposal itself.
- The inherent complexity of research, adaptation and use of multi-criteria methods applicable to the problem space (Analytic Hierarchy Process (AHP), Analytic Network Process (ANP)).
- Identification of a domain concept map, used to compose an EIA model.

1.4 RESEARCH QUESTION AND GOALS

The research question can be exposed as "how a capability model and a diagnosis method of interoperability, in the public administration domain, allows measuring an entity's level of potential interoperability?"

Considering all the aspects and relevancy previously exposed, Table 1 shows the goals of the research project.

Table 1: Research goals

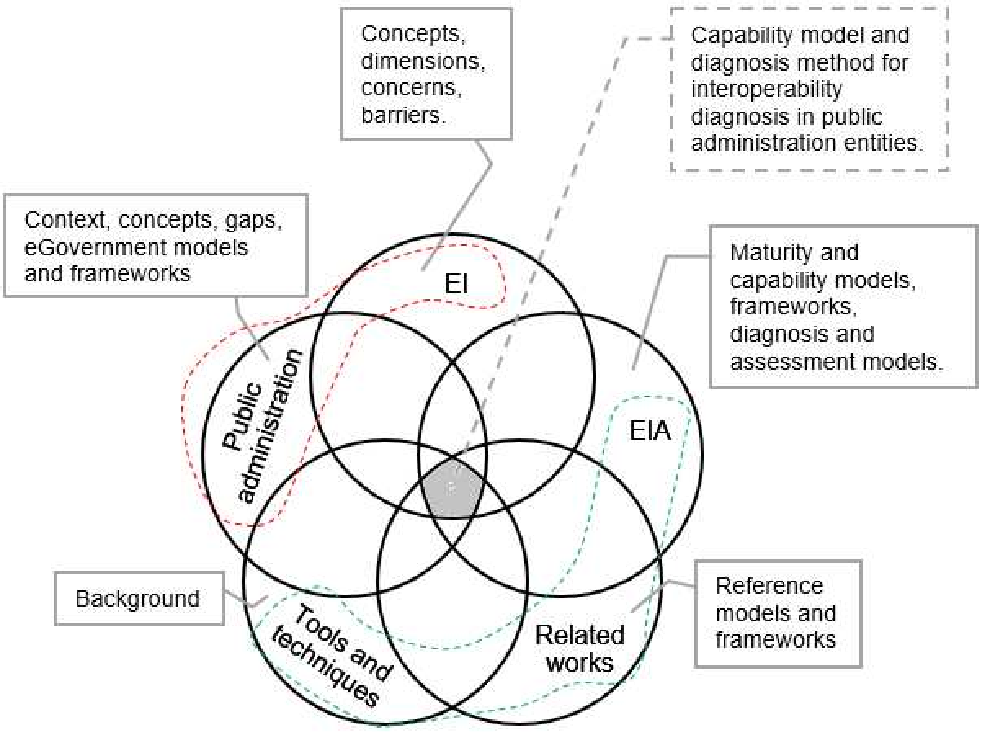
Main goal (MG)	
Propose a framework methodology to diagnose the interoperability in a public administration scenario, including the capability model and the diagnosis method.	
Specific goals (SGs)	
SG1: Define the domain.	
SG2: Define the attributes and the capability model.	
SG3: Conceive a diagnosis method.	
SG4: Evaluate the applicability of the framework in a public administration entity.	
Brief description:	
SG1:	Provide a background, literature and theoretical review, gathering main concepts, models, and frameworks, also performing a content analysis and a study of the world position of the domain. Define the research domain using concept mapping, considering areas such enterprise interoperability, eGovernment interoperability, maturity models, and assessment.
SG2:	Define the attributes based on the literature and in a knowledge extraction process. Execute a survey to review the preliminary set of attributes and create guidelines within the attributes. The result is the proposition of a capability model.
SG3:	Definition of a set of rules and general workflows and procedures to diagnose the public administration entity's interoperability capability level.
SG4:	Using the framework, execute application cases in two public administration entities, providing a capability level diagnosis regarding the interoperability aspects. Collect information and suggestions for updating the framework.

As a brief introduction and to better illustrate some aspects of the goals exposed in Table 1, it is important to mention three aspects:

- A framework is a real or conceptual structure intended to serve as a support or guide for building something that expands the structure itself into something useful.
- The capability model defines capability levels and measurable aspects (attributes), including guidelines related to "best practices" regarding the application domain. It is an abstract representation of the reality and it is not a process, although it can suggest some practices and/or examples. More details in section 6.
- The diagnosis method is composed of a set of processes, activities and roles regarding the execution of an interoperability diagnosis.

In order to better illustrate the main areas involved, Figure 2 shows the problem space (EI, public administration) within the red dashed line and solution space (EIA, related works, tools and techniques) within the green dashed line. The conceptual reference has a particular importance in the Brazilian context because the interoperability domain is not yet well disseminated. The intersection of the problem space and solution space illustrates the scope of this proposed research project.

Figure 2: Problem space versus solution space



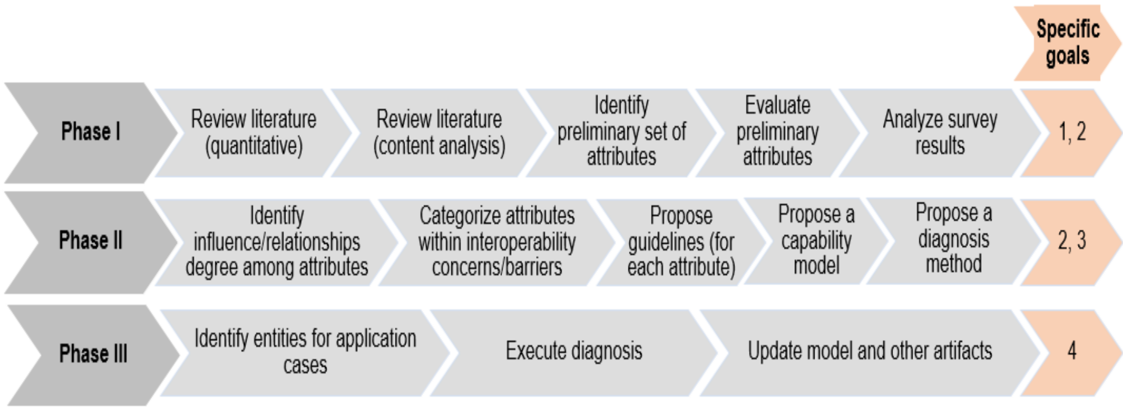
Source: The author (2015).

1.5 RESEARCH STRUCTURE

This research is based on the elaboration of a theoretical, conceptual framework derived from the literature review, author propositions, and subsequent refinement through experts evaluation and application cases. All these steps and phases are organized in terms of a research methodology, as illustrated generally in Figure 3. The diagram identifies basic steps (which are contained in phases and may contain activities), purposing a structure of how to collect attributes and compose the guidelines, and how to define a diagnosis method in order to fulfill the requirements and goals stated in Table 1.

The phases are macro organized as (i) collection and formalization of knowledge in the problem space and solution space (EIA), (ii) conception of the capability model and the diagnosis method and (iii) execution of the diagnosis using application cases.

Figure 3: Illustration of the methodological steps and phases



Source: The author (2015).

Phase I (structuring) includes a systematic literature review and content analysis in order to identify related work, trends and gaps, creating a database on the topic, formalizing the knowledge with a domain concept map and identify attributes to the measured. The knowledge obtained is treated in Phase II (developing), where the relationship (influence) degree among attributes is identified, capability model and a diagnosis method are proposed.

In Phase III (execution), the evaluation of the interoperability capability level is carried out using application cases in selected public administration related entities. The models and other artifacts can be updated according to the results and gathered suggestions, generating new versions of the framework for future iterations.

Although the representation in Figure 3 may indicate that the steps are sequentially organized, some of them can be executed in parallel or in an iterative incremental way, once it is only a bi-dimensional representation of the research structure. Section 2 describes the steps with more details, using an IDEF0 diagram as modeling notation, in order to formalize a research framework.

1.6 DOCUMENT STRUCTURE

This document is organized as follows: section 1 (introduction), presenting the main goals, relevance and justifications of the research and section 2 presents the research framework and its processes. Section 3 (methodology) exposes methods (e.g., literature review, survey, and application case) adopted in the conduction of the research, including achieved results. Section 4 presents background information regarding the comprehension of the domain and its associated components, while section 5 provides theoretical references, approaching concepts, definitions, some existing models, frameworks, benefits and difficulties. Section 6 presents the capability model (PAICM) proposition and section 7 presents the diagnosis method (PAIDM) proposition. Finally, sections 8 and 9 present, respectively, the application cases executed and the conclusion and final considerations, followed by the references and appendix information.

1.7 CONSIDERATIONS AND CHAPTER SYNTHESIS

Interoperability is a critical success factor for entities facing with collaborative-cooperative environments and diagnosis the adherence or the level of interoperability according to a model provides an organization the opportunity to know their strengths, weaknesses and prioritize actions to improve its performance and maturity.

Almost all identified and reviewed literature presents works strongly related to technical interoperability issues, and the methodology behind the interoperability assessment or diagnosis are not presented.

The main goal of this research is to propose a framework methodology to diagnose the interoperability in a public administration scenario and by doing this, answer the question of “how a capability model and diagnosis method of interoperability, in the public administration domain, allows measuring an entity’s level of potential interoperability?”

In summary, this chapter presented a general introduction to the research, approaching preliminary concepts regarding interoperability and public administration issues in order to contextualize the readers.

2 RESEARCH FRAMEWORK

In order to detail the initial structure exposed in Figure 3, this chapter presents a complete overview of the research structure, represented as a framework exposed in Figure 4.

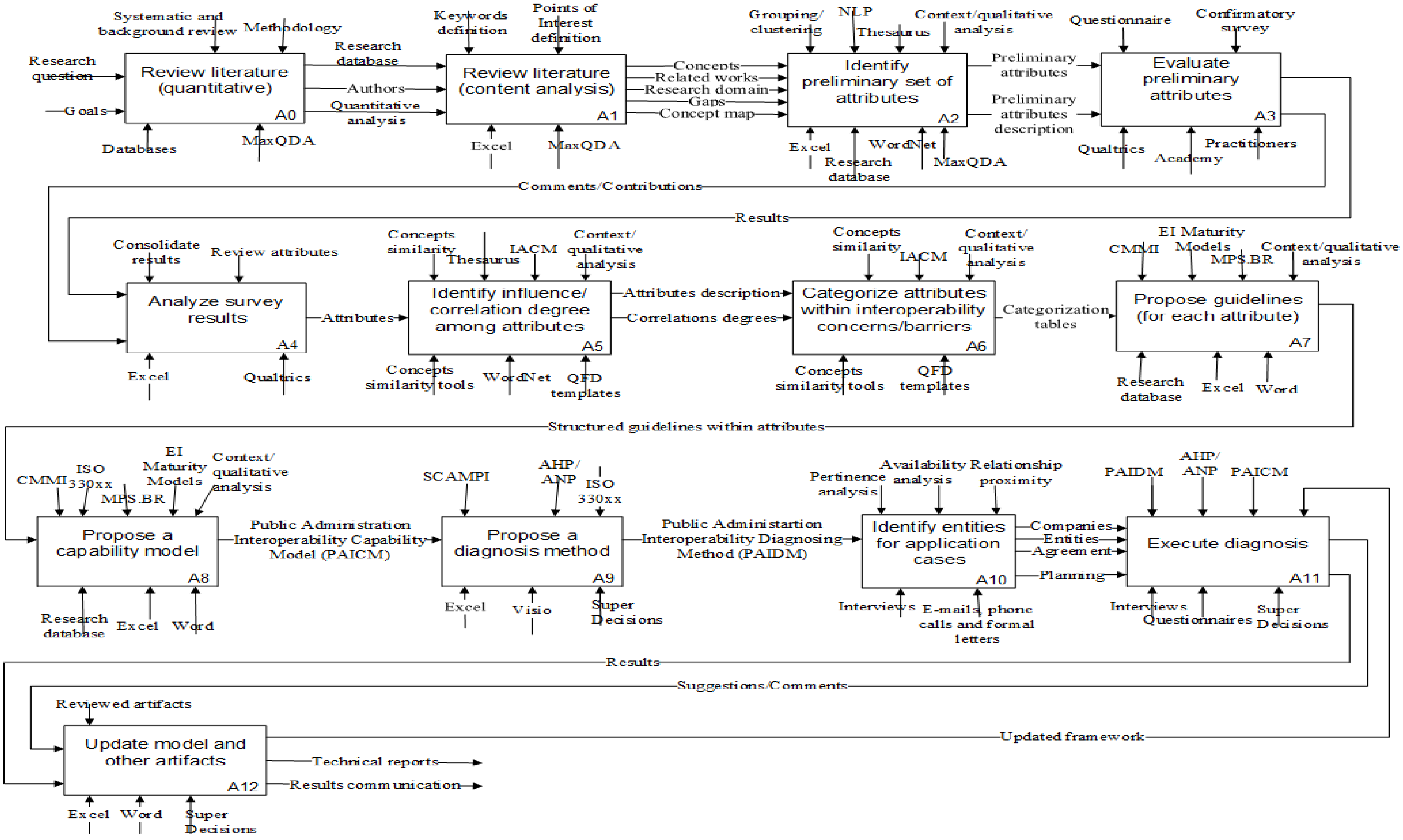
For the purpose of this research, and based on the concepts of Oxford (2014) and Princeton University (2010), a framework is a real or conceptual structure intended to serve as a support or guide for building something that expands the structure itself into something useful.

The framework representation is based on IDEF0 notation (NIST, 1993), and helps to model the strategy at the highest level of inputs, controls, outputs, and mechanisms. Boxes represents functions (i.e., processes, operations, activities) and horizontal arrows indicates “Inputs” (entering the boxes (on the left)) and "Outputs" (leaving the boxes (on the right)), in this case representing the transformation and evolution of the information (products of the research) through the process. “Controls” (arrow entering from the top) represents aspects that constrain or govern the function (e.g., methods and tools) and “Mechanisms” (arrows entering from the bottom) represents the resources which perform the function (e.g., people, software, database).

In the expanded framework of Figure 4, processes A0 to A4 are related to the structuring phase (Phase I) of Figure 3, while processes A5 to A9 are related to the developing phase (Phase II) and processes A10 to A12 are related to the execution phase (Phase III).

To achieve the proposed goals, the presented research framework allows the characterization of a life cycle that supports the elaboration of a capability model called **Public Administration Interoperability Capability Model (PAICM)** and the definition of a diagnosis method called **Public Administration Interoperability Diagnosis Method (PAIDM)**, both related to the public administration application domain.

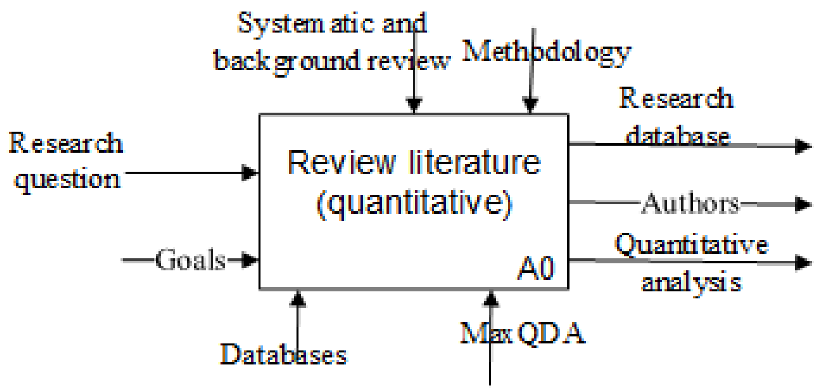
Figure 4: Research framework



Source: The author (2015).

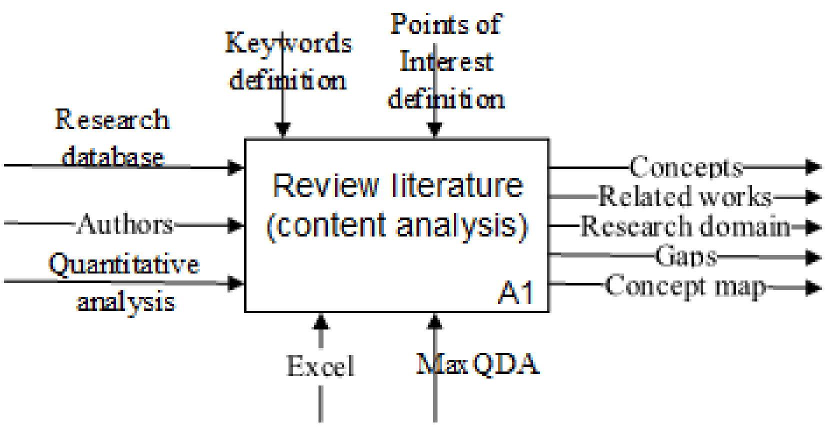
The results of A0 (Figure 5) and A1 (Figure 6) can be summarized as (i) definition of related papers database, (ii) analysis regarding the world publication and authoring in order to help the justification of the research and map the distribution of the subject, (ii) definition of the domain and (iv) identification of gaps regarding the existence models and related works. The MaxQDA tool (MaxQDA, 2014) was used to organize and storage the files, create categories and extract information. MaxQDA is a software for qualitative and mixed methods data analysis, where it is possible to create code system, organize, sort and use categories, and categorize data. It also retrieves coded segments and integrate quantitative methods or data into the project. The literature review and content analysis are exposed in section 3.

Figure 5: Process A0



Source: The author (2015).

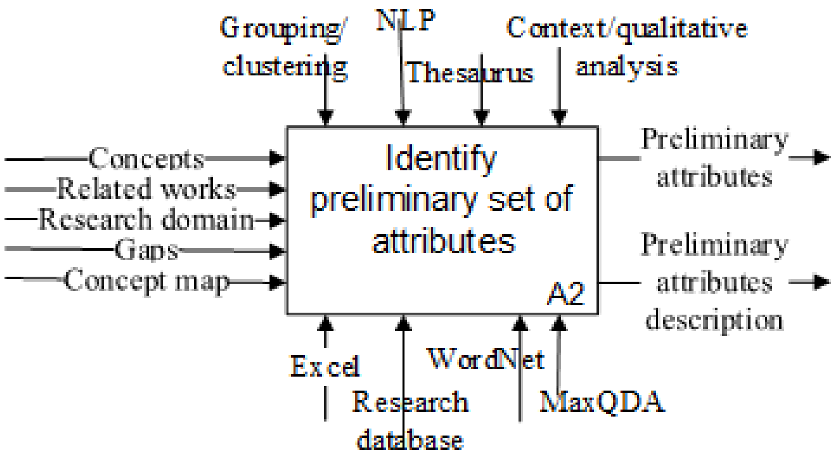
Figure 6: Process A1



Source: The author (2015).

Based on the results and information gathered in A0 and A1, the next process (A2), represented in Figure 7, relates to the extraction of the preliminary set of attributes, which can be considered as a set of requirements or desired characteristics of interoperability within the public administration (or related) entities.

Figure 7: Process A2

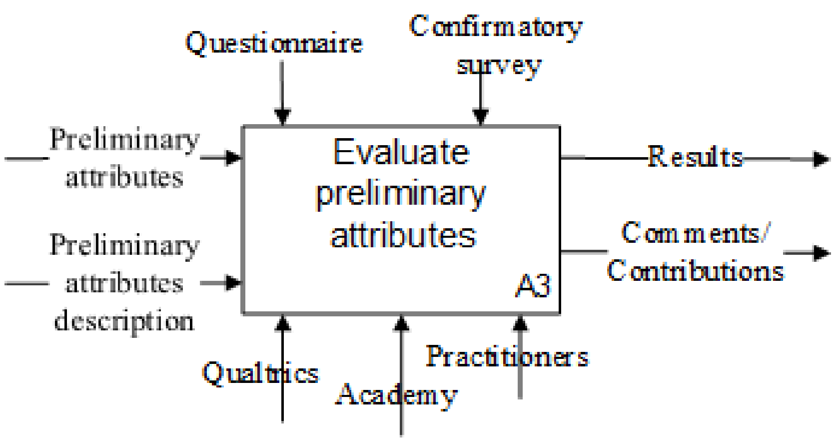


Source: The author (2015).

The identification of the preliminary attributes occurs with a quantitative and qualitative approach. There are mechanisms regarding Natural Language Processing (NLP), context and qualitative analysis, and other techniques that are exposed in section 4. Thesaurus and the WordNet (Princeton University, 2010) were used to gather related attributes definitions and similarities of the words.

The set of attributes is evaluated by experts (practitioners and academy) in process A3, as depict in Figure 8. A confirmatory survey is executed using questionnaires in order to evaluate the extracted attributes and, if it is necessary, update and review some of the items. The questionnaires were build using a web tool called Qualtrics (Qualtrics, 2015), which organize, create, distribute and analyze pools.

Figure 8: Process A3

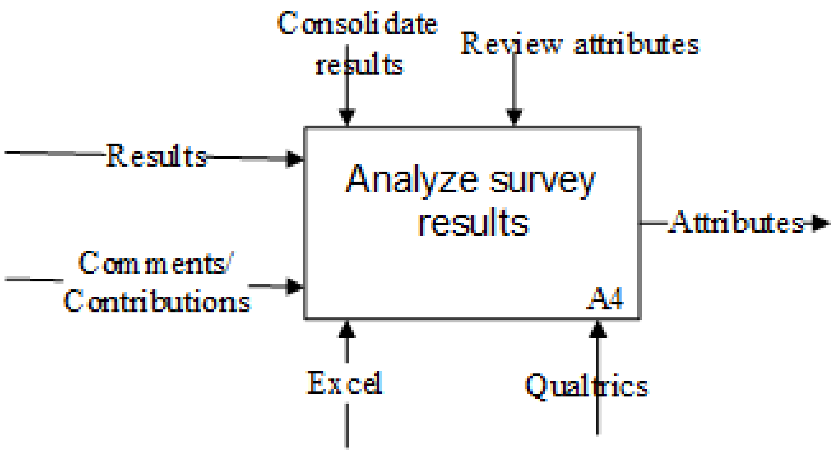


Source: The author (2015).

With the survey, it is also possible to (i) gather another source of information other than the papers from the database, (ii) review the collected data verifying its pertinence to the subject (The vocabulary are correct? Are the items feasible? Is there complementary information?), (iii) evaluate the initial attributes. The survey method is exposed in section 3, and the execution and the results of the survey, as well as the selection criteria for the respondents and other details regarding this process, are described in section 6.

Figure 9 (process A4) represents the analysis of the survey results, with the evaluation of the answers, comparisons and outcomes (list of attributes). Qualtrics provides some statistical information, and Excel was used to execute some other specific statistical analysis (e.g., consistency and hypothesis test).

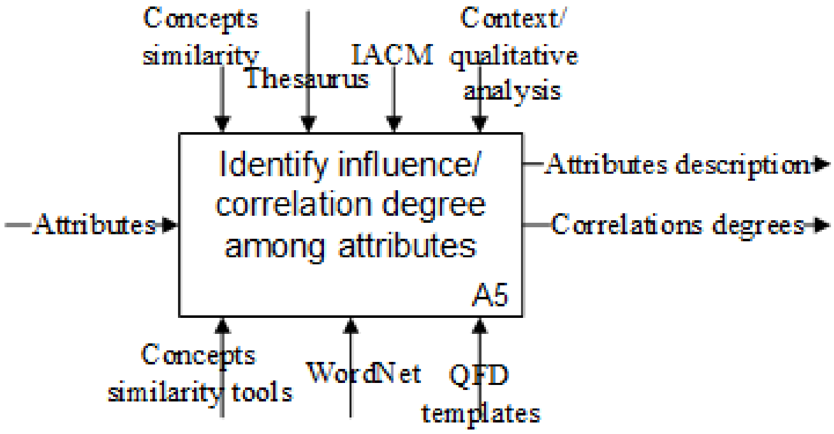
Figure 9: Process A4



Source: The author (2015).

The next process, represented in Figure 10, is dedicated to the calculation of a relationship (influence) degree among the attributes. These values will be used to evaluate (during diagnosis) the level of influence between one attribute and another. This process uses concept similarity tools to calculate the semantical “proximity” of two or more words or sentences and the results are used to help the structuring of the correlations and influence degrees. These correlations are structured within a proposed method called **Interoperability Attributes Correlation Matrix (IACM)**, based on the Quality Function Deployment (QFD) (Akao, 1990). The IACM adopts some QFD spreadsheet templates to organize its model. The tools and mechanisms employed in this process are better detailed in section 4, and the results are exposed in section 6.

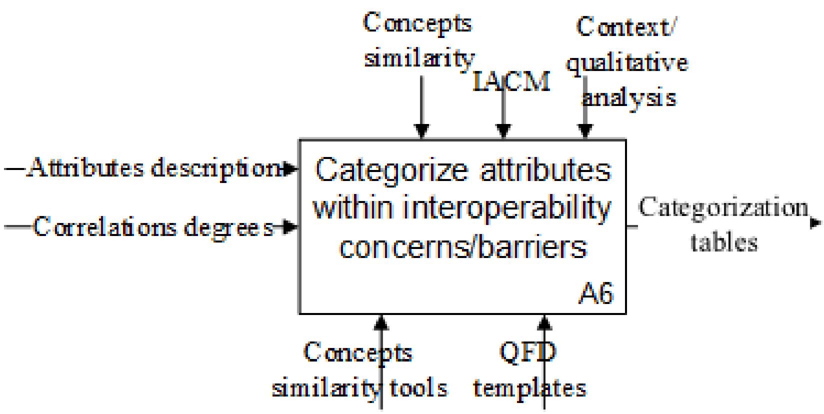
Figure 10: Process A5



Source: The author (2015).

Figure 11 illustrates the process of categorization of the extracted attributes into the interoperability structure of concerns and barriers. This provides the grouping of the items into categories, better organizing the information for the construction of the capability model and further diagnosis evaluation. The IACM was used to map and create the relative position of the attributes within the interoperability structure. The tools and mechanisms used in this process are better described in section 4, and the results are exposed in section 6. It is relevant to mention that the order of execution between Process A5 and Process A6 are not relevant for this research.

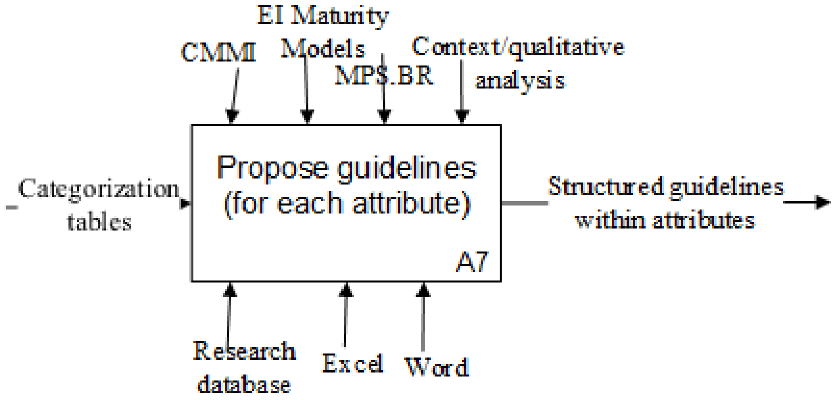
Figure 11: Process A6



Source: The author (2015).

To evaluate better each attribute, it is important to mention that guidelines can illustrate some characteristics and divide the whole attribute vision into “practices” that compose the achievement for that attribute. Figure 12 exposes this process, using CMMI (CMMI Product Team, 2010) and MPS.BR (SOFTEX, 2012) as content references, once they are consolidated models and can provide information regarding some of the already adopted practices.

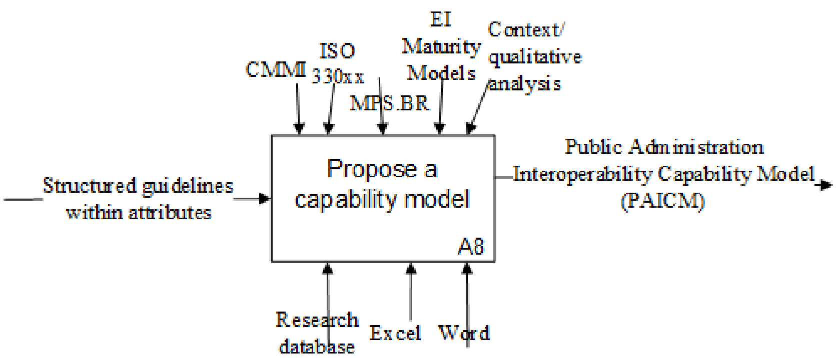
Figure 12: Process A7



Source: The author (2015).

With the measurement aspects organized together (e.g., attributes, guidelines, interoperability concerns), the whole information can be used to define a capability model, regarding its levels description, the composition of the model, structure and other aspects as exposed in Figure 13. The ISO 330xx (ISO/IEC, 2015), CMMI and MPS.BR provides a classical organization reference of a capability and maturity models, helping the structure of the capability levels, organizing the practices and levels descriptions. The whole content of the generated model is called **Public Administration Interoperability Capability Model (PAICM)** and is composed of several components, including capability levels, descriptions and structure.

Figure 13: Process A8

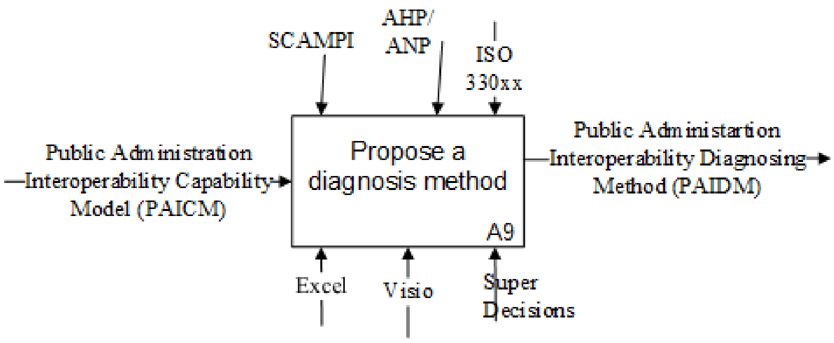


Source: The author (2015).

After the definition of the guidelines, attributes and the capability model itself, it is necessary to define the diagnosis method, which will describe how the assessment will occur, how to rank the items evaluated, what are the steps and other issues. Adopting some basic models and methods as references (e.g., SCAMPI, AHP), process A9 (represented in Figure 14), represents the construction and organization of a diagnosis method, called **Public Administration Interoperability Diagnosing Method (PAIDM)**. The method identifies, among other things, information regarding the activities of the diagnosis as well as define how to collect information (e.g., interviews, observation) and calculate the levels (using AHP/ANP). The main reference for the diagnosis method is the Standard CMMI Appraisal Method for Process Improvement (SCAMPI Upgrade Team, 2011) which is designed to provide benchmark-quality ratings relative to the model. The ISO 330xx is also a source for capability diagnosing method and it is important to mention that the group of ISO 33000 is the reviewed version of the "old" ISO 15504 – SPICE (Software Process Improvement and Capability dEtermination). The Visio tool is used to build the activities and workflows of the method.

The diagnosis method relies on an aggregation of information that is collected via defined types (interviews, questionnaires) and is better described in section 7.

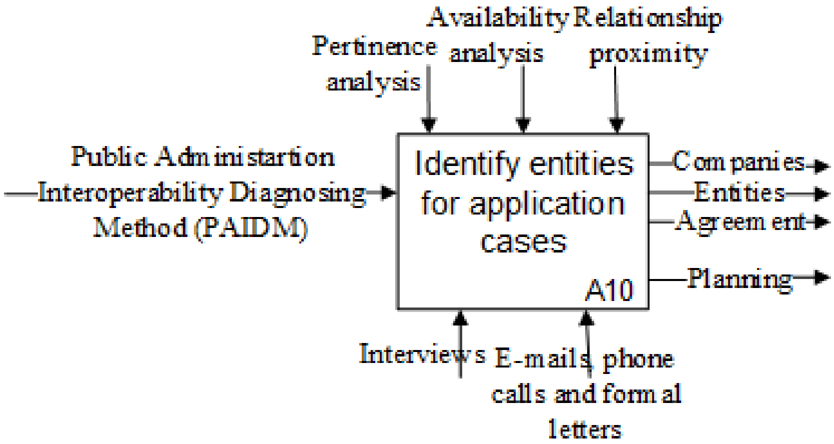
Figure 14: Process A9



Source: The author (2015).

Figure 15 (process A10) deals with the identification of the entities and definition of which will be the focus of the diagnosis. The choice will depend on several criteria, such as availability, relationship proximity, pertinence, management approval.

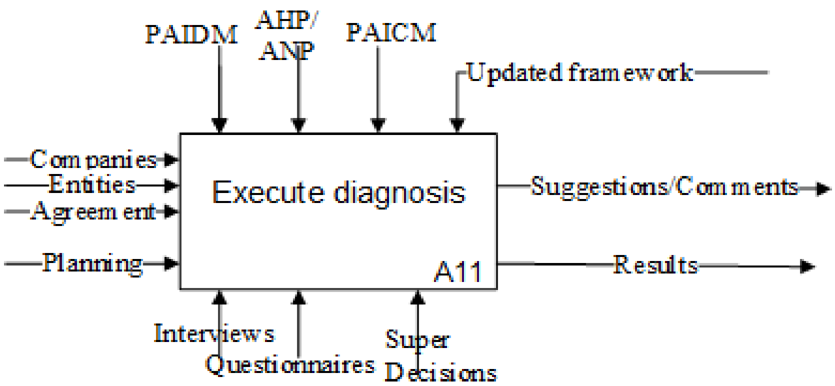
Figure 15: Process A10



Source: The author (2015).

Figure 16 (process A11) is the diagnosis execution itself. The diagnosis can also be considered as an application case of the model (guidelines, attributes and methods) and to the whole research framework. That is, together with process A12 (Figure 17), the model and its artifacts can be updated as a result of the diagnosis, according to the comments and other detected perceptions. The execution of the diagnosis uses the proposed PAIDM and PAICM as the reference models, and the Super Decisions software (Adams and Creative Decisions Foundation, 2013) implements the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP), setting priorities and doing the calculations regarding the capability levels.

Figure 16: Process A11

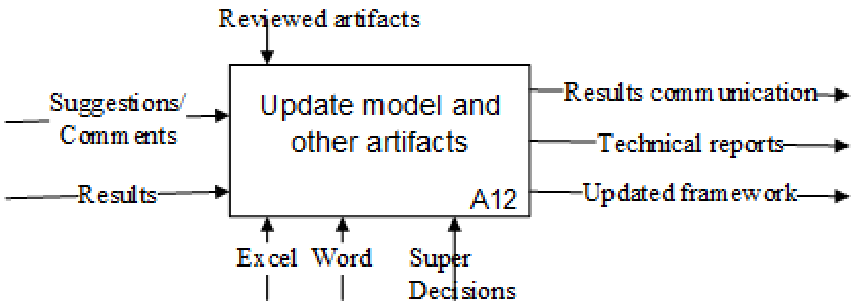


Source: The author (2015).

The diagnosis execution, as already planned at the diagnosis method, uses AHP/ANP to categorize and “choose” the capability level of the diagnosed entity, with a quantitative and more deterministic approach to control the inconsistency of the gathered information.

Finally, process “A12”, represented in Figure 17, is related to the update of all related information regarding the framework. That is, after the diagnosis and results, suggestions and perceptions can be consolidated to review and upgrade the framework itself (e.g., new attributes, new ways of diagnosis, new guidelines, update the Super Decisions model). This process consolidates the results of the diagnosis and pertinent technical reports for the entities, with general suggestions regarding the diagnosis to improve the capability levels of the attributes (when necessary).

Figure 17: Process A12



Source: The author (2015).

2.1 CONSIDERATIONS AND CHAPTER SYNTHESIS

This chapter presented the research structure in the form of a framework, describing the main processes executed to achieve the research goals. The framework details the overview structure initially presented in Figure 3. Each of the processes is presented separately from the main illustration (Figure 4) and some details of its tools and activities are exposed.

The framework, within its processes, creates and adopts three contributions of this research: (i) the **Public Administration Interoperability Capability Model (PAICM)**, the (ii) the **Public Administration Interoperability Diagnosis Method (PAIDM)** and the (iii) **Interoperability Attributes Correlation Matrix (IACM)**.

3 METHODOLOGY

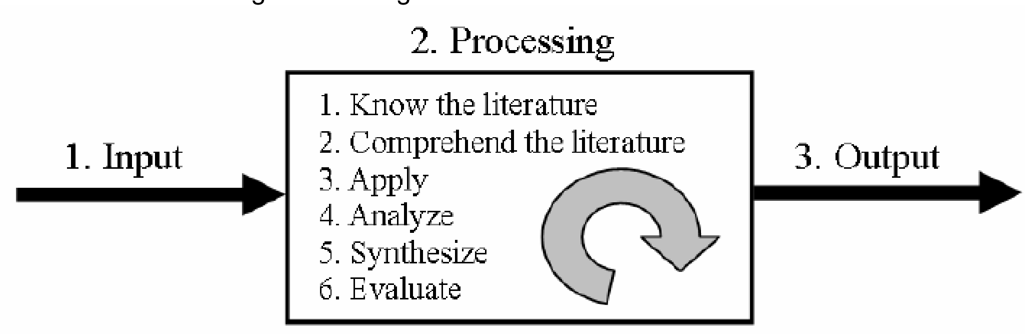
It is possible to consider that the methodology adopted for the research is integrated within the representation of the research framework (Figure 4), and this chapter exposes the techniques, tools and methods used to support and help the achievement of the research goals and its activities.

3.1 SYSTEMATIC LITERATURE REVIEW

Related to the “structuring” phase (Phase I) of Figure 3, and with the processes A0 and A1 of the research framework (Figure 4), the systematic literature helps the definition of the goals and objectives regarding the research, besides mapping and positioning the actual context of the subject.

The adoption of a literature review is crucial since it contributes to filter and details some specific topics, providing an overview and identification of gaps to formulate new approaches to the research. The literature review also supports the establishment of a prior theoretical base that will help the analysis of evidence collected in qualitative and quantitative studies, providing ways for identifying, evaluate and interpret documents and available research work products that are relevant to a theme or area of interest. This document adopts a model proposed by Levy & Ellis (2006), as shown in Figure 18.

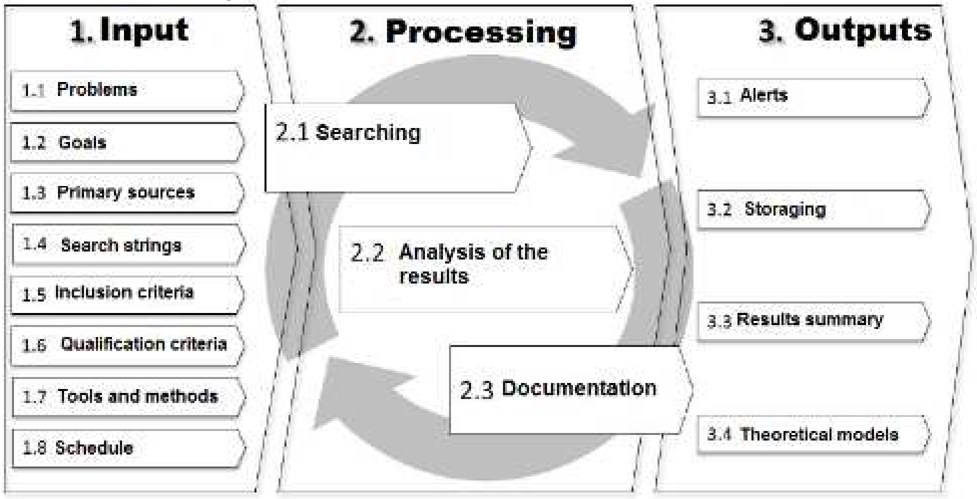
Figure 18: Stages for a literature review



Source: Levy & Ellis (2006).

There are three basic stages proposed by Levy & Ellis (2006): input, processing and output. In the “input” stage, some preliminary data are processed (documents regarding the study filed, papers, books and others). The second phase (processing) contains a protocol describing how the review will be executed (process, techniques, and tools used). At the third stage (output) the work products, reports, and results are consolidated. Figure 19 presents a model, based on Levy & Ellis (2006) and Conforto et al., (2011), regarding the conduction of a literature review.

Figure 19: Structure of a literature review.



Source: Levy & Ellis (2006) and Conforto et al., (2011).

The stages (and substages) are described as follows:

- 1.1 Problems: definition of a problem could be considered as the starting point for a literature review. The idea is answer one (or more) questions through the review.
- 1.2 Goals: the goals must be aligned with the research goals.
- 1.3 Primary sources: identify papers, journals, magazines, databases and other artifacts useful to the definition of keywords, identification of the authors, have an overview and then apply filters to select a small universe of more relevant documents. As the stage name says, it is the primary source for the beginning of the research and the literature review.
- 1.4 Search strings: identification of the search strings that will be used to gather, find and filter the artifacts relevant do the research.
- 1.5 Inclusion criteria: definition of the criteria used to select the artifacts (papers and other documents). It must be aligned with the research goals.
- 1.6 Qualification criteria: the definition of these criteria is useful to classify the importance of an artifact for the research theme.

- 1.7 Tools and methods: define the search filters, how the database will be accessed, how data will be storage and so on.
- 1.8 Schedule: define the schedule of the review, tools, equipment, software and other relevant needs.
- 2.1 Searching: execution of the search per se. Using and applying the filters and selecting the documents from the databases.
- 2.2 Analysis of the results: verification and validation of the results.
- 2.3 Documentation: initial selection and storing of the documents selected: number of documents found, countries related to the papers, authors and other information collected.
- 3.1 Alerts: it may be possible to insert some "alerts" in the journals to receive information about future publications and editions. This may be useful if the goal is (also) to keep track of the future works and keep the researcher database updated.
- 3.2 Storing: the selected documents are stored in the search repository. A software may be used in this action.
- 3.3 Results summary: brief report about the literature found and analyzed. May be employed in the theoretical reference chapter and/or the literature review chapter of the thesis or a paper.
- 3.4 Theoretical models: construction of theoretical models (thesis purpose) and/or definition of a hypothesis.

To obtain the benefits of a literature review as described in this section, the research proposed in this document adopted the basic structure exposed in Figure 19 to organize and implement the literature review. Table 2 presents the **first stage (input)** and its description, considering that this is the fundamental structure adopted to organize and perform all the searches in the databases.

Table 2: First stage (inputs) of the literature review

Input stages	Description
Stage 1.1: Problem(s)	How are the relations between interoperability and public administration (considering eGovernment)? Which are the countries engaged in the theme? What are the main definitions of eGovernment Interoperability? How is the distribution of papers during the years?
Stage 1.2: Goals	Obtain the main concepts regarding interoperability, eGovernment, existing frameworks, distribution around the world, position in Brazil, assessment models.

Input stages	Description
Stage 1.3: Primary sources	Google Scholars, SciELO, Capes database, Google, Scopus.
Stage 1.4: Search string	It will be considered a mix of search strings, considering the objectives and the idea to compare the results of different strings. The detail of when (and how) these mixes of strings were used is described in the results paragraphs. The basic strings used are “interoperability”, “eGovernment”, “governo eletrônico” (Portuguese for electronic government), “public administration”, “administração pública” (Portuguese for public administration).
Stage 1.5: Inclusion criteria	The combination of the strings defined, considering the filters regarding the relevance of the document to the research theme.
Stage 1.6: Qualification criteria	The document has relevant information for the research theme and it is not related to another theme which may use some of the same strings adopted (e.g., warfare papers also uses government and interoperability strings, radio transmission topics, and others).
Stage 1.7: Tools and methods	Access to world databases. It was considered searches in the title and abstract (considering the strings defined). The details are described in the exposition of the results. Excel and MaxQDA (MaxQDA, 2014) were adopted to organize and storage the files, create categories and extract information.
Stage 1.8: Schedule	Six months.

As the **stage 2 (processing)** of the literature review model (Figure 19) is the execution of the search *per se*, the detailed results are described in the following paragraphs.

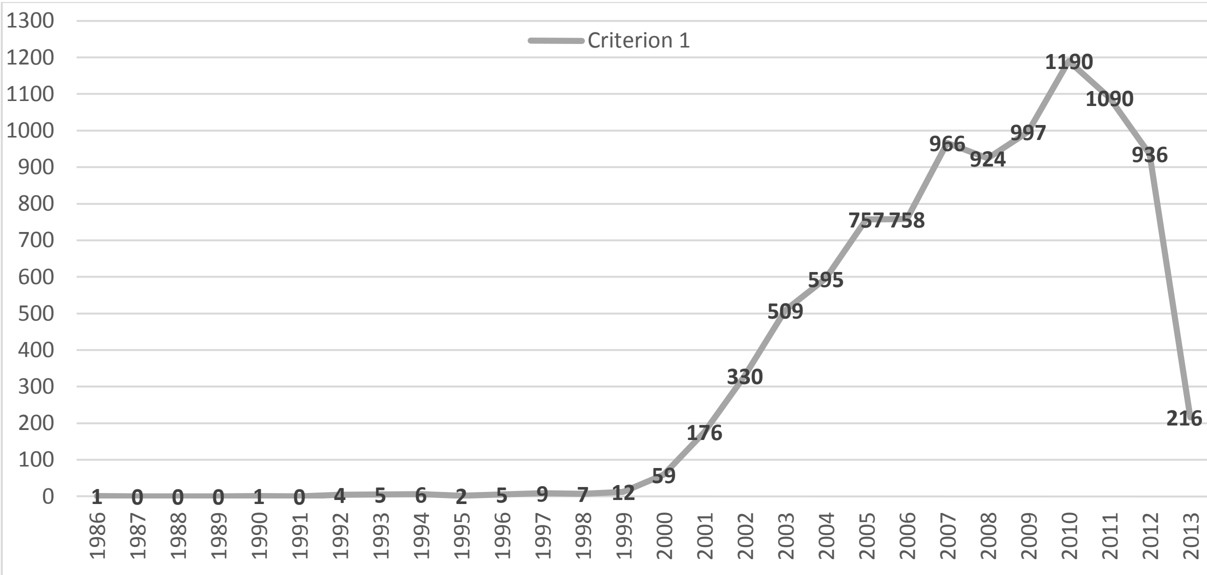
To illustrate the quantitative difference in the research field regarding ‘eGovernment’ and the composition of ‘eGovernment’ and ‘interoperability’ fields, an initial search, considering only the string eGovernment and similar (egov, e-gov, electronic government), were done. The idea was to verify the distribution of the eGovernment subject during the years. The attributes used are described in Table 3 and the results in Figure 20.

Table 3: Attributes within the Scholars databases regarding electronic government

Attributes	Description
Database	Google Scholars.
Goal	Provide an overview of the position of the string (and composition of the strings) regarding the theme eGovernment (within the public administration major theme) in order the have a reference prior to executing other searches. Verify the distribution of the findings over the years. Verify the distribution of English strings versus Portuguese strings.
Start/Finish dates	Considered since 1986 until may/2013.

Attributes	Description
Criteria	Criterion 1: at least one of the following strings in the title (or abstract) of the document: “eGovernment”, “e-government”, “egov”, “e-gov” or “electronic government”. Criterion 2: string "governo eletrônico" in the title (or abstract) of the document.
Filters	No filters applied (as the idea is only to generate an overview and not compose the final database for the research).

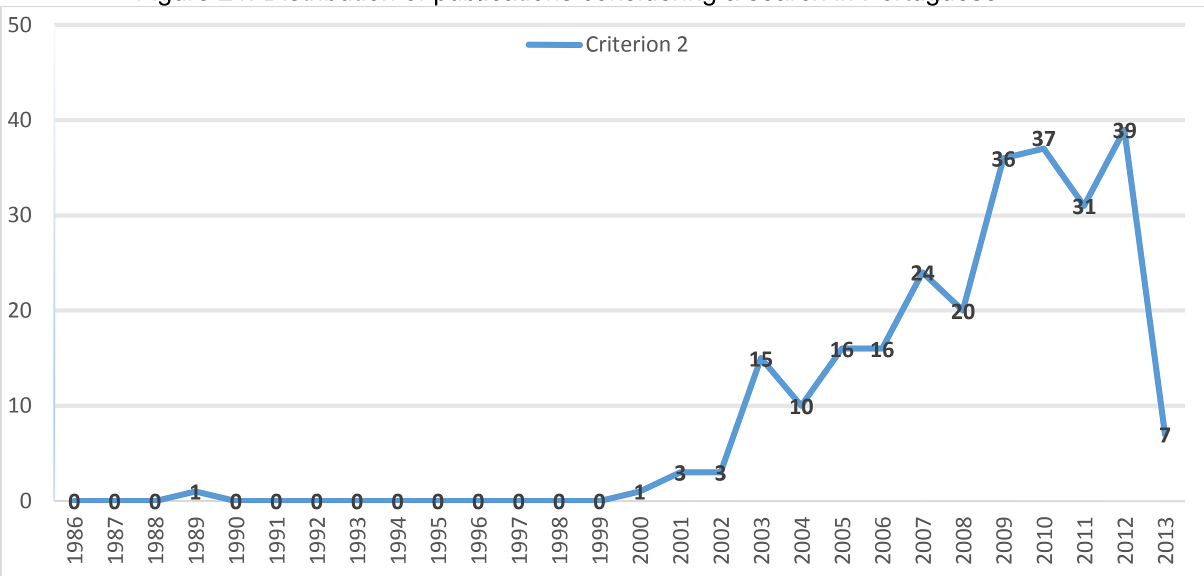
Figure 20: Distribution of publications regarding the subject eGovernment within the Scholars database



Source: The author (2015).

As Figure 20 shows, it is possible to detect that the domain begins to increase its importance in the research field in the late 1990s. This information gave a preliminary view of the time positioning and evolution of the domain. Across the evolution of the research, the data were confirmed using other sources. The fact is that the results of the increasing publications from the late 1990s are expected once, as this research later on detected, the concepts and definition of eGovernment were formalized by the end of 1999 and during 2000 (Chahin et al., 2004). After that, there was an increasing number of papers and documents until 2010, with some decrease after 2011. There is a significant amount of documents related to the subject (at least in the English language): criterion 1 returned 9,555 matches. On the other hand, Figure 21 shows that the search string in Portuguese language (criterion 2) returned only 259 results. There is, of course, a large amount of papers written in English, even though the authors are not English native speakers (in the case of Brazilian authors). Despite that, Figure 21 can be considered as an indicator that the amount of produced work in Brazilian context are much smaller than the rest of the world. Another possible interpretation of Figure 21 is that the Brazilian authors prefer (or are demanded) to publish in English rather than in Portuguese but, although this may seem obvious considering that most of the conferences and journals accept only English papers, that's not what was detected during the research.

Figure 21: Distribution of publications considering a search in Portuguese



Source: The author (2015).

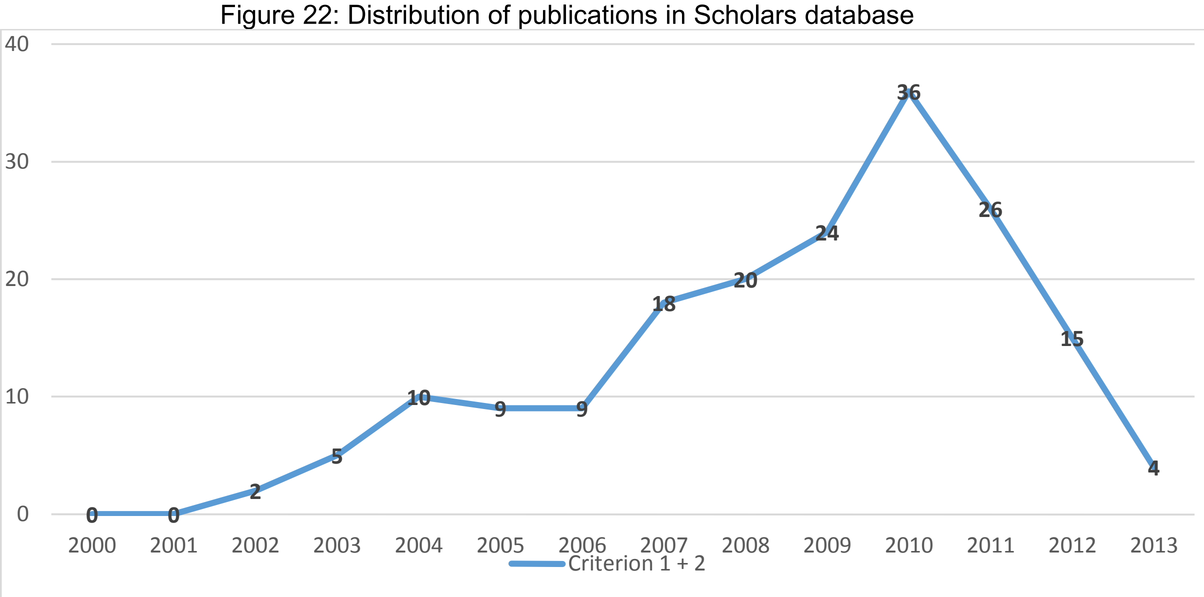
As detect in the English publications (Figure 20), it is also possible to see in Figure 21 that the number increase (with some variations) from 2000 to 2010 (with 37 publications), although the peak is in 2012 (with 39 matches). The information related to Figure 21 is another important output from the literature review once, besides the explicit comparison intent (publications in English versus in Portuguese), it also helps to justify this research, considering that there are gaps in the domain, and there is space for development and applying application cases in Brazil. The previous data exposed in Figure 20 and Figure 21 provided a simple quantitative overview and distribution over the years, with a core intention of positioning the domain in a time-related distribution and create some comparative information considering English and Portuguese publications.

To continue the analysis, a composition of strings was done, this time already considering the goals of this research, which considers eGovernment and public administration interoperability issues. Table 4 shows the attributes created to run the search, with the definitions of strings, databases, and filters. The results are exposed in Figure 22.

Table 4: Attributes used in the search for files within the Google Scholars database

Attributes	Description
Database	Google Scholars.
Goal	Verify the publications regarding public administration (including eGovernment) in the context of interoperability (and vice versa). That is, research considering the interoperability aspects within government organizations. This helps to provide the overview over the years and beginning the creation of the research repository publications and documents.
Start/Finish dates	Considered since 1986 until may/2013.
Criteria	Criterion 1: string “interoperability” and ("government" or "public administration") in the title of the publication. In this case, strings such as “e-government”, “eGovernment” and “eGov” are also considered. Criterion 2: string “interoperabilidade” and ("governo" or "administração pública" or "egov" or "e-gov") in the title of the publication. In this case, strings such “e-governo” are also considered). The words “governo”, “administração pública” e “interoperabilidade” are Portuguese and stands, respectively, for “govern”, “public administration” and “interoperability”.
Filters	Filter 1: documents before 2000 were removed, once this research considers the formalization of eGovernment in the year 2000. Filter 2: duplicated documents were removed.

Figure 22: Distribution of publications in Scholars database



Source: The author (2015).

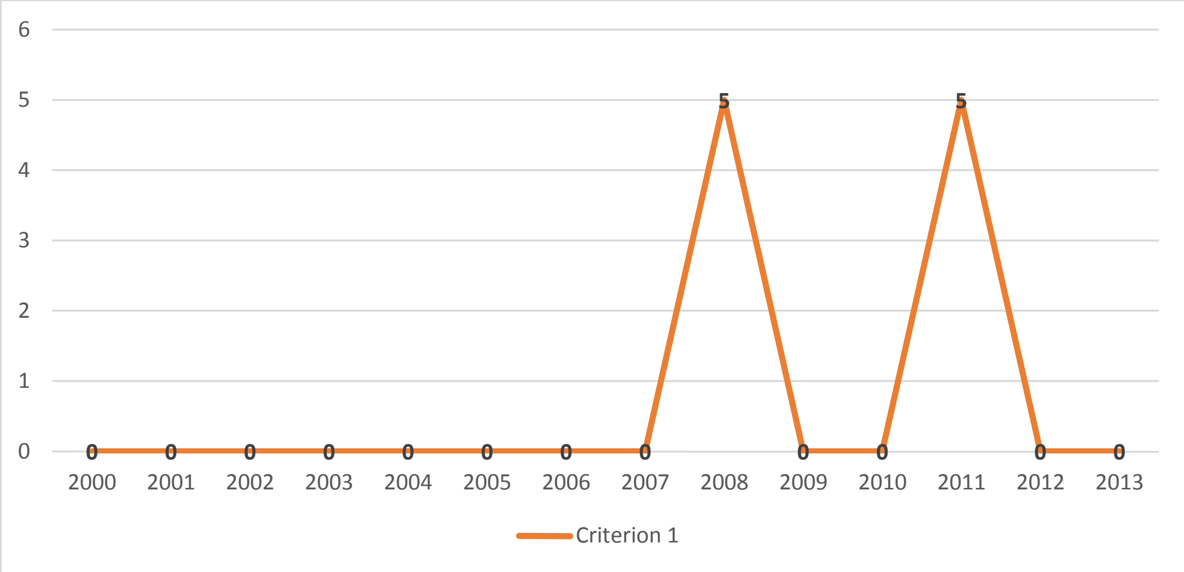
Figure 22 shows a result of 178 matches (papers and others documents) regarding the criterion 1 + 2 and the applied filters. During 8 years, from 2002 to 2010, there were an increasing number of publications, although the absolute number and the increasing rate is not so high. The peak is reached in 2010, with 36 matches, and since then, the publications number began to decline. From the 178 publications, there are 9 regarding the criterion 2, i.e., published in the Portuguese language.

The next verified database was SciELO (Scientific Electronic Library Online). SciELO is a 15 years old electronic library with a collection of more than 1000 journals mostly focused in Latin America, Spain, Portugal and South Africa (SciELO, 2013). Table 5 shows the attributes adopted in the execution of the search in SciELO, with the results presented in Figure 23.

Table 5: Attributes used in the search for files within the SciELO database

Attributes	**Description**
Database	SciELO.
Goal	Verify the publications regarding eGovernment (within public administration domain) in the context of interoperability (and vice versa). That is, research considering the interoperability aspects within government organizations. Provide this overview over the years and begin the creation of the research repository publications and documents.
Start/Finish dates	Considered since 1986 until may/2013.
Criteria	Criterion 1: string "interoperability" and ("government" or "public administration”) in the title or abstract of the publication. In this case, strings such as “e-government”, “eGovernment”, “eGov” are also considered. Criterion 2: "interoperabilidade" and ("governo" or "administração pública") in the title or abstract of the publication. The words “governo”, “administração pública” e “interoperabilidade” are Portuguese and stands, respectively, for “govern”, “public administration” and “interoperability”.
Filters	Filter 1: documents before 2000 were removed, once this research considers the formalization of eGovernment in the year 2000. Filter 2: duplicated documents were removed.

Figure 23: Distribution of publications in SciELO database



Source: The author (2015).

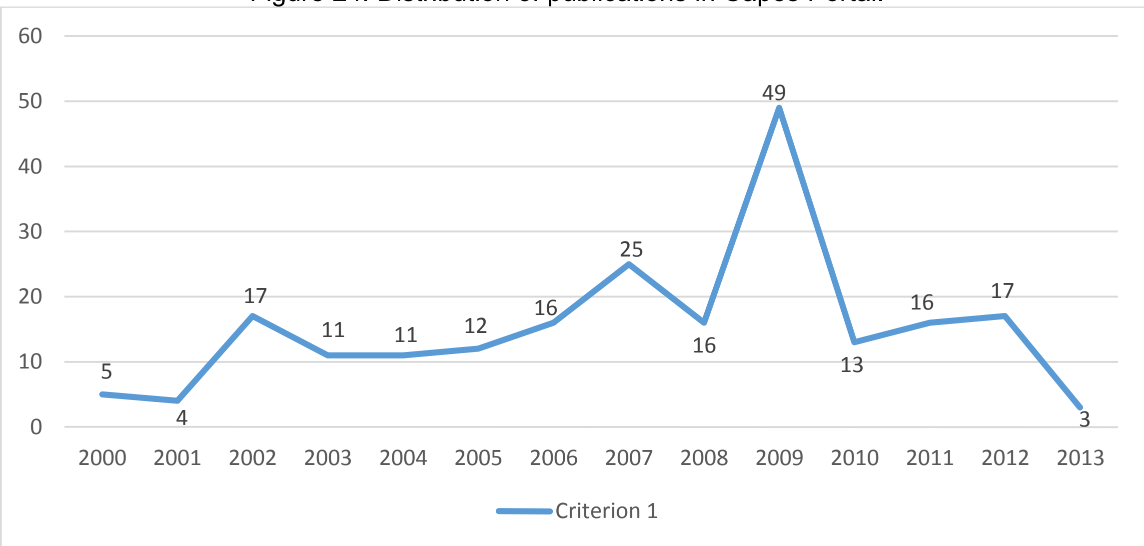
Figure 23 shows a result of 10 matches (papers and others documents) considering the criteria (criterion 1) and applied filters, exposing that there are publications in two years: 2008 and 2011, both with five publications each. Criterion 2 is not presented in Figure 23 because the search returned zero matches, i.e., no publication was found using the Portuguese idiom.

The last database considered is the Capes Portal (CAPES, 2013). Capes stands in Portuguese for “Coordenação de Aperfeiçoamento de Pessoal de Nível Superior” (which can be freely translated to “Coordination of Improvement of Higher Education Personnel”). Capes is an official federal government organization (linked to the Ministry of Education) which helps to regulate and organize undergraduate, masters and doctoral degree courses, assessing degree levels to the universities, providing scholarships to researchers and students among other activities. The Capes organization maintain a portal through which is possible to access a series of world bases and journals (e.g., IEEE Xplore Science Direct, Springer Verlag, Oxford Journals and others). The Capes Portal has more than 246 related databases, providing access to more than 31 thousand international and national publications (CAPES, 2013). Table 6 shows the attributes adopted in the execution of the search in Capes Portal, with the results presented in Figure 24.

Table 6: Attributes used in the search for files within the Capes Portal

Attributes	Description
Database	Capes Portal.
Goal	Verify the publications regarding eGovernment (within public administration domain) in the context of interoperability (and vice versa). That is, research considering the interoperability aspects within government organizations. Provide this overview over the years and begin the creation of the research repository publications and documents.
Start/Finish dates	Considered since 1986 until may/2013.
Criteria	Criterion 1: string "interoperability" and ("government" or "public administration") in the title or abstract. In this case, strings such as "e-government", "eGovernment" and "eGov" are also considered. Criterion 2: "interoperabilidade" and ("governo" or "administração pública") in the title (or abstract) of the publication. The words "governo", "administração pública" e "interoperabilidade" are Portuguese and stands, respectively, for "govern", "public administration" and "interoperability".
Filters	Filter 1: documents before 2000 were removed, once this research considers the formalization of eGovernment in the year 2000. Filter 2: duplicated documents were removed.

Figure 24: Distribution of publications in Capes Portal.



Source: The author (2015).

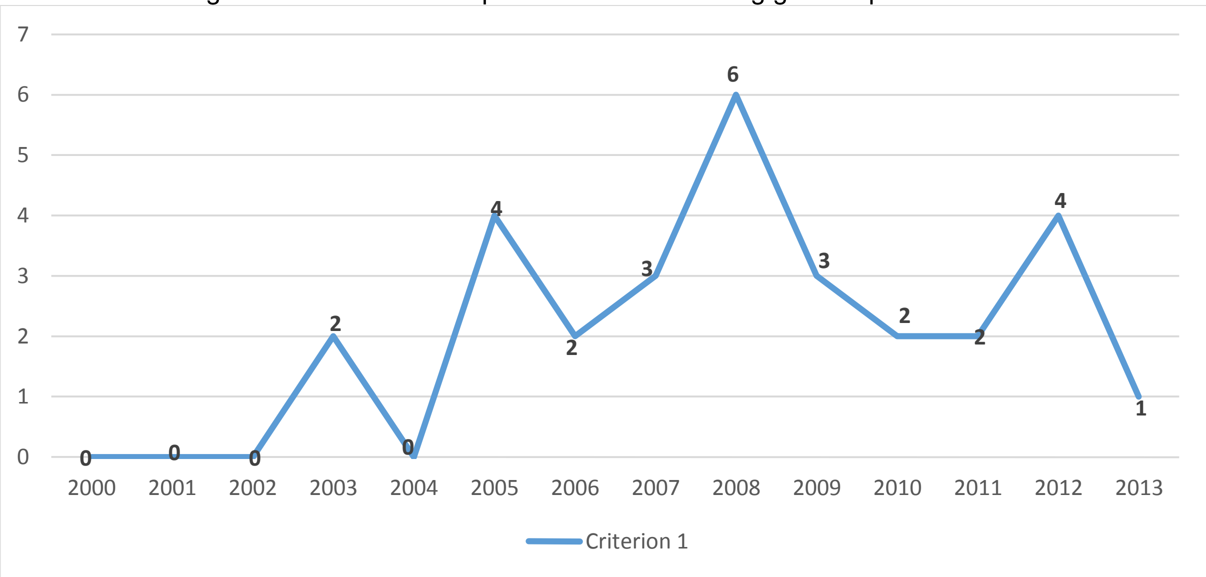
Figure 24 shows a result of 215 matches (papers and others documents) considering the criteria (criterion 1) and applied filters. It is interesting to verify that, similarly to Figure 22, the increasing of publication occurs (almost in a linear way) until the year 2009, where it reaches a peak of 49 publications. In 2010, there is an enormous fall, with 13 publications, and then the number maintain some stability until 2013. Criterion 2 is not presented in Figure 24 because the search returned zero matches, i.e., no publication was found using the Portuguese idiom.

To verify if it was possible to find some relevant documents apart from specific databases, a search was made considering the use of internet search mechanisms (Google and Bing). Table 7 describes the fundamental characteristics of that search, and the results are presented in Figure 25.

Table 7: Attributes used in the search for files considering generic portals and tools

Attributes	Description
Database	Google, Bing or free indications from other authors.
Goal	Verify the publications regarding eGovernment in the context of interoperability (and vice versa) that were not found in the other specific databases (Scholars, SciELO, and Capes Portal). Provide this overview over the years. Begin the creation of the research repository publications and documents.
Start/Finish dates	Considered since 1986 until may/2013.
Criteria	Criterion 1: string "interoperability" and ("government" or "public administration) in the title or abstract. In this case, strings such as “e-government”, “eGovernment” and “eGov” are also considered. Criterion 2: "interoperabilidade" and ("governo" or "administração pública") in the title (or abstract) of the publication. The words “governo”, “administração pública” e “interoperabilidade” are Portuguese and stands, respectively, for “govern”, “public administration” and “interoperability”.
Filters	Filter 1: documents before 2000 were removed, once this research considers the formalization of eGovernment in the year 2000. Filter 2: duplicated documents were removed.

Figure 25: Distribution of publications considering generic portals

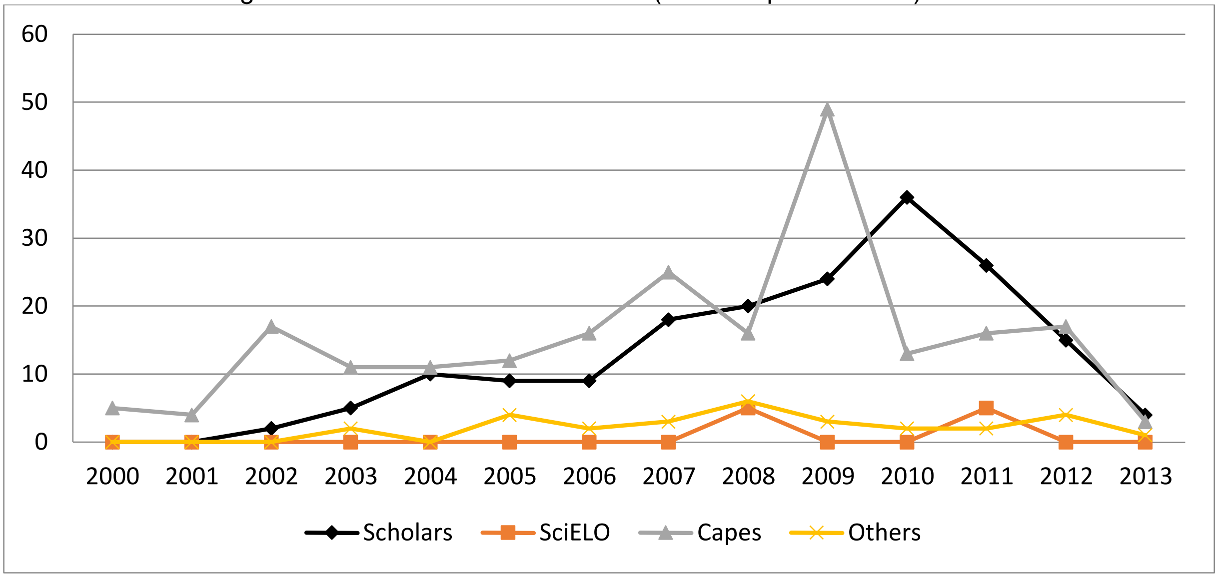


Source: The author (2015).

Figure 25 shows a result of 29 matches (papers and others documents) considering the criterion 1 and the selected filters applied. Criterion 2 is not presented because all the returns found were the same as the results found in the previously searches considering the Google Scholars, Capes Portal, and SciELO.

Until this point, no quality, relevant, content analysis or filter was applied. The idea was to create a quantitative overview of the three databases chosen plus a free search using Google and Bing. The preliminary results, before the content analysis, are interesting in a way that it was possible to identify some primary sources of the publications and yet develop a vision of the publications distribution across the years. Figure 26 shows a compilation of all results found in one graph, with the results of all the three databases (Google Scholars, SciELO, and Capes Portal) plus the free search as described in Table 7. The sum of all publications found is 432, again without no specific filter except the year 2000 baseline and the removal of duplicated items. It is possible to notice that the period with more publications is around the year 2009 and 2010, followed by a decrease of publications found in all databases. Although it is not the objective of this research to identify the causes of this reduction in the number of publications, some comments regarding the fact are exposed in section 3.3. Nevertheless, this is an interesting fact that can be explored for future research. Yet, another relevant fact is the low number of publications in Portuguese idiom, as already stated previously.

Figure 26: Results from all database (without specific filters)

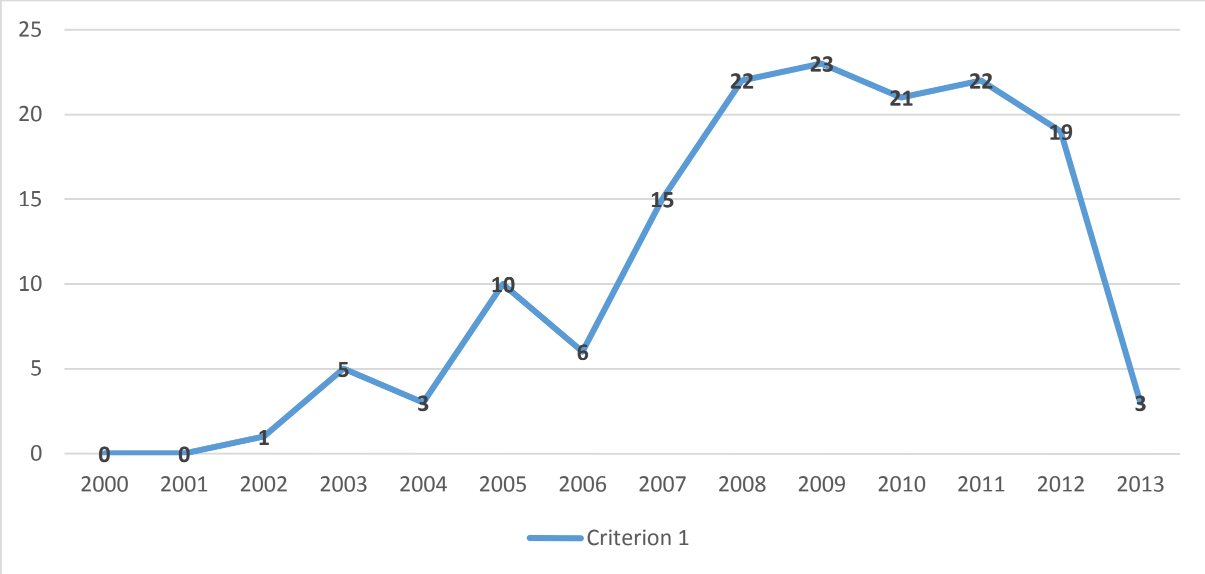


Source: The author (2015).

3.2 OTHER ANALYSIS (AUTHORS DISTRIBUTION, TYPES OF DOCUMENTS)

As a next step in the research, it was necessary to execute a content analysis of the documents found in the initial search. The object was to review all the 432 publications found and apply filters in order to select only those with connection to the research field and remove those not related to the theme but whose may use some of the same strings adopted (e.g., warfare papers also uses government and interoperability words, like radio transmission topics and others). The general qualification criteria (as proposed in stage 1.6 described in Table 2) is that the documents retrieved from the initial searches must be analyzed to check if they are relevant to the research subject and goals. The method adopted to perform this task was the reading of the title and abstract (and when it was necessary the introduction) of all the 432 documents and the application of a relevance and pertinence analysis. After the execution of this step, an amount of 150 documents left, as indicated in Figure 27. Documents considered not relevant do not compose the results of the 150 documents and are not part of the final repository of files regarding this research.

Figure 27: Distribution of publications considering all documents found in all search mechanisms



Source: The author (2015).

The 150 publications remained are distributed according to Table 8, considering the types of documents.

Table 8: Distribution per type of publication

Type of publication	Quantity
Papers in conference	47
Papers in journals	60
Whitepapers	11
Technical reports	19
Book chapters	5
Dissertation (masters and doctors)	6
Others (presentations, documents)	2

Considering the research database (150 documents retrieved from the literature review), a brief author analysis was made. The objectives are, among others:

- Verify the dissemination regarding the number of authors related to the documents.
- Verify the production of these authors (# of published documents).
- Try to detect if there is a main group of authors that is responsible for the major number of publishing.

It is important to state that no citation/co-citation analysis was not made and the researchers of this project know that, despite an eventual low number of publications, an author (or paper) may have a high impact factor because, for example, of the number of citations to his work, journal impact and so on.

The literature review identified 239 different authors associated with the 150 documents of the database. Most of the authors contributed only with one document, and there was only one author with the maximum number of contributions detected (six). Table 9 shows the distribution regarding the authors and the number of contributions. For those documents generated by a committee and/or government agency, it is considered that the author is the "committee". Therefore, from the 239 authors identified, there is one (the committee) that is responsible for 19 documents. The Table 9 does not consider the "committee" for its distribution.

Table 9: Percentage of authors according to the number of contributions

# Contributions	1	2	3	4	5	6
# Authors	193	28	5	6	4	2
% Authors	81.09%	11.76%	2.10%	2.52%	1.68%	0.84%

As Table 9 shows, more than 81% of the detected authors contributed with only one document, followed by approximately 11% who have two contributions. At least two things come to attention regarding this information:

- The "small" number of the maximum contribution, once that it was not detected anyone who has more than six documents.
- The significant number of researchers involved: 239 (plus the "committee").

Table 10 shows the name of the identified authors according to their number of contributions (considering only from six to three publications).

Table 10: Name of the authors

# of contributions	Author name
6	Hans Solli-Saether Yannis Charalabidis
5	Ralf Klischewski Theresa A. Pardo Ernani Marques dos Santos Vassilios Peristeras
4	Apitep Saekow Elsa Estevez G. Brian Burke Hans Jochen Scholl Luis Guijarro

# of contributions	Author name
	Tomasz Janowski
3	Choompol Boonmee Dimitris Askounis Herbert Kubicek Marijn Janssen Petter Gottschalk

The main results of the literature review are briefly described in Table 11, according to the steps of **stage 3 (outputs)** of the review methodology, exposed in Figure 19.

Table 11: Last stage (outputs) of the literature review

Outputs	Results
Stage 3.1: Alerts	Not applicable.
Stage 3.2: Storing	Excel was used to organize and filter information regarding the documents properties. In addition, the MaxQDA tool was used to organize and categorize the documents in quantitative and qualitative ways. A folder repository was created and the documents found were inserted. The MaxQDA tool is also a repository itself.
Stage 3.3: Results summary	After the application of all filters and criteria, it was selected 150 documents. Some of the results are exposed in chapter 3 as theoretical references.
Stage 3.4: Theoretical models	Theoretical references, documents, publications.

3.3 CONSIDERATIONS

The purpose of this section (so far) was to detail and explore the literature review aspects proposed in the methodology structure. In the first paragraphs, the idea is to present the conceptual issues of a literature review, exposing the steps, phases, and briefly detailing the activities. During the progress of the research, the already defined methodology was instantiated, executed, implemented, and the results were collected. Therefore, instead of letting this section only with concepts and planning, as a “proposal” section (to be executed during the research), this section presents some quantitative results, remembering that the other information and analysis are distributed in the following chapters and sections. This literature review was useful to, among other things:

- Map the distribution of the research domain (public administration interoperability) in terms of time.

- Define the late 1990s as the beginning period of the research and identify the year 2000 as the launch year for the concept of eGovernment within public administration.
- Identify existent models, frameworks, concepts, barriers, and concerns.
- Identify which are the countries most engaged in the research area of public administration (including eGovernment) interoperability to verify the importance of this research in Brazil.
- Identify authors and their publication.
- Help to define a concept map for the research domain.

There are at least two other important general aspects detected: the first is that there is little research considering Brazilian aspects and few publications in the Portuguese idiom, showing that there is, at a minimum, a gap in the research domain, although does not imply that there aren't Portuguese speakers researchers. The second is that, during the qualitative review, it was detected that most of what is approached in the research domain have a technical focus, indicating that there is also a gap regarding business process and organizational concerns as well as other issues. The third aspect is related to the decrease in the number of publications after 2010. Although this aspect is not part of the research goals, some reflections can be made considering the actual position of the research domain:

- As one of the focus is more strongly related to technical aspects (e.g., protocols, exchange parameters, codes, IT infrastructure, software), there may have been a "saturation" in this particular research aspect. There are, nowadays, an emerging scientific community dedicated to the exploration more related to organizational aspects of the interoperability assessment. Actually, renowned researchers with important reference on this proposal thesis focus on this. Researchers as in Whitman & Panetto (2006), Zutshi et al., (2012), Cornu et al., (2012), Pardo et al., (2012) and Chalmeta & Pazos (2014). The number of contributions may not be as high as considering technical aspects and/or some of the research are still ongoing and yet not published.

- The application of interoperability assessment is a new line of research in this mentioned organizational aspect, representing a very pertinent approach to contexts and application domains where collaboration and cooperation are present and very pertinent.
- The public administration area is traditionally assessed under already established benchmarks in the literature, as approaches to assessment of processes, organizational architectures and maturity assessments. New trends such as Lean Office (Lean Office, 2015) and BPM (ABPMP, 2015) are part of current scientific papers, but without due attention to aspects of cooperation and coordination processes - inherent to a good organizational performance. This is a gap not approached significantly in recent years.

All these gaps and scientific trends signaled by the previous graphics open a motivational scenario to focus on the interoperability assessment (or diagnosis) as an innovative element within the organizational diagnosis in the public related domain.

In summary, the literature review helped in the definition and systematic method for implementing the searches and analyze the results, define a theoretical baseline that supports the creation of a reference assessment (or diagnosis) model for public administration interoperability.

3.4 CONTENT ANALYSIS

Content analysis is the use of techniques for clarification and systematization of the content of the messages and expressions, to produce knowledge from the data analyzed. It can be used to enrich an exploratory analysis or to prove (validate) hypotheses (Bardin, 2011) and obtain fast notions about a text, identifying key ideas, categorizing texts and helping the execution of qualitative and quantitative analysis.

There are two basic directions related to content analysis, proposed by Henry & Moscovici (1968): executing procedures with a closed approach, or with an open and exploratory view. The first case is those with pre-defined categories of analysis. The second case deals with open or exploratory procedures, being therefore purely exploratory, with no pre-defined categories. This research adopted a mixed of these two approaches, with a higher tendency to the "open" view, collecting categories and important information during the analysis of the documents.

Adapted from Freitas & Janissek (2000), the following steps were executed (and/or will be executed) to perform the content analysis:

- Definition of the universe: define all the survey elements that qualify for inclusion in the research study.
- Categorization of the studied universe: define the dimensions that will be analyzed, keywords, content qualification and quantification, categories.
- Chose the analysis units: define the appropriated units regarding each type of contexts and contents (e.g., geographical units, quantitative units).
- Qualification: may provide the relationship (and inferences) of the characteristics found in the contents of the studied universe.

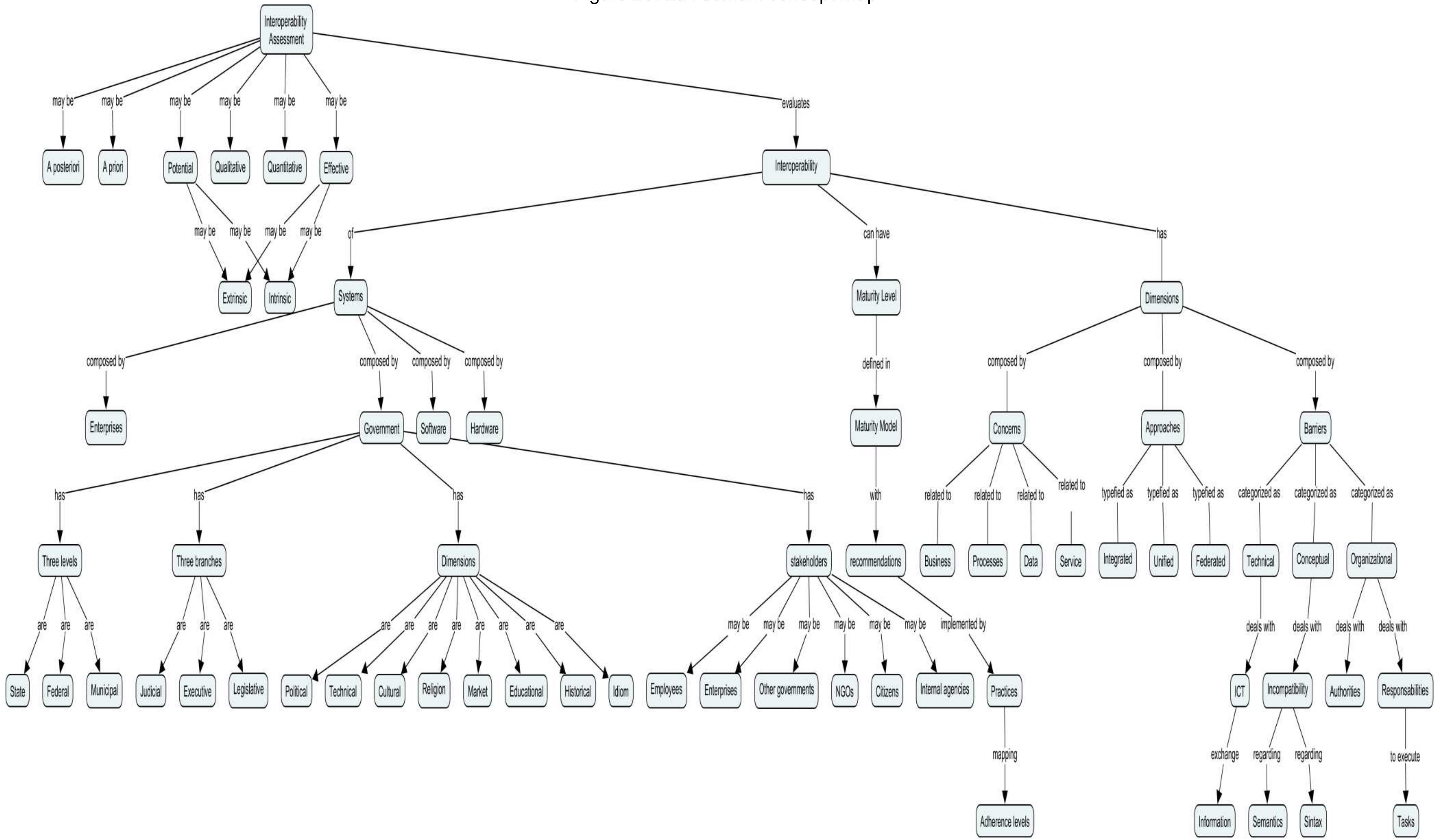
The information collected and other results are treated in sections 4 and 0, and used as a reference in the whole research. All select documents were inserted into the MaxQDA software, using functions such as the creation of codes, search strings, mapping, dictionary and others. After the creation of the codes and variables, it is possible to create associations among these codes and important contents in the documents. One of the first action was the creation of a conceptual analysis of the subjects related to the research (e.g., interoperability, public administration, eGovernment, assessments). The next steps were related to the collection and analysis of data, regarding, for example, information about countries involved, journals and main frameworks adopted in the research area.

3.5 DOMAIN CONCEPT MAP

A concept map diagram depicts suggested relationships between concepts, typically representing ideas and information as boxes or circles, connected with labeled arrows in a kind of hierarchical structure (Novak & Cañas, 2006). The relationship between concepts is represented by linking phrases such as “causes”, “requires”, or “contributes to”. Concept maps can represent a real or abstract system or a set of concepts, and have a more freely representation. Although a concept map is not an ontology or a mind map, it can be seen as a first step in ontology building.

A concept map generated after the literature review (see the framework in Figure 4, process A1) and representing the domain is presented in Figure 28. The idea is to map the main concepts of the research and some of its horizontal and vertical relations regarding the EIA domain. The concept map was created based on general concepts regarding ontology mapping, ontology alignment and ontology merging (Noy & Musen, 1999). Some of the ontology used to compose the concept map are exposed in Chen & Shorter (2008), Guédria (2012), Ferchichi et al., (2008) and Soydan & Kokar (2006). The concept map contributed, among other things, with the definition of PAICM and PAIDM structure and the organization of the attributes and criteria.

Figure 28: EIA domain concept map

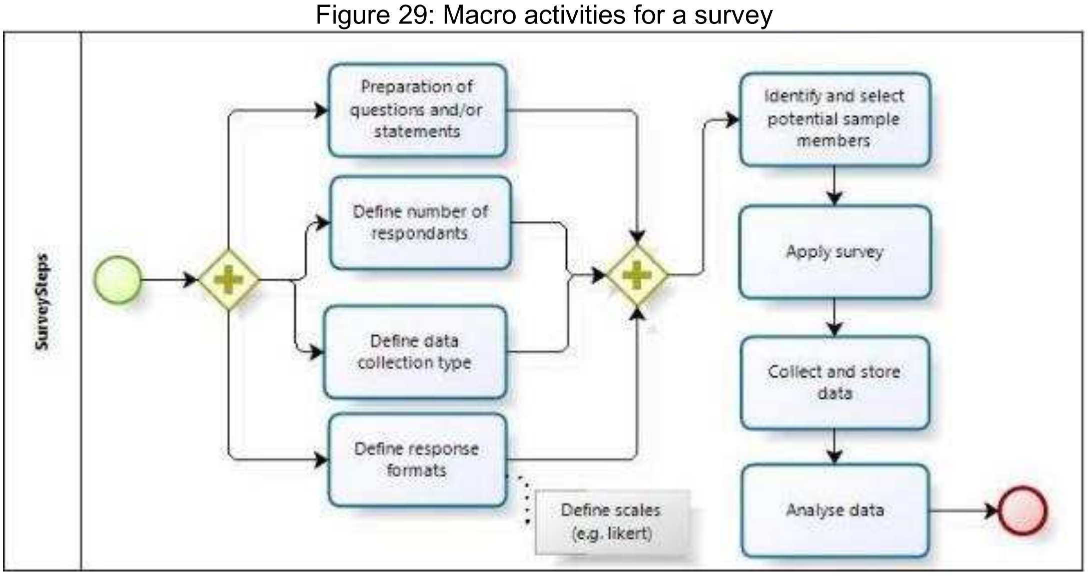


Source: The author (2015).

3.6 SURVEY

The survey activities are related to process A3 within Figure 4 and Figure 8. According to Scheuren (2004), the word survey is adopted mostly to describe a method of gathering information from a sample of individuals. A survey is a non-experimental, descriptive research method and it is useful to collect data that cannot be directly (or hard to be) observed (such as opinions). A survey uses a sample, a method of data collection (e.g., a questionnaire) and questions (or items) that become data to be analyzed. According to Forza (2002), a confirmatory survey aims to test the adherence of the developed concepts in relation to the object of study and validate the model boundaries. The basic activities of a survey, based on Groves et al., (2009), are shown in Figure 29.

Figure 29: Macro activities for a survey



Source: The author (2014). Adapted from Groves et al., (2009).

Since survey research is (usually) based on a sample of the population, the success of the research depends on the representativeness of the sample with respect to a target population of interest. However, it is important to remember that as this research has, among others, the goal to create and apply a diagnosis method within public administration entities, the quality of the respondents is also important.

Some decisions regarding the activities of Figure 29 are already made, for example, the data collection type will be online surveys, providing the questionnaire using a web tool called Qualtrics (Qualtrics, 2015).

A questionnaire to evaluate the proposed attributes for interoperability measurement diagnosis was carried out to achieve the objective of this research project. The questionnaire was applied to specialists of the area, considering practitioners and researchers. The results are exposed in section 6.

3.7 APPLICATION CASES

The application cases intend to apply the defined capability model (PAICM) and diagnosis method (PAIDM) in a public administration related organization. These activities are mainly related to process A11 within the research framework (Figure 4), but also have connections with process A10 and A12.

In a way, the application cases activities have some similar issues related to a case study. Because of this, it is important to expose some fundamental concepts regarding case studies to, afterward, adopt and extends these concepts to the application cases of this research. Although this research does not use the case study method *per se,* it follows some basic principles, such as dealing with single or multiple cases, qualitative and quantitative evidence, sources of evidence, and related to a prior development of theoretical propositions.

A test case is a research strategy that uses an empirical inquiry to investigate a phenomenon within its real-world context, usually when the frontiers between the phenomenon and the context are not clearly defined (Yin, 2014). It may be very useful in situations such as when the questions to be answered are based on “how” or “why”, when the researcher has little control over the events and when the phenomena are complex and contemporary (dealing the day-to-day context). The application cases can follow the same aspects as proposed in Yin (2014) (e.g., explanatory, exploratory, descriptive).

Yin (2014) also defines three main aspects (phases) to be considered when applying the case study method: (i) the case selection, (ii) the definition of data collection protocol and (iii) the definition of analysis protocol. All of these aspects are covered in the diagnosis method PAIDM and are applied in the context of the application case.

As an output of the application cases, it is possible to expose, among other, the following issues:

- A public administration entity will be diagnosed according to the capability levels within the PAICM and using the PAIDM, generating

information about the capability levels in several aspects (business, strategic, operational).
- Suggestions and adjustments can be made in the framework for future application cases.

The results of the application cases are treated in section 8.

3.8 CONSIDERATIONS AND CHAPTER SYNTHESIS

In this chapter, the general methodology for the research is exposed, approaching aspects regarding the literature review, the use of a survey and execution of application cases. These methodological activities were identified as main contributions related to the research aspects and goals, and each subsection of this chapter briefly describes these methods. Besides that, there are also presented results derived from the already applied methodology step of the literature review. That is, analysis and information regarding the literature were exposed, showing the distribution of publications over the years, according to the searched database and selected queries. The literature review helped in the identification of relevant publications, generation of concept map and identification of some gaps in the research domain (interoperability diagnosis within public administration).

4 BACKGROUND

The main objective of this section is to provide a general background information for a better comprehension and understanding regarding the model goals of this research. The section provides a description of tools, methods and other references and, the concepts and explanations exposed here are, somehow, a set of a minimum background needed to better comprehend the framework and research development and outputs.

4.1 INTEROPERABILITY

There are many interpretations regarding interoperability and, according to Ford (2008), it was possible to find 34 definitions proposed since 1977. Among all, one of the most common definitions is that interoperability is “the ability of two or more systems or components to exchange information and to use the information that has been exchanged” (IEEE, 1990). There are other complementary definitions, usually using the IEEE definition as a basis, and considering some other aspects such as semantics, organizational and technical issues. Some of these concepts and statements are the following:

> “Interoperability is like a chain that allows information and computer systems to be joined up both within organizations and then across organizational boundaries with other organizations, administrations, enterprises or citizens” (Commission of the European Communities, 2003).
>
> "The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together" (C4ISR, 1998).
>
> “The condition achieved among communications-electronic systems or items of communications-electronic equipment when information and services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases” (C4ISR, 1998).
>
> “Implies that one system performs an operation on behalf of another” (Chen & Doumeingts, 2003).
>
> “The ability of information and communication technology (ICT) systems and the business processes they support to exchange data and to enable information and knowledge to be shared” (Archmann & Nielsen, 2006).

The European studies examine interoperability in terms of a typology with four major categories: semantic, organizational, technical (European Commission, 2004) and governance elements (CEPA, 2007).

- Technical interoperability: concerned with technological issues of linking up computer systems, the definition of open interfaces, data formats and protocols, including telecommunications (Commission of the European Communities, 2003), (European Commission, 2004). Address technical issues involved in interconnecting computer systems and services, including elements such as interfaces, services, integration of data and middleware, presentation and exchange of data, accessibility and security services (CEPA, 2007).
- Semantic interoperability: "concerned with ensuring that the precise meaning of exchanged information is understandable by any other application not initially developed for this purpose" (Commission of the European Communities, 2003), (European Commission, 2004). Ensures that the precise meaning of information that is exchanged is unambiguously communicated and that systems are able to process it properly (CEPA, 2007).
- Organizational interoperability: concerned with modeling business processes, aligning information architectures with organizational goals and helping business processes to co-operate (Commission of the European Communities, 2003), (European Commission, 2004). Deal with business objectives, modeling processes, and collaboration issues among entities wishing to exchange information, even when their organizational structures and internal processes differ (CEPA, 2007).
- Governance interoperability: in this context refers to agreements between governments and other actors involved in interoperability, and to ways of achieving them, including the creation of ways of establishing such agreements. Governance activities are designed to provide government entities the institutional structures needed to set interoperability standards and ensure that they are adopted, and to provide government agencies the organizational and technical capacity required to implement them (CEPA, 2007).

There are also some basic concepts related to interoperability, which is important to understanding to comprehend better the interoperability concept itself. Terms such as integration, collaboration, cooperation, and compatibility are frequently used to compose or explain some aspects of interoperability.

Integration, for example, has a strong link with concepts of coordination and consistency (between local and global objectives) in which the parts are tightly coupled; whereas interoperability has the meaning of coexistence and environment, characterizing two loosely coupled (independent) parts.

Collaboration and cooperation are concepts closely related to the ability of enterprises to interoperate. Collaboration deals with sharing the work or the mutual engagement of participants in a coordinated effort, whereas cooperation concerns the division of labor among participants, where each person is responsible for a portion of the solution (Dillenbourg et al., 1996). In both terms, there is an idea of engagement to work together to achieve a common goal. Compatibility is also related to interoperability, once that to interoperate, systems must be compatible, i.e., capable of existing together and/or possible to work with another part.

Interoperability has three main dimensions: barriers, concerns and approaches (Ullberg et al., 2009). Interoperability concerns define the content of interoperation that may take place at various levels of the enterprise (data, service, process, business) i.e., the level/area/dimension at which the interoperation occurs. Interoperability barriers identify various obstacles to interoperability in three categories (conceptual, technological, and organizational), i.e., the type of obstacle to interoperability. A barrier is a kind of “incompatibility” or “mismatch” which obstructs the sharing and exchanging of information. Interoperability approaches represent the different ways in which barriers can be removed.

4.1.1 Interoperability barriers

There are three categories of barriers identified as follows (Guédria et al., 2009): conceptual, technological, and organizational.

4.1.1.1 Conceptual barriers

The conceptual barriers are most related to the syntactic and semantic differences or incompatibilities of information to be exchanged. These barriers can be associated with a high level of abstraction (e. g, enterprise models of a company) as well as the level of source code programming. According to Ullberg et al., (2009), syntactic incompatibility can be found whenever different people or systems use different structures or languages to represent information and knowledge and semantic incompatibility deals with the fact that the information and knowledge represented have no clearly defined semantics to allow unambiguous understanding of the information meaning.

4.1.1.2 Technological barriers

The technological barriers are concerned with the use of ICT to communicate and exchange information. Typical technological barriers are for example incompatibility of IT architecture & platforms, infrastructure, operating system, etc. From a purely technical perspective, these problems concern the standards to present, store, exchange, process and communicate data and information using ICT devices. Examples of technological barriers are:

- Communication barriers (e.g., incompatibility of the protocols used to exchange information).
- Content barriers (e.g., different techniques and methods used to represent information or incompatibility in the tools used to encode/decode the information being exchanged).
- Infrastructure barriers (e.g., use of different incompatible middleware platforms).

Even though standards exist in some of these areas, there still exist such barriers because different standards and different versions of the same standards are being used. Technological barriers are concerned only if when ICT devices are used in an interoperation (Chen & Daclin, 2006).

4.1.1.3 Organizational barriers

Relates to the definition of responsibility, authority and others “human factors” associated with human and organization behaviors that can be obstacles to interoperability. Concerned with the incompatibilities of organization structure and management techniques implemented in entities. It also includes characteristics regarding the structure of an entity and the organization of the decision-making process (e.g., differences among centralized vs. decentralized entities or hierarchical vs. matrix or networked structures may affect the interoperability issues). Compared with conceptual barriers (centered on information problems) and technological barriers (concerned with machine problems), organizational barriers originate from the problems of humans (Chen & Daclin, 2006).

4.1.2 Interoperability concerns

Interoperability can take place considering various viewpoints (or concerns) of an entity. Although the definitions are mainly given from a point of view of IT-based applications, they apply to non-computerized systems as well. This categorization was firstly based on ATHENA Consortium (2003), and it is cited in various other papers and studies such as Chen et al. (2008), Ullberg et al. (2009), Guédria (2012) and others. There are four main areas (viewpoints, concerns):

- Business concerns: the ability of an entity to interoperate with others in spite of different working practices, legislations, methods, structures, rules, labor legislations, models, cultures and commercial approaches. It concerns how business is understood and shared without ambiguity among interoperation stakeholders.
- Process concerns: make various processes work together. Entities usually have several processes running and, in the case of two entities working with an interoperability approach, it is necessary to analyze how to connect internal processes of the entities to create common processes. It deals with the linkage of different process descriptions (documents or software) to form collaborative processes and perform verification, simulation and execution. Usually, different process description languages are used to

define different process models for different purposes. Typically, barriers prevent process interoperability are different semantics and syntax used in various process modeling languages; incompatible process execution engines and platforms, different process organization mechanisms, configurations, and managements.

- Service concerns: composing and making work together various services/applications by solving possible syntactic and semantic differences as well as finding the connections to the various heterogeneous databases. Services are an abstraction and an encapsulation of the functionality provided by an autonomous entity and, in this interoperability context, is not limited to the computer-based applications; but also functions of the company or of the networked enterprises. Service interoperability deals with the capability of exchanging services (works) among entities. It has two main problems: service exchange between a service demander and a service provider, and interconnection between different services to form a complex service. Issues relating to service interoperability are concerned with the description (both the syntax and semantic aspects) of the services required and provided, the mechanisms to search and discover a distributed service provider, the ICT supports for service discovery, composition, and the organizational issues relating the management of service exchange, etc.
- Data concerns: it refers to make work together different data models, different languages, heterogeneous bases and information in general.

Table 12, adapted from Guédria et al., (2011a) and Ullberg et al., (2009), shows a few examples of barriers types related to each concern.

Table 12: Barriers x concerns examples

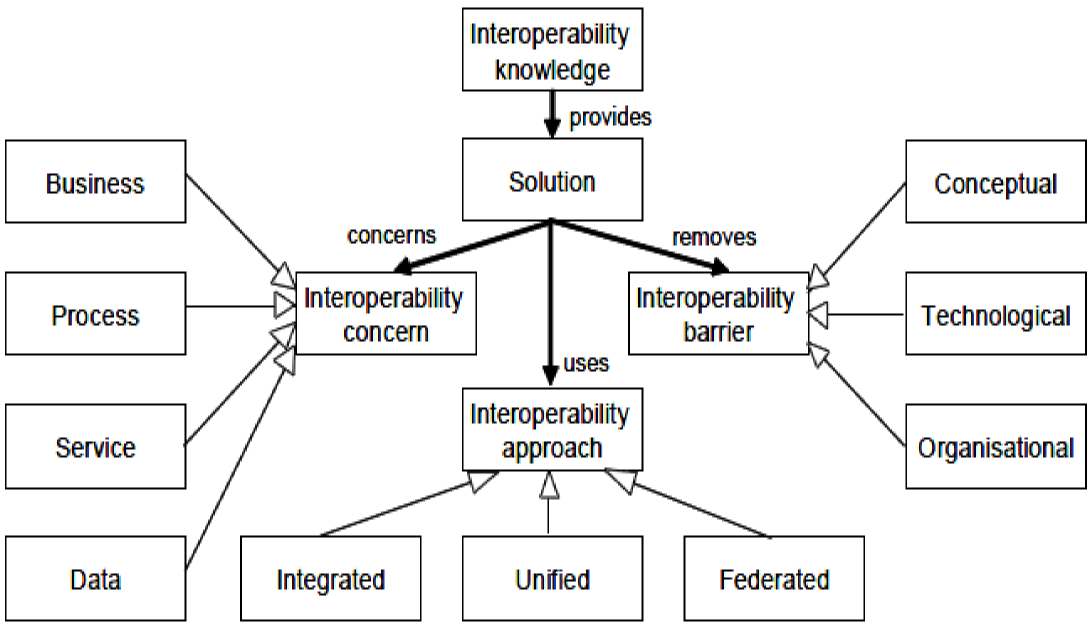
		Barriers		
		Conceptual	**Technological**	**Organizational**
Concerns	**Business**	Visions, strategies, mission and culture. Differences in the respective companies goals and views. Business syntax (format, template or model used for describing enterprise business). Business semantics (meaning of terms used to express business issues).	Infrastructure. The degree of computerization (data, services and processes automated in IT). The ability of IT to support the requirements of the business.	The legislative requirements that influence different actors. Organization structure (how enterprises are organized on a high level). Methods of work (high-level differences regarding how work is performed in the organizations).
	Process	Process content and coverage. Process syntax (description, language grammar and graphical representation). Process semantics (meaning of the processes).	Engines, automation. Process behavior (order of operations in the computerized processes).	Procedures, guidelines. Business process behavior (order of operation in business processes).
	Service	Descriptions of services. Service content and coverage. Service syntax (language/formalism syntax used to describe the services). Service semantics (meaning of services descriptions).	Interfaces, architectures. Service granularity (definitions of what constitutes the services, interface problems).	Responsibility, authority. Resource control (the allocation of technical and non-technical resources).
	Data	Dictionary, format. Data content and coverage. Data representation and syntax (heterogeneous data format and structure). Data semantics (data meaning and disagreements).	Exchange format protocol or format available to exchange Information.	Responsibility, change data. Information ownership (the structures for assigning rights to data). Classified information (how to handle it).

One other interoperability dimension is related to the approach used, that is, the method adopted to put entities together to establish interoperations. According to ISO (1998) and Panetto (2007), there are three basic ways:

- Integrated approach: there exists a common format for all models. This common format is not necessarily a standard, but must be agreed by all parties.
- Unified approach: there also exists a common format but only at a meta-level. The related metamodel is not an executable entity, as it is in the integrated approach, but it provides a mean for semantic equivalence to allow mapping between models and systems.
- Federated approach: there is no common format. To establish interoperability parties must accommodate 'on the fly'. Using this approach implies that there is no imposition of models, languages and methods of work by one of the parties.

Figure 30, proposed by Chen & Shorter (2008), shows the basic concepts described above along with their relationship.

Figure 30: Overview of enterprise interoperability concepts



Source: Chen & Shorter (2008).

The concepts exposed are important to understanding the organization and framework structure regarding interoperability issues, helping to build ideas such as of how to deal with the barriers and what dimension to assess.

4.2 EGOVERNMENT WITHIN PUBLIC ADMINISTRATION

A domain with current evidence is the public administration sector commonly referred to, in literature, as e-government. Usually, eGovernment works with models relating the following types of interactions (Laskaridis et al., 2007), (UNDP, 2007), (Charalabidis et al., 2007), (De Angelis, 2009), (Da Silva, 2009), (Gatautis et al., 2009), (Bettahar et al., 2009), (Gatautis & Vitkauskaite, 2009), (Pruse& Zeiris, 2010), (Huijsman et al., 2012), (Scholl et al., 2012), (Stefanus et al., 2012), (Widodo et al., 2013):

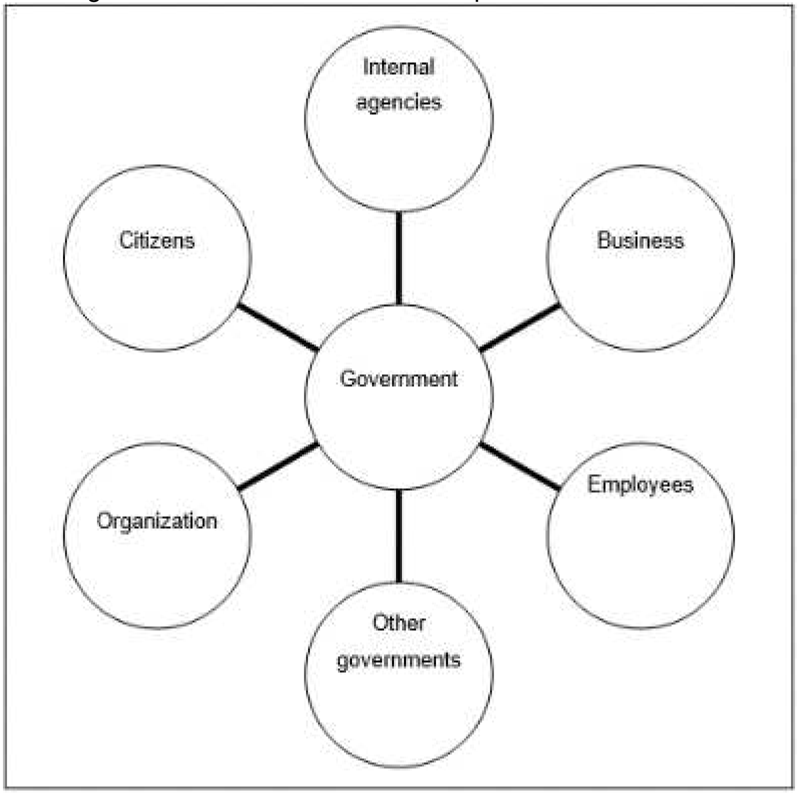
- G2C: government to citizens.
- G2B: government to business.
- G2E: government to employees.
- G2G: government to government.
- C2G: citizen to government.

There are also two other complementary relations (UNDP, 2007):

- G2Org: government-to-organizations.
- G2OG: government-to-other-governments.

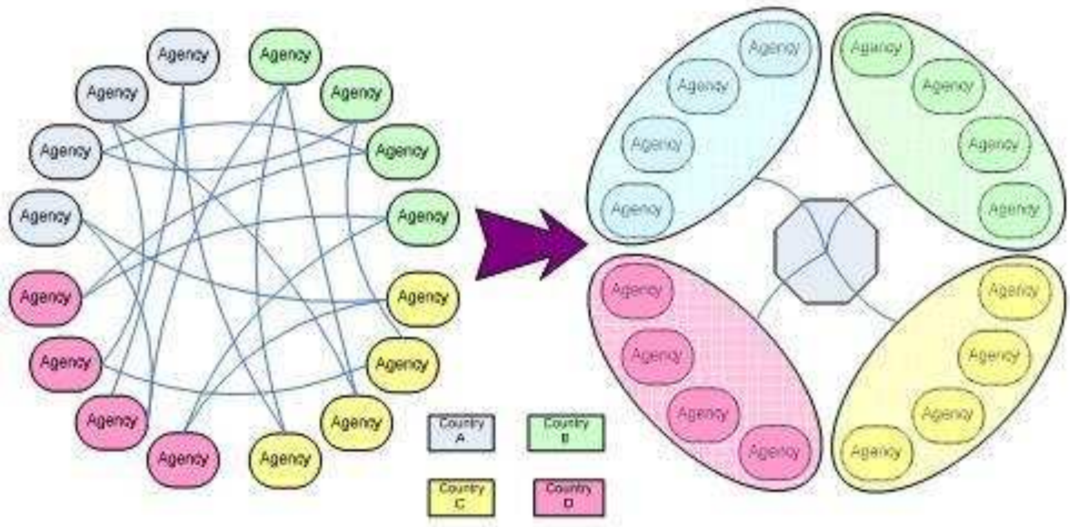
Figure 31 and Figure 32 shows examples of possible relations among government and others stakeholders, considering that may also exist other internal relations (inside each unit or circle regarding the inner process).

Figure 31: Government with some potential stakeholders



Source: The author (2015).

Figure 32: Relations inter and intra agencies



Source: CEPA (2007).

According to Camargo (2009), eGovernment is relatively a recent concept, formalized in January 1999, when Al Gore, then-Vice President U.S. opened the 1st Global Forum on Reinventing Government, in Washington, attended by representatives of 43 countries. Officially, in Brazil, according to Ministério do

Planejamento (n.d.), the eGovernment came up in 2000, with the creation of an inter-ministry work group that had the objective of evaluating and propose policies, guidelines and standards regarding the new forms of electronic interaction.

EGovernment (or its equivalents terms) is defined in Novakouski & Lewis (2012) as the use of information and communication technologies to support the government business, such as providing or enhancing public services or managing internal government operations. Other statements and/or definitions are exposed in Table 13:

Table 13: Some statements and definitions of eGovernment within public administration

Source	Statements
Commission of the European Communities (2003)	“eGovernment is not ‘old government’ plus the Internet. EGovernment is the use of new technologies to transform Europe’s public administrations and to improve radically the way they work with their customers, be they citizens, enterprises, or other administrations”. “EGovernment is now a key vehicle for the implementation and achievement of higher policy objectives.” “EGovernment is built on two main but inter-related developments. The first is the business models adopted in the recent past by the enterprise sector. These are largely concerned with obtaining a competitive advantage by activities such as continuous process improvement, focus on core competencies and the re-organization of their internal processes. The second is the use of a broad range of information and communications technologies (ICTs), of which the Internet is the most visible, in supporting organizational change, more productive ways of working and the improved provision of information and interactive services to customers”. “An essential aspect of eGovernment is to bring public administration closer to citizens and enterprises.”
Neumann & Benda (2005)	“The notion of what e-government is and what e-government should deal with is changing and has not yet stabilized into a unique form. For the Czech Republic, the most significant influence is an understanding of and the use of e-government in the European Union (and in its member-states). E-government is understood […] as a modern technology tool used to improve the quality of public administration (PA) services and to enable qualitative changes in PA”. “ICT in e-government (or e-government in a technical context) is understood in the paper as technical infrastructure that enables political e-government targets to be accomplished. ICT in e-government must not prevent political e-government targets being reached; it must offer a set of services that enables political e-government targets to be reached. A

Source	Statements
	fundamental feature of modern e-government is the full "electronization" of the internal agendas (back office) of the PA. Only an entirely electronic back-office enables every citizen to select where and how she communicates with the PA. A fully electronic state administration is not sufficient. It is not enough for every municipality administration to be fully electronic. Both are necessary conditions but not a satisfactory state of affairs". "The development of e-government is a long-term task. This is because of the size and complexity of PA, the need for continuity and long-term stability, and budgetary constraints. It is impossible to change everything in PA within one ICT lifecycle (3-5 years) or within one electoral term".
Nils et al., (2006)	"EGovernment is the use of information and communication technology to promote more efficient and user-friendly public services."
Van Overeem et al., (2007)	"Effective and innovative public administrations are essential to a globally competitive Europe. EGovernment is the key to unlocking potential in the public sector". "E-Government is one of the pillars that can contribute to the realization of this EAS."
Xiao et al., (2007)	"E-government is an application system that meets various demands of all levels of government such as concrete service, business and conference affair, etc. by using of information technology".
Pankowska (2008)	"Emerging trends in Europe suggest that current thinking on e-Government is focusing on exceptional quality and efficiency in public services. According to the view, e-Government needs to be more knowledge-based, user-centric, distributed and networked". "The vision of e-Government in the EU in the next decade defines eGovernment as an ICT tool for better government in its broadest sense. It places e-Government at the core of public management modernization and reform, where technology is used as a strategic tool to modernize structures, processes, the regulatory framework, human resources and the culture of public administrations to provide better government and ultimately increased public value". "e-Government is not an objective *per se*; it has to be seen more as means of organizing public governance for better serving citizens and enterprises. E-Government concerns the whole scope of administrative actions and the connected political processes because ICT is an enabling force that will enhance effectiveness, quality and efficiency of public actions as well as its legitimacy". "The aim of e-Government is to enhance public participation in decision making. Worldwide varieties of e-Government websites have been set up, providing services and information at different levels".
Vogel et al., (2008)	"EGovernment is considered to be an enabler as it incorporates the use of information and communication technologies combined with the organizational change to improve public services."

Source	Statements
Vatuiu & Popeanga (2008)	"EGovernment is the best way of organizing public management to increase efficiency, transparency, accessibility, and responsiveness. It also helps to reduce bureaucracy and corruption in the inner administration of the public sector and in its daily relations with citizens and business users of public services".
De Angelis (2009)	"[…] e-Government is an emergent multidisciplinary research field that has the aim to support the delivery of electronic information and services to citizens, businesses, and other stakeholders. This vision should be based on an effective cooperation between Public Administrations (PAs) that need to be more and more organized to deliver value-added e-Government services. Such cooperative environments should interconnect several PAs using interoperability architectures exploiting the service-oriented paradigm". "Use of information and communication technologies in Public Administrations combined with organizational change and new skills to improve public services and democratic processes and strengthen support to public policies." "E-Government is not e-Business." "E-Government is a way for governments to use innovative technologies to provide citizens and businesses with more convenient access to government information and services, to improve the quality of the services and to provide opportunities to participate in democratic institutions and processes". "E-Government is the continuous optimization of services delivery, constituency participation, and governance by transforming internal and external relationships through technology, the Internet, and new media."
Bettahar et al., (2009)	"The main purpose of e-government is to build a government that exists everywhere and is ready to serve at any time. Through the use of different information equipment, e-government allows enterprises and the public to receive related services at any place and anytime." "EGovernment is defined as the utilization of Information Communication Technology (ICT) in serving the priorities of a government in meeting the specific social, economic and political endeavors of the state."
Rosa (2010)	"The research on eGovernment is mainly focused on the front-office issues and not on the impact that back-office achievements have on the success of electronic service delivery." "EGovernment is about using the information systems made possible by ICTs to provide better public services to citizens and businesses, both at national and local levels." "EGovernment also involves re-thinking organizations and processes so that public services are delivered more."
European Commission (2010)	"EGovernment is about using the tools and systems made possible by information and communication technologies (ICTs) to provide better public services to citizens and businesses."
Kiu et al., (2010)	"E-Government is the use of ICT to unify the services of government agencies into a portal which we refer to as, ideally speaking, a one-stop knowledge-intensive government portal

Source	Statements
	service to improve the efficiency, convenience and accessibility of services to the public”.
Valdés (2011)	“[…] electronic government is far more than using technology to provide online services; it often involves the integration of different services offered by public agencies that had never worked together previously, the provision of 24/7 service delivery, the assimilation of new laws and government regulations, and so on. Therefore, technological change should be accompanied by organizational change (e.g.,, new institutions for new forms of interaction between public agencies), process redesign (e.g., new processes to operate under new service delivery models), information technology (IT) governance implementation (to achieve alignment between IT resources and business objectives), and human capital training (e.g.,, training for staff to operate new technologies)”. “E-Government initiatives arise due to a combination of the need to improve the quality and efficiency of public services and the acceptance of ICT as an important element to achieve that goal.”
Novakouski & Lewis (2012)	“E-government is broadly defined as the use of information and communication technologies to support the business of government, such as providing or enhancing public services or managing internal government operations. Its benefits include improved efficiency, transparency, accountability, and access as well as coordination of services at lower costs. However, the task of delivering these benefits is not only difficult but also poorly understood”. “The use of information and communication technologies (ICTs) to improve the activities of public sector organizations.” “The use of information technology to free movement of information to overcome the physical bounds of traditional paper and physical based systems.” “The use of technology to enhance the access to and delivery of government services to benefit citizens, business partners and employees.” “e-government as the use of ICTs to support the business of government, such as providing or enhancing public services or managing internal government operations. This definition is general enough to encompass not only different systems and technologies but also different contexts”. “The purpose of egovernment is to achieve agility, customer focus, accountability, visibility and efficiency in public services. To create increased value, interoperability between independent information systems is essential”. “The use of information and communication technologies combined with organizational changes and new skills, to improve public services, promote democratic participation and improving public policy making.”
Pardo et al., (2012)	“The application of information technology to government processes to improve services to constituents, considering that various government organizations can share and integrate information between each other.”

4.2.1 eGovernment (maturity) in the world

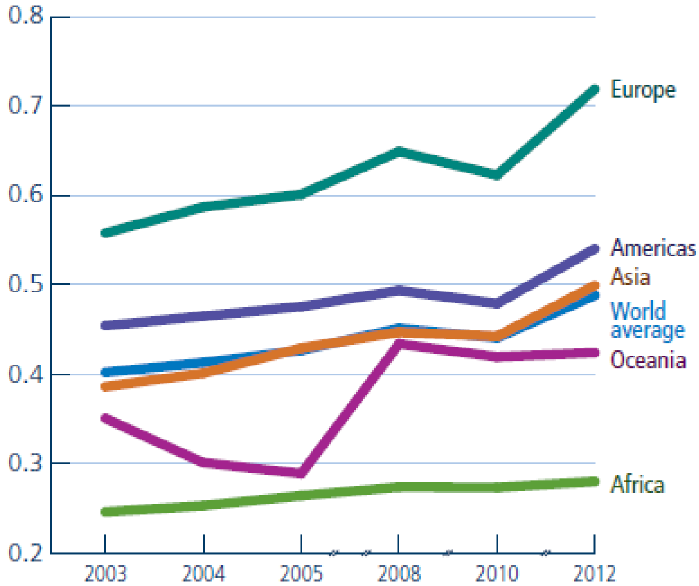
The United Nations (2012) survey presents eGovernment development rankings for 2012, analyzing how governments of the world are employing eGovernment policies and programs to support efficiency, effectiveness, and inclusiveness as the parameters of sustainable development efforts worldwide. The measured index can go from zero (no eGovernment) to one (high degree of e-government implemented in the country). According to the survey, the Republic of Korea is the world leader (0.9283) followed by the Netherlands (0.9125), the United Kingdom (0.8960) and Denmark (0.8889), with the United States, Canada, France, Norway, Singapore and Sweden close behind. Table 14 shows the ranking of the first 20 positions.

Table 14: World eGovernment development leaders 2012. Retrieved from United Nations (2012)

Position	Country	eGovernment development index
1	The Republic of Korea	0.9283
2	Netherlands	0.9125
3	United Kingdom	0.8960
4	Denmark	0.8889
5	United States	0.8687
6	France	0.8635
7	Sweden	0.8599
8	Norway	0.8593
9	Finland	0.8505
10	Singapore	0.8474
11	Canada	0.8430
12	Australia	0.8390
13	New Zealand	0.8381
14	Liechtenstein	0.8264
15	Switzerland	0.8134
16	Israel	0.8100
17	Germany	0.8079
18	Japan	0.8019
19	Luxembourg	0.8014
20	Estonia	0.7987

Brazil is in the 59° position (with a ranking of 0.6167), and in 2010 Brazil was in 61° (with 0.5006). Figure 33 shows that Europe (0.7188) shows the highest eGovernment development ranking, followed by the Americas (0.5403).

Figure 33: eGovernment development evolution by regions (in the last decade)



Source: United Nations (2012).

EGovernment strategies in the Americas focus on user-centric solutions, which serve to synergize governance processes and systems across multiple public administration domains. The top-ranked countries in the Americas remained the United States followed by Canada, both of which were also among the world leaders (see Table 15, retrieved from United Nations (2012)). Considering South America, Table 16 (retrieved from United Nations (2012), shows the ranking and the index of the selected countries, including Brazil.

Table 15: Top-ranked countries in the Americas.

Position	**Country**	**eGovernment development index**	**World eGovernment development ranking**
1	United States	0.8687	5
2	Canada	0.8430	11
3	Chile	0.6769	39
4	Colombia	0.6572	43
5	Barbados	0.6566	44
6	Antigua and Barbuda	0.6345	49
7	Uruguay	0.6315	50
8	Mexico	0.6240	55
9	Argentina	0.6228	56
10	Brazil	0.6167	59

Table 16: Top-ranked countries in South America.

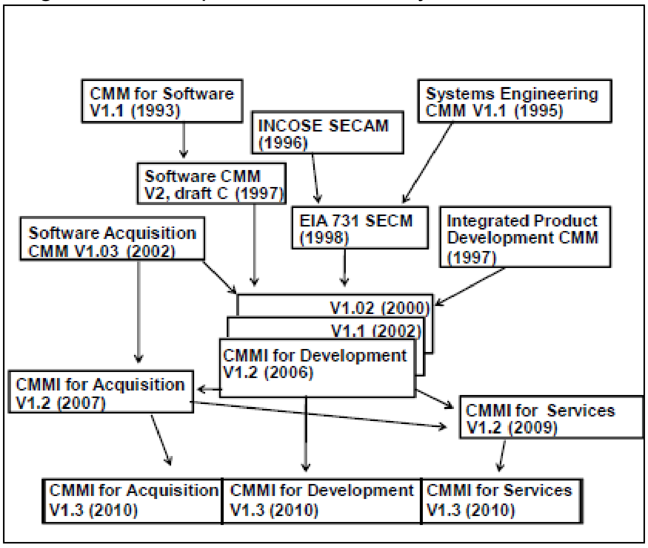
Position	Country	eGovernment development index	World eGovernment development ranking
1	Chile	0.6769	39
2	Colombia	0.6572	43
3	Uruguay	0.6315	50
4	Argentina	0.6228	56
5	Brazil	0.6167	59
6	Venezuela	0.5585	71
7	Peru	0.5230	82
8	Ecuador	0.4869	102
9	Paraguay	0.4802	104
10	Bolivia	0.4658	106
11	Guyana	0.4549	109
12	Suriname	0.4344	116

Although the United Nations survey deals with general eGovernment maturity around the world, not focusing on specific themes such as interoperability, frameworks, and models, it gives a good idea of the world adoption regarding the theme.

4.3 CAPABILITY MATURITY MODEL INTEGRATION (CMMI)

According to CMMI Product Team (2010), CMMI is a maturity model for process improvement and it is a composition of best practices addressing development and maintenance activities for the product lifecycle, since its inception until its deployment and maintenance. The model was created because of a need from the DoD (Department of Defense, USA), which was dealing with suppliers that were not providing quality (on time, on cost and on budget) software projects. DoD began a partnership and sponsorship with Carnegie Mellon University, located in Pittsburgh, Pennsylvania, USA. As a result of this collaboration, the Software Engineering Institute (SEI) was created to research and develop frameworks, models and good practices, based, among others, on the concepts of Crosby (1979), Juran (1988), Deming (1986) and Humphrey (1989). The idea was that the DoD's suppliers could follow these practices and be adherent to the model, reducing the risks of delivering poor quality software. Figure 34 illustrates the composition and history of CMMI models.

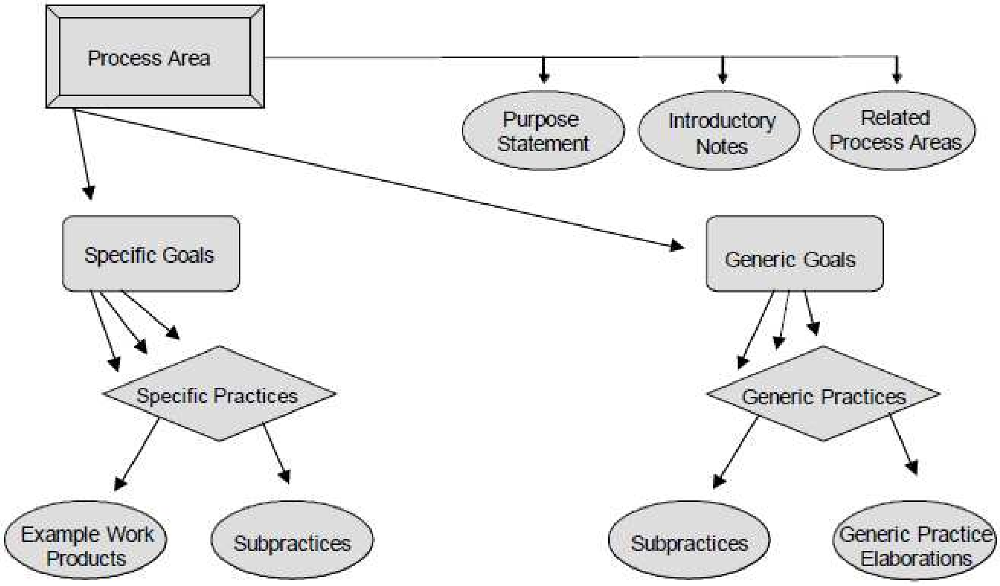
Figure 34: Composition and history of CMMI models



Source: CMMI Product Team (2010).

Nowadays, the direct responsible for the CMMI is the CMMI Institute, which is a part of Carnegie Innovations, a technology commercialization enterprise, and part of Carnegie Mellon University. There are mainly three areas of interest regarding the CMMI models: (i) CMMI for Acquisition (CMMI-ACQ), (ii) CMMI for Development (CMMI-DEV) and (iii) CMMI for Services (CMMI-SVC). In general, CMMI-ACQ refers to interactions with suppliers; CMMI-DEV is used to improve engineering and development processes in an organization that develops products; CMMI-SVC is used to improve management, and service delivery processes in an organization that develops, manages, and delivers services. All CMMI models share the same architecture and core process areas, which are tailored to each model but contain essentially the same information. A process area is a group of related practices of a specific area, which can be also be considered as a discipline, important areas of concerns and bodies of knowledge (e.g., project management, validation, requirements management, measurement and analysis). The components of a CMMI model is exposed in Figure 35.

Figure 35: Components of a CMMI model



Source: CMMI Product Team (2010).

The most rectangular forms are considered as required components, and they are essential to achieving process improvement in a given process area. Diamonds forms are the expected components, and describe activities that are important in achieving a required CMMI component and oval forms are informative components, helping model users to understand the required and expected components, providing some examples work products, notes, and other information.

The CMMI models describe “what to do” rather than “how to do” and are not processes, but it has a focus on the importance of having a structured process, once that the process is the item that holds everything together. “Processes allow you to align the way you do business. They enable you to address scalability and provide a way to incorporate knowledge of how to do things better. Processes allow you to leverage your resources and to achieve process maturity and analyze business trends”, (CMMI Product Team, 2010).

The CMMI models are organized in levels, which are used to describe an evolutionary path recommended for an entity that wants to improve the activities it uses to develop products or services. Levels can also be the outcome of the rating activity in assessments or diagnosis and can apply to entire organizations or to smaller groups (entities inside the organization).

CMMI supports two improvement paths using levels:

(i) One path enables organizations to improve incrementally processes corresponding to an individual process area (or group of process areas) selected by the organization. This path is associated with maturity levels.

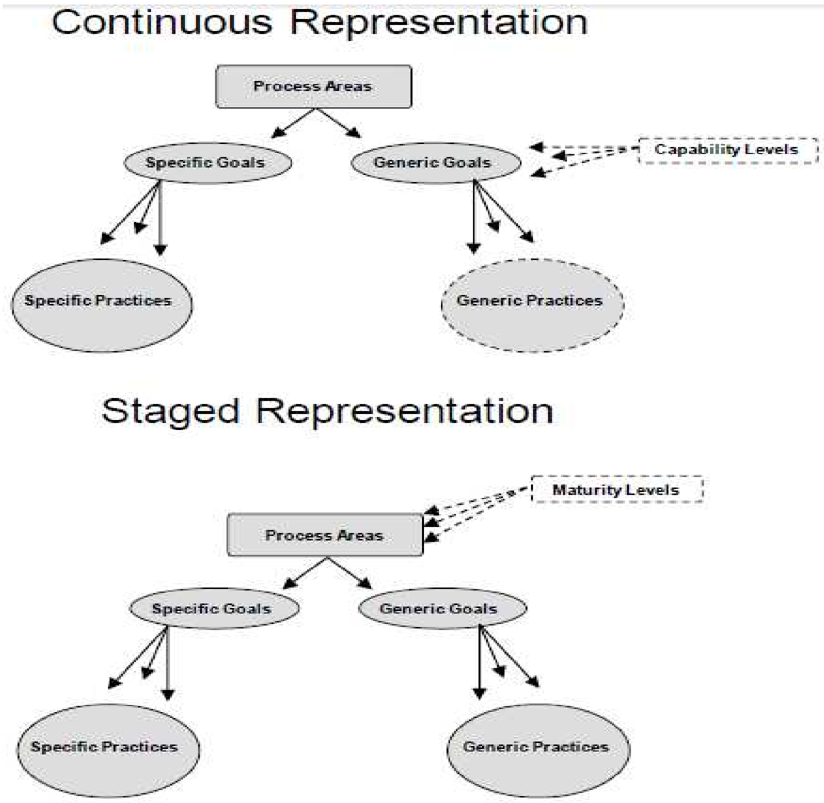
(ii) The other path enables organizations to improve a set of related processes by incrementally addressing successive sets of process areas. This path is related to capability levels.

These two types of levels correspond to two approaches for process improvement, and they are called “representations.” The two representations are called “continuous” (capability levels) and “staged” (maturity levels). Maturity levels characterize the overall state of the organization’s processes relative to a model as a whole and capability levels characterize the state of the organization’s process relative to an individual process area. Figure 36 shows a comparison of the structures, illustrating the above characteristics.

In a maturity level structure, the focus in on the overall maturity as measured by maturity levels. Maturity levels apply to an organization’s improvement achievement across multiple areas. These levels are means of improving the processes corresponding to a given process area (i.e., maturity level). In this structure, there are five maturity levels (from 1 to 5). Each maturity level is composed of a set of process areas, and the levels are cumulative. That is, to achieve the Maturity Level 3 it is necessary also do achieve the Maturity Level 2.

In a capability level structure, the focus is on process area capability as measured by capability levels. Capability levels apply to an organization’s improvement achievement in individual process areas. These levels are ways for incrementally improving the activities corresponding to a given area. This approach is concerned with selecting a particular set of process areas to improve their performance level. There are four capability levels (from 0 to 3) in this structure.

Figure 36: Structure of the CMMI representations



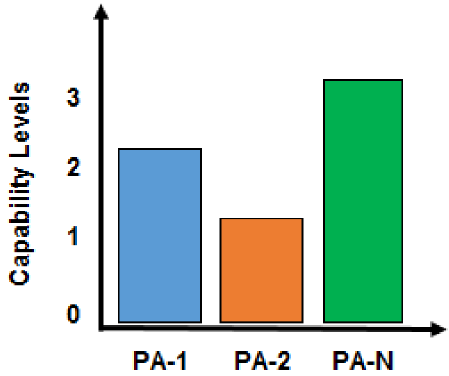
Source: CMMI Product Team (2010).

Table 17 compares and exposes the maturity and capability levels and Figure 37 and Figure 38 illustrates the differences in the two representations.

Table 17: Capability and maturity levels. Based on CMMI Product Team (2010)

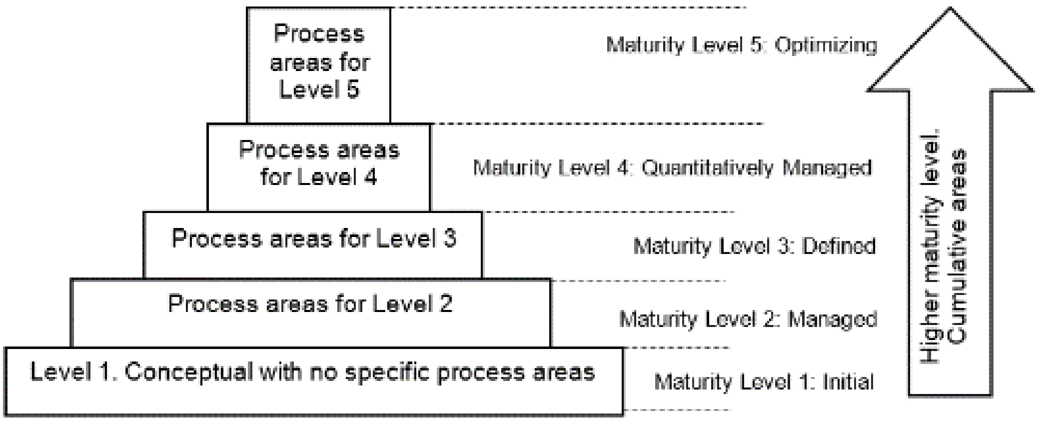
Levels	**Representations**	
	Continuous – Capability levels	**Staged – Maturity levels**
	Level's names	
Level 0	Incomplete	*Non-existent*
Level 1	Performed	Initial
Level 2	Managed	Managed
Level 3	Defined	Defined
Level 4	*Non-existent*	Quantitatively Managed
Level 5	*Non-existent*	Optimizing

Figure 37: Capability levels for each process area in a continuous representation



Source: The author (2015).

Figure 38: Maturity levels in a staged representation



Source: The author (2015).

Figure 38 indicates that to achieve the maturity level 3, it is necessary to achieve and implement all the process areas and practices related to maturity level 2 and 3. Table 18 exposes the process areas distribution within the maturity levels, considering the CMMI-DEV as a basis.

Table 18: The 22 process areas of CMMI-DEV within the maturity levels

Process areas	**Maturity Levels**
Requirements Management (REQM)	2
Project Planning (PP)	
Project Monitoring and Control (PMC)	
Supplier Agreement Management (SAM)	
Measurement and Analysis (MA)	
Process and Product Quality Assurance (PPQA)	
Configuration Management (CM)	
Decision Analysis and Resolution (DAR)	3
Integrated Project Management (IPM)	
Organizational Process Definition (OPD)	
Organizational Process Focus (OPF)	
Organizational Training (OT)	
Product Integration (PI)	
Requirements Development (RD)	

Process areas	Maturity Levels
Risk Management (RSKM)	
Technical Solution (TS)	
Validation (VAL)	
Verification (VER)	
Organizational Process Performance (OPP)	4
Quantitative Project Management (QPM)	
Organizational Performance Management (OPM)	5
Causal Analysis and Resolution (CAR)	

CMMI is adopted around the world, with organizations reporting its assessment from more than 78 countries (SEI, 2012). The practices are stable and consistent enough to provide a benchmark among organizations and, for example, Brazil is in the seventh position (SEI, 2012) of reporting appraisals (from 2006 to 2012), behind China, USA, India, Spain, Japan and Republic of Korea.

The adoption and implementation of maturity models, such as CMMI, deriving to a more mature process, with disciplined and managed activities reveal improvements and better performance results in areas such as quality, effort, rework, productivity and schedule (Cestari et al., 2013).

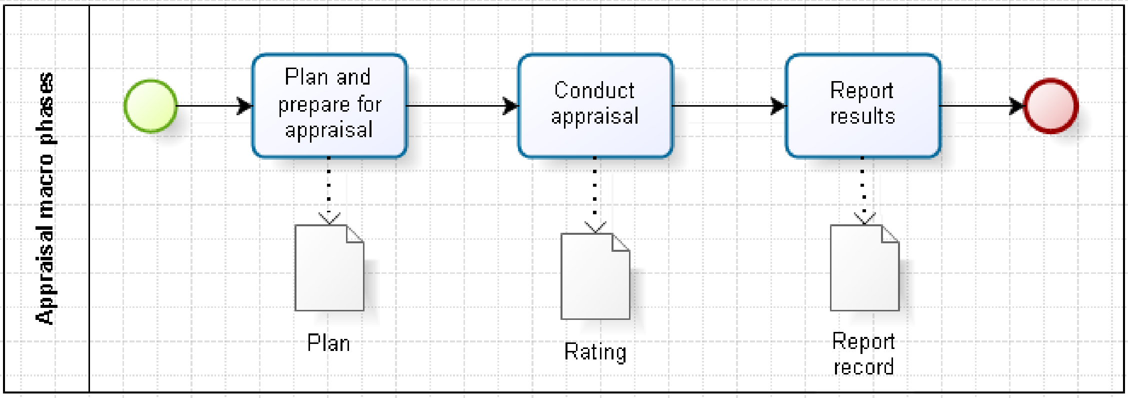
4.3.1 Standard CMMI Appraisal Method for Process Improvement (SCAMPI)

One very interesting issue of CMMI models is their appraisal assessment method, called SCAMPI (Standard CMMI Appraisal Method for Process Improvement) (SCAMPI Upgrade Team, 2011). The method describes, among other things, how to assess the process areas, how to define if a process is adequate or not, how to collect and sample the data and so on.

SCAMPI provides benchmark-quality ratings relative to the CMMI. The method relies on an aggregation of information that is collected via objective evidence (usually artifacts and affirmations). According to (SCAMPI Upgrade Team, 2011), objective evidence is a “qualitative or quantitative information, records, or statements of fact pertaining to the characteristics of an item or service or to the existence and implementation of a process element, which are based on observation, measurement, or test and are verifiable.”

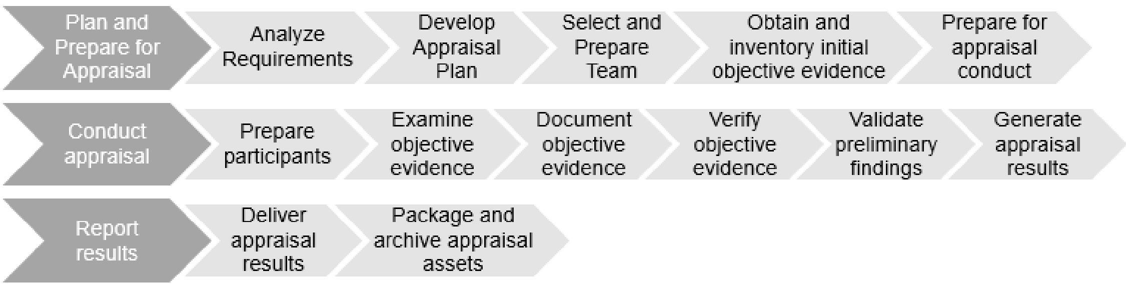
The evidence feeds an “information processing engine” whose parts are made up of a series of data transformations. The appraisal team observes, hears, and reads information that is transformed into notes, and then into characterizations of practice implementation gaps or compliance, and then into preliminary findings. These findings are validated by the organizational unit before they become final findings. The method is based on three macro phases, as illustrate in Figure 39 and expanded in Figure 40.

Figure 39: General steps of the SCAMPI assessment



Source: The author (2015).

Figure 40: Appraisal macro processes



Source: The author (2015).

The first phase (Plan and Prepare for Appraisal) is mostly characterized, among other things, by the need to understand the business requirements of the organizational, document the requirements, agreements, risks schedule and other considerations, obtain the sponsor’s approval of the appraisal plan and check the team qualifications.

The “Conduct appraisal” phase has the main goal to examine information about the practices implemented in the organization and relate the resultant data to the appraisal reference model (e.g., CMMI-DEV, CMMI-AQU, and CMMI-SVC). There are other concerns relating the auditing process itself: such as schedule, team engagement and risk management, but the main aspect is to validate all the findings to generate the results and then rate the achievement (or not) of the particular level that is being evaluated. The conduction of the appraisal itself is done with a combination of interviews and document analysis.

The last phase (Report results) formalizes all the results, build an executive presentation and deliver the results to the stakeholders of the organization. Some strengths and weaknesses can be exposed and discussed, and the final characterization of the maturity (or capability) level is shown. That is, if an institution were reaching the maturity level 3, the results would show if they were succeeded in achieving that or an inferior level. There is also internal work that must be done with the appraisal team, such as dispose of sensitive materials in an appropriate manner, contact the CMMI Institute regarding the conclusion and results of the appraisal and so on.

To execute the characterization of the process areas and then derive to a characterization of the maturity level or capability level, a rating procedure is applied, based on the characteristics exposed in Table 19. The rating is defined by a team consensus regarding the aspects being discussed.

Table 19: Ratings based on SCAMPI Upgrade Team (2011)

Label	Brief description
Fully Implemented (FI)	Sufficient affirmations and artifacts are present and judged to be adequate to demonstrate the process implementation, and no weaknesses are noted.
Largely Implemented (LI)	Sufficient affirmations and artifacts are present and judged to be sufficient to demonstrate the process implementation, and one or more weaknesses are noted.
Partially Implemented (PI)	Some or all activities and/or artifacts required are absent or judged to be inadequate, some data are present to suggest some aspects of the process areas and activities are implemented. Affirmations supplied conflicts, and one or more weaknesses are noted.
Not Implemented (NI)	Some or all activities required are absent or judged to be inadequate, data provided does not support the conclusion that the guideline is implemented, and one or more weaknesses are noted.

After the rating judgments based on Table 19 is applied to the practices and process areas, an analysis of the results is executed based on the rules exposed in Table 20 to obtain the final classification of the maturity or capability level of the organization unit.

Table 20: General guidelines for rate definition

Implementation (attributes/process areas/practices)	Outcome	Comments
All FI	FI	All implementations are characterized FI.
All LI or FI	FI or LI	All implementations are characterized LI or FI. Judgment is applied.
At least one LI or FI and at least one PI or NI	LI or PI	There is at least one implementation that is characterized as LI or FI and at least one implementation that is characterized as PI or NI. Judgment is applied to choose LI or PI based on whether the weaknesses, in aggregate, have a significant negative impact on goal achievement.
All PI or NI	PI	All implementations are characterized PI or NI. Judgment is applied.
All NI	NI	All implementations are characterized NI.

The execution of an appraisal (only the "Conduct Appraisal" phase) can take about five business days with more than 5 persons involved, depending on the maturity level to be assessed and the number of projects. There are some calculations that can be done regarding the number of projects or assets to be evaluated, the number of people involved and other variables.

It is important to mention that when an organization unit is implementing maturity models or standards, the process towards the final appraisal is long and usually has one or more previous "readiness" or "gaps" evaluations before the final one. Those initial assessments can be more informal at the beginning and then growing into a more formal structure according to the evolution of the model implementation and proximity to the final appraisal date. The method as proposed in SCAMPI Upgrade Team (2011) has the letter "A" after the title of the document, as a reference to the type of appraisal that is officially covered by the method. SCAMPI A is the name of the final, most formal and "official" appraisal that occurs when an organization unit wants to be evaluated to obtain an official assessment regarding its maturity or capability level. There are also a SCAMPI C and SCAMPI B events, where the letter "C" indicates an event more related to a gap analysis format, evaluating the situation of the organization (*as is*) in comparison to the model (*to be*) and discovering the gaps related to the achievement of a specific maturity or capability level. Usually, a SCAMPI C occurs at the beginning of a model and/or standard implementation, or some process improvement related actions. The letter "B" indicates that the process is more related to a kind of preparation for SCAMPI A, and it is a test and preparation for the final evaluation.

It is almost as formal as SCAMPI A, but it is not yet the final official event. There is an expectation of around 90% achievement in the SCAMPI B, as a form of “readiness” status for going to the SCAMPI A event within the next 1 or 2 months. Despite the objectives and the timing regarding the execution of appraisals “B” and “C”, it is common to adopt the SCAMPI A as a basis method to organize and structure both events.

Therefore, although the gain of insight into the organization’s capability is indeed a benefit of SCAMPI, the SCAMPI A is a method regarding the assessment of the organization and not a consultancy activity. That is, when a company contracts a SCAMPI A assessment, the goal is to achieve success in the appraisal for that specific level needed, and the auditors will work in such a way. If the result of SCAMPI A is a fail (the process are not adherent with the desired model and level), it would be necessary to hire (after the corrections of the detected gaps) a new SCAMPI A evaluation (with new costs, schedules and so on). Only after a successful SCAMPI A appraisal, the organization unit can declare officially (and for the market) its maturity or capability level (according to the CMMI Institute).

4.4 MULTI-CRITERIA DECISION-MAKING (MCDM)

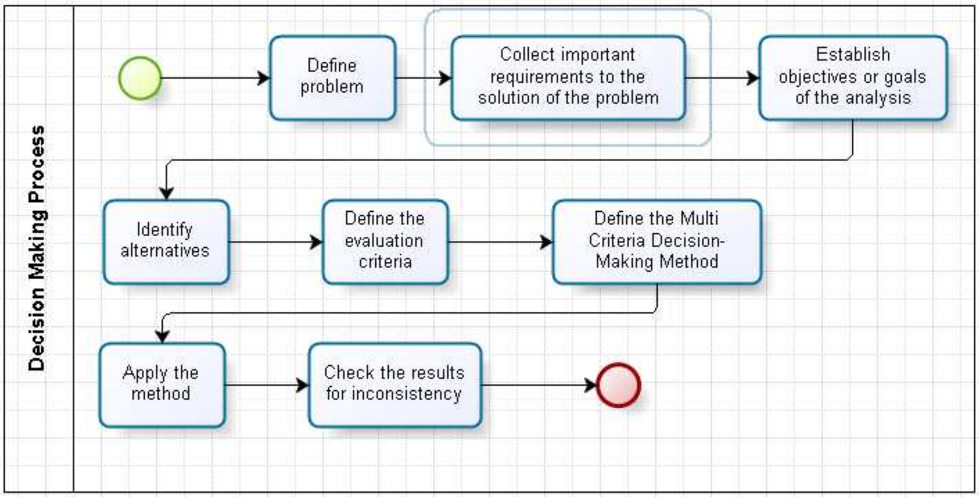
According to the International Society on Multiple Criteria Decision Making, "Multi-Criteria Decision Making (MCDM) is the study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process" (ISMCDM, 2015). In other words, an MCDM helps the decision makers in understanding his preferences (using criteria) to choose an adequate alternative or prioritize and ranking a set or alternatives. The whole process is done, usually, in the presence of multiple and conflicting criteria.

MCDM has been used as a decision analysis or decision making since 1960's and today there are dozens of methods, books, tools (Baizyldayeva et al., 2013), papers and courses (Alias et al., 2008). It is also found in the literature as MCDA (Multi Criteria Decision Analysis), MODM (Multi-Objective Decision Making), MADM (Multi-Attributes Decision Making) and MDDM (Multi Dimensions Decision-Making).

There are many possible applications and use for an MCDM such as education, construction, management and, according to Alias et al. (2008), the majority of MCDM applications are in the areas of management, transportation and manufacturing (Toloie-Eshlaghy & Homayonfar, 2011). In management, for example, most MCDM are used for selection, ranking and evaluation of alternatives. In manufacturing, most MCDM is used for selection and evaluation.

Generally, a decision-making process follows the steps as presented in Figure 41, based on the exposition of Zardari et al., (2015).

Figure 41: Decision making process



Source: The author (2015).

MCDM problems can be grouped based on some of their characteristics. For an initial perspective, for example, MCDM problems can be classified into multi-objective decision making (MODM) and multi-attribute decision-making (MADM). Table 21, based on Eldrandaly et al., (2009), describes some of the major components and their characteristics.

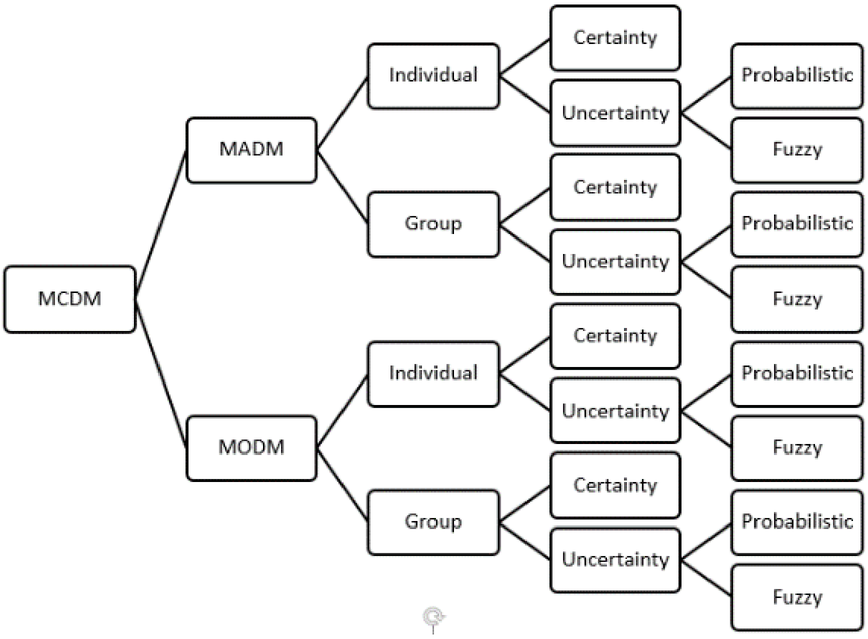
Table 21: some characteristics of the MCDM problem.

Components/characteristics	Brief description
MODM	A large number of feasible alternatives, where the objectives and constraints are functionally related to the decision variables.
MADM	Relatively a small number of alternatives, where the alternatives are represented in terms of attributes.
Individual Decision-Making	Single goal-preference structure, regardless of the decision makers actually involved.
Group Decision Making	Individuals (interest group) are characterized by different goal-preference structures.
Under certainty	All (or a big part of the) relevant information about the decision situation is known and that there is a known deterministic connection

Components/characteristics	Brief description
	between every decision and the corresponding outcome.
Under uncertainty	Some lack information or doubts regarding this information. Two basic types of uncertainty in a decision situation: (1) limited information and/or (2) fuzziness regarding the semantic meaning of the events, phenomena, or statements themselves. Problems under uncertainty can be also subdivided into probabilistic (stochastic) and fuzzy, depending on the type of uncertainty.

Figure 42 better depicts the information and structure exposed in Table 21.

Figure 42: Classification of MCDM problems



Source: Eldrandaly et al., (2009).

Besides all those characteristics previously exposed, according to Mollaghasemi & Pet-Edwards (1997), it is also possible to consider a time-relative aspect regarding the solving of the problems, grouping the methods in three other categories, as exposed in Table 22 and based on Eldrandaly et al., (2009).

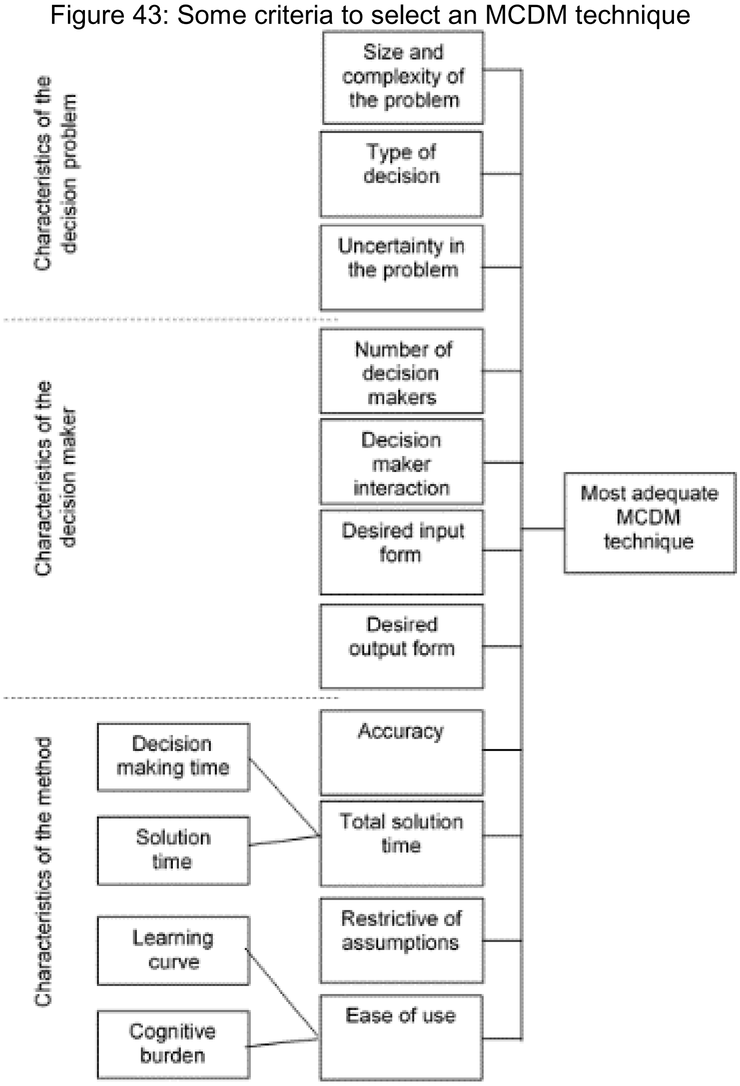
Table 22: characteristics considering a time aspect.

Time aspects	Brief characteristics
Prior articulation of preferences	The decision maker's preferences are obtained through detailed interviews between the decision maker and the analyst before the start of the optimization process.
Progressive articulation of preferences	Interactive method. The decision maker receives a subset of alternatives and provides some preference (ranking). This allows the formulation of a single-criterion subproblem, which is then solved. The new solution and outcome are then presented to the decision maker, and the process is repeated.

Time aspects	Brief characteristics
Posterior articulation of preferences	Least common. The idea is to find all or almost all of the solutions to the problem. The solutions are then presented to the decision maker to select the preferred one. Very complex algorithms and usually difficult to understand, use and analyze.

Different MCDM techniques suit various types of decision, and it is important to decide which kind of MCDM technique will be the most suitable. To guide the decisions, it is important to analyze and put all together the characteristics previously exposed and other factors such as (i) characteristics of decision problem, (ii) characteristics of the decision maker, and (iii) characteristics of solution (Mollaghasemi & Pet-Edwards, 1997). Figure 3 exposes these factors and other subdivisions.

Figure 43: Some criteria to select an MCDM technique



Source: Mollaghasemi & Pet-Edwards (1997).

In order to choose the suitable MCDM technique, all the previously aspects and characteristics were qualitatively analyzed in comparison with the features of some of the most adopted methods, such as AHP, ANP, Promethee, Macbeth and some fuzzy approaches (Mota, 2013), (Baizyldayeva et al., 2013), (Toloie-Eshlaghy & Homayonfar, 2011) and (Singh & Malik, 2014) .

Table 23 shows the comments and “answers” for some of the criteria/aspects in the context of this research, to select a most suitable decision-making method.

Table 23: Analysis of the factors for select the suitable method

Aspects/criteria/factors		**Comments/Answers**
MADM or MODM?		MADM.
Individual or group decision-making?		Individual.
Regarding the timing of the preferences articulation.		Prior articulation of preferences.
Characteristics of the method	Accuracy.	High (or moderate to high)
	Total solution time.	Fast (or moderate to fast)
	Restrictive of assumptions.	Moderately restrictive.
	Ease of use.	Easy to use and understand, with a low learning curve, the existence of tools, cases, papers and reference applications.
Characteristics of the decision maker	The quantity of decision-makers.	Usually one (the responsible for the diagnosis). In some cases, it can be possible the existence of a group of decision makers.
	Decision maker interaction.	High interaction with the method and the stakeholder.
	Desired input form.	Comparison (pairwise).
	Desired output form.	Cardinal. Ranking.
Characteristics of the decision problem	Size and complexity of the problem.	Moderate.
	Type of decision.	Deterministic.
	Uncertainty in the problem.	Certainty.

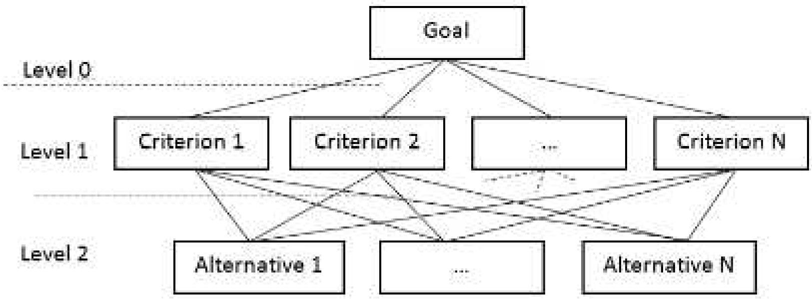
Considering all the “answers” of Table 23 and exemplified by some of the guidelines exposed in Eldrandaly et al. (2009), Mota (2013) and Li (2007), the most suitable method for this research context is the Analytic Hierarchy Process (AHP) or its derivation (depending on the case scenario), the Analytic Network Process (ANP). The choice for AHP/ANP also considers that the diagnosis of interoperability degrees using the proposed models (PAICM and PAIDM) must extract information based on a tacit knowledge, in a complex environment (public related entities) and with a difficult possibility to perform an absolute evaluation (i.e., define an interoperability degree without relative comparisons).

4.4.1 Analytic Hierarchy Process (AHP)

The AHP method, proposed in Saaty (1987), is one of the widely accepted and frequently used mathematic analysis method that supports multi-criteria decision-making. The priority assessment in AHP is based on mathematical analysis of pairwise comparisons defined on the hierarchical tree structure, in which, the priority scales between each two related terms are relying on the judgments of domain experts.

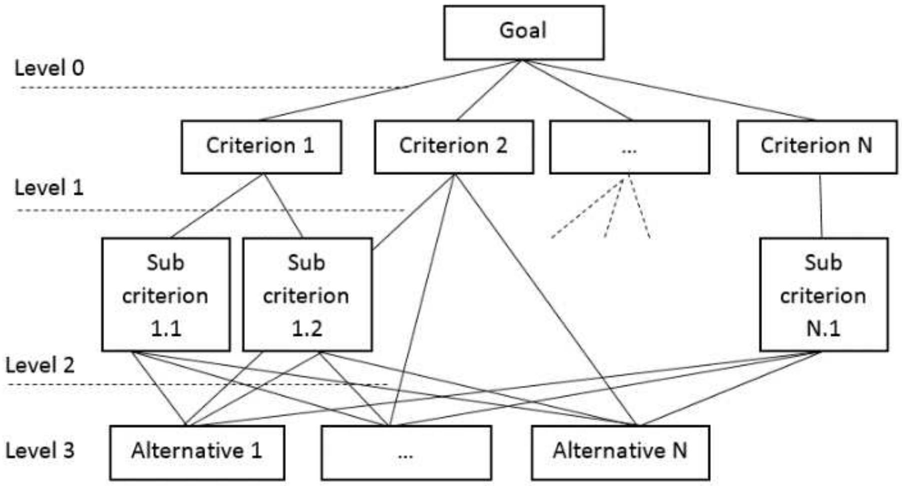
AHP is a structured technique for organizing and analyzing complex decisions, adopted in a variety of decision situations, in fields such as government, business, industry, healthcare, and education. AHP helps decision makers find one that best suits their goal and their understanding of the problem. It consists of three parts: create the hierarchy structure of the decision problem, evaluating the weights of the answers by pairwise comparison and calculating global weights. It is a top-down structure: from the overall objective down to criteria, from criteria to sub-criteria down to alternatives. Figure 44 illustrates the general structure of the AHP method and Figure 45 exposes the possible existence of sub-criteria.

Figure 44: General structure of AHP



Source: The author (2015).

Figure 45: AHP structure considering sub-criteria



Source: The author (2015).

In both figures, Level 0 indicates the position of the "Goal" of the decision-making problem. That is, what is the "Goal" to be achieved by selecting or ranking the alternatives? What is the achievement or the purpose? The criteria are parameters, characteristics and or attributes that are common to all alternatives and are essential to perform the comparison between alternatives. According to each objective, the criteria may have different levels of importance in the selection, so, during the decision-making process, AHP assigns weights to each criterion. Level 1 (Figure 44 and Figure 45) represents the structure location of the criteria. It is possible to have as many as sub-criteria as needed, according to the details of the decision decision-making problem. Level 2 at Figure 45 shows that Criterion 1 has two sub-criteria (Sub-criterion 1.1 and Sub-criterion 1.2), and Criterion N has only one sub-criteria (Sub-criterion N.1). In the other hand, still in Figure 45, Criterion 2 has no sub-criteria and is directed connect to the alternatives. As the criteria are common to all alternatives, the sub-criteria also have to have the same behavior (that is, all the sub-criteria must be connected to all alternatives). The alternatives, positioned at the last levels of the structure (Level 2 in Figure 44 and Level 3 in Figure 45) comprise a list of elements to be selected according to the goal established and the all the criteria pointed out.

After completing the structure of the problem in a hierarchical format, the next step of AHP is the comparison between pairs of elements in the level of criteria and alternatives, to define the relative importance of one element over another within each level. The AHP pairwise comparison provides an analytical engine to combine and consolidate the evaluation of alternatives and consequently reduces the complexity of the choice to be made. The next steps are (i) construction of the comparative matrix; (ii) normalization and weights calculation; (iii) consistency analysis and (iv) construction.

4.4.1.1 Construction of the Comparative Matrix

Elements of each level (criteria and alternatives) are compared in pairs to define the relative importance of preference regarding an element over another within each level. These comparisons must consider the relative importance regarding the father node at the previous levels. That is, considering Figure 45 as an example, "Sub-criterion 1.1" must be compared with "Sub-criterion 1.2" regarding the expectations and context of "Criterion 1" (their father node).

In that way, pairwise comparison within a certain level can be represented as a square matrix $M = [m_{ij}]_{n\,x\,n}$, considering *n* columns and *n* lines, as exposed in Equation 1.

$$M = \begin{bmatrix} M_{11} & M_{12} & M_{1n} \\ M_{21} & M_{22} & M_{2n} \\ M_{n1} & M_{n2} & M_{nn} \end{bmatrix}$$

Equation 1: General square matrix

Considering that the matrix will always be a square matrix, once the comparisons occur among the elements themselves, the number of comparisons needed is represented in the Equation 2 and the inferior left triangle of the matrix is the inverse of the right superior triangle, as can be seen in the following example.

$$ncomp = n\,(n-1)/2$$

Equation 2: Number of comparisons according to the number of elements

The reference pairwise comparisons follow Saaty (1987) proposal, with values from 1 to 9, as shown in Table 24.

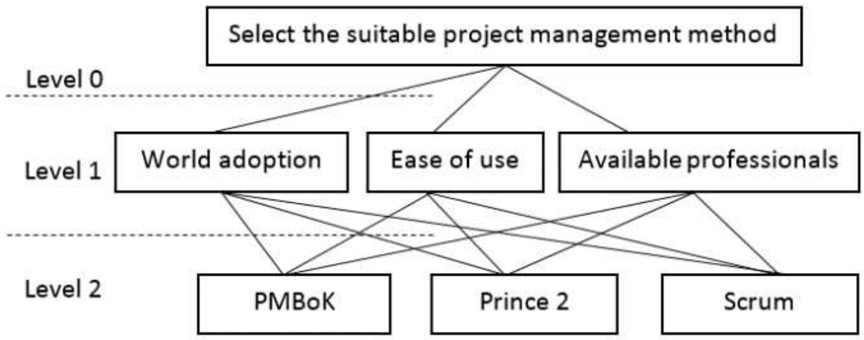
Table 24: Pairwise comparison values

Degree of importance (M_{ij}) (comparing *i* to *j*)	**Definition**	**Inverse degree (1/ M_{ij}) (comparing *j to i*)**
1	Equal Importance	1
2	Between equal and moderate	1/2
3	Moderate importance	1/3

Degree of importance (M_{ij}) (comparing *i* to *j*)	Definition	Inverse degree (1/ M_{ij}) (comparing *j to i*)
4	Between moderate and strong	1/4
5	Strong importance	1/5
6	Between strong and very strong	1/6
7	Very strong	1/7
8	Between very strong and extreme	1/8
9	Extreme importance	1/9

To exemplify the step of the comparative matrix and the following ones, it will be considered, as an example, a decision problem represented in Figure 46.

Figure 46: Example of an AHP selection problem



Source: The author (2015).

The objective related in Figure 46 is to select the suitable project management method, considering three basic criteria (world adoption, ease of use and available professionals) and three alternatives (PMBoK, Prince 2 and Scrum). The comparison matrix is represented in Table 25, according to random values regarding the preference of the criteria. Table 26 represents the values of Table 25 without the fraction representations.

Table 25: Comparison matrix

	World adoption	Ease of use	Available professionals
World adoption	1	1/7	1/5
Ease of use	7	1	4
Available professionals	5	1/4	1

Table 26: Comparison matrix (without fractions)

	World adoption	Ease of use	Available professionals
World adoption	1	0.1428	0.2000
Ease of use	7	1	4
Available professionals	5	0.2500	1

4.4.1.2 Weights calculation

Once the comparison matrix is created, it is necessary to obtain the ranking of priorities. According to Saaty (1990), the best approach is to use an eigenvector. The eigenvector is a matrix unlinked from magnitudes because it contains only the order of the relative priority (or ranking) of the elements, based on comparing pairs. The calculation of the eigenvector or the relative weighted matrix are used to give weights to the elements and can be resumed in the following steps:

a. Multiply the pairwise matrix by itself.
b. Calculate the row sums and normalize.
c. If it is the first time, then repeat the steps; else, compare the actual sum with the previous one. If the difference is smaller than a predefined value, stop the process.

Continuing with the example exposed in Table 26, and removing the labels (criteria name), Equation 3 shows the values after the first step (multiplying the matrix by itself).

$$\begin{bmatrix} 1 & 0.1428 & 0.2000 \\ 7 & 1 & 4 \\ 5 & 0.2500 & 1 \end{bmatrix} * \begin{bmatrix} 1 & 0.1428 & 0.2000 \\ 7 & 1 & 4 \\ 5 & 0.2500 & 1 \end{bmatrix} = \begin{bmatrix} 2.9996 & 0.3356 & 0.9712 \\ 34.0000 & 2.9996 & 9.4000 \\ 11.7500 & 1.2140 & 3.0000 \end{bmatrix}$$

Equation 3: Matrix multiplication by itself

Following the steps, it is necessary to calculate the row sums (exposed in Equation 4), sum the rows' totals (Equation 5) and then normalize the values (Equation 6).

$$\begin{bmatrix} 2.9996 & 0.3356 & 0.9712 \\ 34.0000 & 2.9996 & 9.4000 \\ 11.7500 & 1.2140 & 3.0000 \end{bmatrix} = \begin{bmatrix} 4.3064 \\ 46.3996 \\ 15.9640 \end{bmatrix}$$

Equation 4: Sum the rows

$$SumRowsTotals = 4.3064 + 46.3996 + 15.9640 = 66.6700$$

Equation 5: Sum the rows' totals

$$\begin{bmatrix} 4.3064/66.6700 \\ 46.3996/66.6700 \\ 15.9640/66.6700 \end{bmatrix} = \begin{bmatrix} 0.0645 \\ 0.6959 \\ 0.2394 \end{bmatrix}$$

Equation 6: Normalized values and first eigenvector

As this is the first step and the first generated eigenvector (represented in Equation 6), it is necessary to repeat the steps, beginning for the multiplication of the first resulted matrix by itself, as exposed in Equation 7.

$$\begin{bmatrix} 2.9996 & 0.3356 & 0.9712 \\ 34.0000 & 2.9996 & 9.4000 \\ 11.7500 & 1.2140 & 3.0000 \end{bmatrix}$$

$$*$$

$$\begin{bmatrix} 2.9996 & 0.3356 & 0.9712 \\ 34.0000 & 2.9996 & 9.4000 \\ 11.7500 & 1.2140 & 3.0000 \end{bmatrix} =$$

$$\begin{bmatrix} 31.8196 & 3.1923 & 8.9814 \\ 314.4228 & 31.8196 & 89.4170 \\ 111.7713 & 11.2268 & 31.8232 \end{bmatrix}$$

Equation 7: Matrix multiplication by itself, second round.

The row sums are exposed in Equation 8, the sum the rows' totals in Equation 9 and the normalization of the values in Equation 10.

$$\begin{bmatrix} 31.8196 & 3.1923 & 8.9814 \\ 314.4228 & 31.8196 & 89.4170 \\ 111.7713 & 11.2268 & 31.8232 \end{bmatrix} = \begin{bmatrix} 44.9933 \\ 435.6594 \\ 154.8213 \end{bmatrix}$$

Equation 8: Sum the rows

$$SumRowsTotals = 44.9933 + 435.6594 + 154.8213 = 635.4740$$

Equation 9: Sum the rows' totals

$$\begin{bmatrix} 44.9933/635.4740 \\ 435.6594/635.4740 \\ 154.8213/635.4740 \end{bmatrix} = \begin{bmatrix} 0.0708 \\ 0.6855 \\ 0.2436 \end{bmatrix}$$

Equation 10: Normalized values and second eigenvector

Now it is necessary to calculate the difference between the two generated eigenvectors (represented both in Equation 10 and in Equation 6). The result is presented in Equation 11.

$$\begin{bmatrix} 0.0708 \\ 0.6855 \\ 0.2436 \end{bmatrix} - \begin{bmatrix} 0.0645 \\ 0.6959 \\ 0.2394 \end{bmatrix} = \begin{bmatrix} 0.0063 \\ -0.0104 \\ 0.0042 \end{bmatrix}$$

Equation 11: Difference between eigenvectors

For the purpose of the example, there should be no difference to two decimal places and, because of value -0.0104, it is necessary to do another round. Considering that all the steps were executed (but not represented here), the third generated eigenvector is represented in Figure 47.

Figure 47: Third generated eigenvector

$$\begin{bmatrix} 0.0691 \\ 0.6871 \\ 0.2437 \end{bmatrix}$$

Source: The author (2015).

Again, it is necessary to calculate the difference between the last two eigenvectors, and the result is exposed in Equation 12.

$$\begin{bmatrix} 0.0691 \\ 0.6871 \\ 0.2437 \end{bmatrix} - \begin{bmatrix} 0.0708 \\ 0.6855 \\ 0.2436 \end{bmatrix} = \begin{bmatrix} -0.0017 \\ 0.0016 \\ 0.0001 \end{bmatrix}$$

Equation 12: Difference between third and second eigenvectors

As the result shows no difference up to two decimal places, the eigenvector exposed in Figure 47 is the final one. It is important to remind that the process could go with more interactions, according to the defined rule (e.g., no differences at the third decimal place).

The eigenvector exposed in Figure 47 gives the relative ranking of the criteria, and the interpretation regarding the criteria is represented in Table 27.

Table 27: Classification and comments regarding the alternatives

Criteria according to comparison matrix	Eigenvector value	Observations
World adoption	0.0691	This is the third most important criterion.
Ease of use	0.6871	This is the most important criterion.
Available professionals	0.2437	This is the second most important criterion.

If, for example, the criteria can be interpreted as a quantitative value (e.g., cost, interest rate), it is possible to direct attribute the values for each alternative, instead of calculating them in the form of a pairwise comparison.

The whole process can also be done with the alternatives, considering that they can be analyzed qualitatively with the same pairwise approach. Therefore, the alternatives will also have a pairwise comparison (each alternative over another) regarding the aspects of each criterion, as a comparison matrix example considering the criterion of "World Adoption" illustrated in Table 28.

Table 28: Comparison matrix of the alternatives regarding the "World adoption" criterion

	PMBoK	Prince 2	Scrum
PMBoK	1	6	4
Prince 2	1/6	1	1/5
Scrum	1/4	5	1

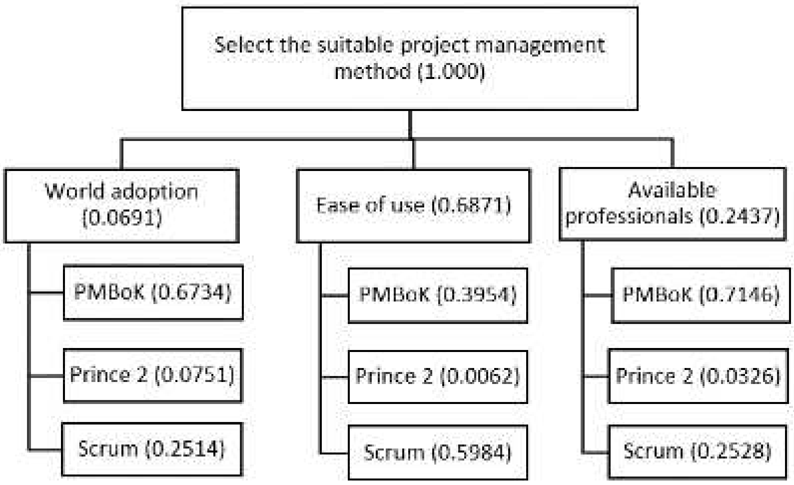
Considering all the calculations and the other comparison matrix (not represented here), the eigenvectors for all the alternatives proposed in the example are exposed in Table 29.

Table 29: Eigenvectors for the alternatives (regarding each criterion)

Alternatives	Eigenvector of "World Adoption" criterion.	Eigenvector of "Ease of use" criterion.	Eigenvector of "Available professionals" criterion.
PMBoK	0.6734	0.3954	0.7146
Prince 2	0.0751	0.0062	0.0326
Scrum	0.2514	0.5984	0.2528

The final representation of the hierarchical tree, with all the weights, considering the decision-making example proposed is represented in Figure 48.

Figure 48: Hierarchical tree for the example



Source: The author (2015).

4.4.1.3 Consistency Analysis

The inconsistency measure is useful for identifying possible errors in judgments as well as actual inconsistencies in the judgments themselves. Inconsistency measures the logical inconsistency of the judgments or values inserted in the matrix.

Before executing the final calculation and obtaining of the final answer for the proposed goal ("Select the suitable project management method"), it is important to run a consistency analysis. According to Saaty (1987), to consider a matrix consistent, a Consistency Ratio (CR), as exposed in Equation 13, must have an uncertainty of lower than 10%. The other two elements of the formula are (i) the Random Index (RI), which is a constant proposed by Saaty (1987) and should be used according to Table 30 and the (ii) Consistency Index (CI), which is represented by Equation 14.

$$\text{CR} = \frac{CI}{RI} * 100\%$$

Equation 13: Consistency Ratio (CR)

Table 30: Random Index (RI)

Number of elements	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

$$\text{CI} = \frac{(\lambda \max - n)}{(n-1)}$$

Equation 14: Consistency Index (CI)

The calculation of λ_{max} can be a complex and consuming time issue and Saaty (1987) himself proposed a simpler way to calculate, generating an approximate value with a deviation of around only 1% (Teknomo, 2006). The first step is sum the columns of the comparative matrix being analyzed and then multiply those values by the eigenvector of this matrix. Table 31 and Equation 15 show an example using the criteria comparison matrix as a basis.

Table 31: Sums of the columns for the comparison matrix.

	World adoption	**Ease of use**	**Available professionals**
World adoption	1	0.1428	0.2000
Ease of use	7	1	4
Available professionals	5	0.2500	1
Sum:	13	1.3928	5.2000

$$\lambda \max = [13 \quad 1.3928 \quad 5.2000] * \begin{bmatrix} 0.0691 \\ 0.6871 \\ 0.2437 \end{bmatrix} = 3.1225$$

Equation 15: Consistency Index example

With the λ_{max} value, and using Equation 14, it is possible to obtain the CI, which in this case is 0.0612 and then using Equation 13, to get the Consistency Ratio, which in this case is 10.55%. In this case, and according to the suggestion of Saaty (1987), the CR is a little higher than the maximum suggested, and it would be interesting to review the values of the comparison matrix. However, just for this illustration purpose, the values of the example will not be changed.

The CR can be calculated at any phase of the process, and is usually done after the generation of the eigenvector of each comparison matrix, so de decision-maker or group can review the values of the matrix as soon as possible.

4.4.1.4 Construction of the final prioritization

After all the calculation and representation presented in Figure 48, the final prioritization can be done multiplying the comparison matrix of the alternatives by the criteria ranking, generating the values for all the alternatives, such as exposed in Equation 16.

$$\begin{array}{ccccccc}
\text{Criteria} \backslash \text{Alternatives} & \begin{matrix}\text{World adoption} & \text{Ease of use} & \text{Available professionals}\end{matrix} & & \text{Criteria Ranking} & & \text{Final ranking weights} & \\
\begin{matrix}\text{PMBoK}\\ \text{Prince 2}\\ \text{Scrum}\end{matrix} & \begin{bmatrix} 0.6734 & 0.3954 & 0.7146 \\ 0.0751 & 0.0062 & 0.0326 \\ 0.2514 & 0.5984 & 0.2528 \end{bmatrix} & * & \begin{bmatrix} 0.0691 \\ 0.6871 \\ 0.2437 \end{bmatrix} & = & \begin{bmatrix} 0.4923 \\ 0.0173 \\ 0.4901 \end{bmatrix} & \begin{matrix}\text{PMBoK}\\ \text{Prince 2}\\ \text{Scrum}\end{matrix}
\end{array}$$

Equation 16: Final prioritization calculus

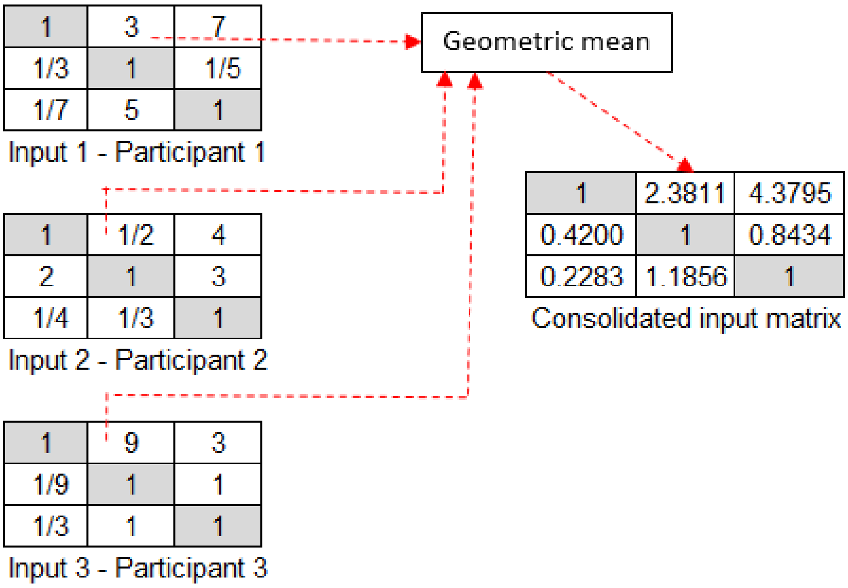
As exposed in Equation 16, the highest-ranking alternative is PMBoK, with a value of 0.4923 and a slightly higher value than the second place (Scrum, with 0.4901). The least ranked alternative is Prince 2, with 0.0173.

AHP allows the combination of multiple inputs, generated by several persons, evidence and/or sources of information. The values of these multiple comparison matrix inputs can be consolidated in one comparison matrix input, by calculating the geometric mean (Equation 17), as exemplified in Figure 49.

$$Geometric\ Mean\ (GM) = \sqrt[n]{A1 * A2 * A3 * \ldots * An}$$

Equation 17: Geometric mean calculation for *n* elements

Figure 49: Multiples inputs generating a consolidated input matrix

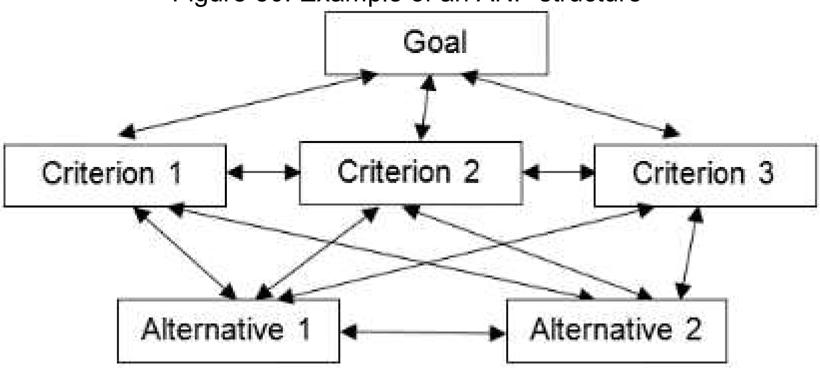


Source: The author (2015).

4.4.2 Analytic Network Process (ANP)

ANP, as described in Saaty (1999) is a generalization of AHP, allowing feedback connections and loops and considering that the criteria, sub-criteria, and alternatives are treated equally as nodes in a network. Each of these nodes might be compared to any other node, as long as there is a relation between them (Figure 50 illustrates this aspect using two-way arrows). In contrast to AHP, where higher-level elements connect to lower levels (i.e., goal to criteria to sub-criteria to alternatives), in ANP nodes might be grouped in clusters, therefore, besides local priorities in comparison one node to a set of other nodes, it is possible to introduce a notion of cluster priorities with respect to the goals.

Figure 50: Example of an ANP structure



Source: The author (2015).

One of the characteristics of ANP is the fact that the elements can be analyzed in an independent way, without the need of specify hierarchy levels and considering that “influence” is a central concept in the method.

The network of an ANP structure is represented as a matrix, called super matrix, which is created by listing all nodes both horizontally and vertically in a way that each non-zero element of the matrix represents the connection & weight from one node (columns-header) to another node (row-header) of the network. Figure 51 exposes an example of an empty super matrix.

Figure 51: Supermatrix example (empty)

			Criteria			Alternat.	
		Goal	Criterion 1	Criterion 2	Criterion 3	Alternative 1	Alternative 2
Goal							
Criteria	Criterion 1						
	Criterion 2						
	Criterion 3						
Alternat.	Alternative 1						
	Alternative 2						

Source: The author (2015).

The comparison of nodes connects to others, and the calculation of the priorities follows the same principle as in AHP. That is, after a given comparison matrix, the priorities are derived from the generated eigenvector and the data is inserted as columns vector in the supermatrix. Figure 52 shows an example with eigenvectors generated by an initial comparison matrix and then inserted into the super matrix.

Figure 52: Supermatrix with some fulfilled information

			Criteria			Alternat.	
		Goal	Criterion 1	Criterion 2	Criterion 3	Alternative 1	Alternative 2
Goal							
Criteria	Criterion 1	0.1600					
	Criterion 2	0.2500					
	Criterion 3	0.5900					
Alternat.	Alternative 1		0.5000	0.2000	0.6700		
	Alternative 2		0.5000	0.8000	0.3300		

Source: The author (2015).

After all initial comparisons are finished (until this point is the usual AHP method), the obtained matrix is called unweighted supermatrix and the final calculation for ranking the alternatives (not represented here but as seen in the AHP section 3.4.1) shows that Alternative 1 has a value of 0.5200 against 0.4800 of Alternative 2.

Continuing the operations, the impact of the alternatives on the importance of criteria will be taken into account and calculated, comparing the criteria with respect to Alternative 1 and them to Alternative 2, as represented in Figure 53 by the dotted red line. At this point, the process has generated the unweighted supermatrix of the network.

Figure 53: Supermatrix considering the impact of alternatives on criteria

			Criteria			Alternat.	
		Goal	Criterion 1	Criterion 2	Criterion 3	Alternative 1	Alternative 2
	Goal						
Criteria	Criterion 1	0.1600				0.7500	0.1300
	Criterion 2	0.2500				0.1300	0.7500
	Criterion 3	0.5900				0.1300	0.1300
Alternat.	Alternative 1		0.5000	0.2000	0.6700		
	Alternative 2		0.5000	0.8000	0.3300		

Source: The author (2015).

The next general step is to normalize the matrix in all its columns, and then the result is the weighted supermatrix. In the case of the example exposed in Figure 53, the values were already inserted in a normalized way. The whole model is summarized by calculating the limit matrix, which is obtained by raising the weighted supermatrix to powers, by multiplying it times itself. When the values in the pertinent columns are the same (in this example occurred in the 14^{th} power, considering the fourth decimal place), the limit matrix has been reached and the matrix multiplication process is finished. As a result of the whole process, the ranking of alternatives in the network model is obtained (it may be needed to do some normalization), as exposed in Figure 54, inside the red dotted line.

Figure 54: Limit matrix with the priorities of the alternatives

		Goal	Criteria			Alternat.	
			Criterion 1	Criterion 2	Criterion 3	Alternative 1	Alternative 2
Goal							
Criteria	Criterion 1		0.1768	0.1768	0.1768		
	Criterion 2		0.2587	0.2587	0.2587		
	Criterion 3		0.0643	0.0643	0.0643		
Alternat.	Alternative 1	0.3666				0.1833	0.1833
	Alternative 2	0.6333				0.3167	0.3167

Source: The author (2015).

As seen in Figure 54, the Alternative 2 has the higher ranking (0.6333), against 0.3666 from Alternative 1. One interesting point to mention is that if the decision was calculated using the AHP method; the results would have given a higher rank to Alternative 1 (around 0.52) against around 0.48 to Alternative 2, as stated when exposed Figure 52.

This occurs because of the following: regarding the Criterion 3, Alternative 1 has 0.6700 against Alternative 2 with 0.3300 (see Figure 53). In an AHP overview, Criterion 3 has the higher ranking (0.5900) regarding the goal (see Figure 53), and this results in a slightly higher ranking for Alternative 1 (0.52). However, in ANP, the method analyzes each Alternative's criteria independent of other Alternatives. Therefore, it is possible to verify that the Alternative 2 has a high evaluation (0.7500) considering the Criterion 2, as seen in Figure 53. Yet, Criterion 2 has an average ranking value (0.2500) regarding the goal (Figure 53). Because of such characteristics and after all the calculations, Alternative 2 appears with a higher rank in the ANP method.

ANP is a complex technique and usually requires the use of a software tool, once both the calculations and the verification of the results are almost impossible to achieve manually.

4.5 CONCEPTS SIMILARITY

The goal of this section is to give a brief description of concepts (words) similarity and its characteristics, once some of these definitions, ideas and tools are used during the development of this research. This concept is used and is related to the research framework (Figure 4) processes A5 and A6, and something in the process A2.

According to Bollegala (2009), similarity can be broadly divided into two types: (i) semantic (or attributional) similarity and (ii) relational similarity. The attributional similarity is the correspondence between the attributes of two objects. If two objects have identical or close attributes, then those two objects are considered similar. For example, the concepts car and automobile have a common set of attributes: four wheels, doors, transportation purpose. Therefore, these two words show a high degree of semantic similarity (Bollegala, 2009).

The relational similarity is the correspondence between the implicit semantic relations that exist between two pairs of words. For example, consider the two word-pairs (ostrich, bird) and (lion, cat). Ostrich is a large bird and lion is a large cat. The implicitly stated semantic relation "*is large*" are common between the two words in each word-pair. Therefore, those two word-pairs are considered relationally similar (Bollegala, 2009).

Similarity plays a fundamental role in categorization, when objects are grouped together according to their similar characteristics and newly encountered objects are assigned to the category to which it is most similar (Bollegala et al. 2007), (Panchenko et al. 2012b).

There are several techniques, methods, applications and tools for measure the semantic and relational similarity, as proposed and discussed in Bollegala et al. (2007), Bollegala (2009), Panchenko et al. (2012a), Panchenko et al. (2012b), Panchenko & Morozova (2012) and Panchenko (2012). The two prevailing approaches to computing word similarity is based on the use of a thesaurus or using statistics from a large corpus (The UMBC Ebiquity Research Group, 2013).

This research (Figure 4, processes A2, A5 and A6) uses the semantical and relational similarity concepts and some of its tools and applications (including Natural Language Processing – NLP) to execute five main activities, as exposed in Table 32.

Table 32: Use of similarity tools and techniques in the research

Definitions /concepts	Purpose	Tools	References
Natural Language Processing	Extract initial concepts from the literature database (see research framework, Figure 4, process A2).	• Stanford POS Tagger	The Stanford Natural Language Processing Group (n.d.), Toutanova et al. (2003)
Semantic and relational similarity	Filter the concepts and grouping them by similarity.	• UMBC Semantic Similarity Service • Serelex • Context analysis (qualitative)	The UMBC Ebiquity Research Group (2013), Panchenko et al. (2013b)
	Group the concepts according to interoperability concerns	• UMBC Semantic Similarity Service	The UMBC Ebiquity Research Group (2013)
	Describe the concepts in terms of its characteristics and other semantically related words.	• UMBC Semantic Similarity Service • Serelex • Context analysis (qualitative)	The UMBC Ebiquity Research Group (2013), Panchenko et al. (2013b)
	Establish a correlation degree (among the concepts) to help the composition of the IACM (section 4.6).	• UMBC Semantic Similarity Service • Context analysis (qualitative)	The UMBC Ebiquity Research Group (2013)

The Stanford POS Tagger tool is maintained by the Stanford Natural Language Processing Group (at Stanford University) and built based on the research of a log-linear part-of-speech taggers described in Toutanova et al. (2003). A Part-Of-Speech Tagger (POS Tagger) is a piece of software that reads a text in some language and assigns parts of speech to each word (and other token), such as noun, verb, adjective and others.

The UMBC Semantic Similarity Service tool was built by the UMBC Ebiquity Research Group from the University of Maryland, Baltimore County UMBC). The tool provides a hybrid approach combining the thesaurus and statistics methods. The statistical method is based on distributional similarity and Latent Semantic Analysis (LSA) with further relations extracted from WordNet. (The UMBC Ebiquity Research Group, 2013). It is important to mention that WordNet is a registered tradename of Princeton University and is a large lexical database of

English, resembling a thesaurus but with extra elements (Princeton University, 2010).

Serelex is "lexico-semantic search engine" based on two semantic similarity measures: relying on definitions of words and on text corpus, and was built with the collaboration between Université Catholique de Louvain (UCL) and Bauman Moscow State Technical University (BMSTU). The tool provides extraction technology for automatic construction of semantic networks and thesauri from a corpus of domain-specific texts, based on a calculation of semantic similarity between words (Panchenko et al. 2013a).

The use of these tools in this research is to have an initial technical approach as the first step to building the concepts definitions and structure, and then apply context and qualitative analysis. That is, the use of similarity definitions helps the creation of the first baseline of concepts and knowledge extraction, instead of purposing “from the scratch”, based “only” on literature and qualitative analysis. Therefore, the first step gives a technical starting point, followed by the step, which analyzes the results of the first step and provides a qualitative and context view of the concepts, according to the interoperability context and expectations.

The achievements, results and details of concepts extraction, similarity calculations and some of its tools and applications are exposed in section 6 of this thesis.

4.6 QUALITY FUNCTION DEPLOYMENT (QFD)

According to Akao (1990), and derived from Bouchereau & Rowlands (2000), Quality Function Deployment (QFD) is a management tool that provides a visual connective process to help teams focus on the needs of the customers throughout the total development cycle of a product or process. It provides the means for translating customer needs into appropriate technical requirements for each stage of a product/process development life cycle. It helps to develop more customer-oriented, higher-quality products.

QFD was developed in Japan in the late 1960s by Professors Shigeru Mizuno and Yoji Akao and the purpose was to develop a quality assurance method that would design customer satisfaction into a product before it was manufactured, once prior quality control methods were primarily aimed at fixing a problem during or after manufacturing (Cao, 2013).

This research does not use formally and exactly the whole QFD method. Rather, the research uses an adaption defined by the author and called **Interoperability Attributes Correlation Matrix (IACM)**. The use and application of the IACM are exposed in section 6. The research frameworks (Figure 4) uses the IACM and some QFD spreadsheet templates in the processes A5 and A6, culminating into the process A8 (capability model proposal – PAICM). Despite the not full adoption of a “formal” QFD, its characteristics, structure and objectives are used in the IACM.

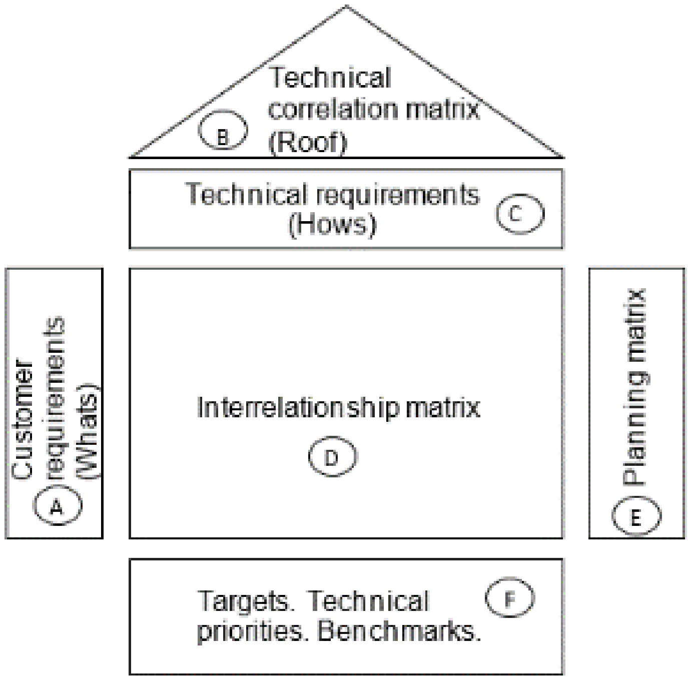
This research uses the IACM to formalize a qualitative view regarding the degree of correlation among the attributes, and the correlation between attributes and interoperability aspects (concerns and barriers). After the use of some quantitative tools (e.g., NLP and concepts similarity in section 4.5, related to processes A5 and A6 of the research framework - Figure 4), the IACM materializes the use of the research context (interoperability in public administration) to analyze the correlation of the terms within a more detailed interoperability context (complementing the semantical quantitative approach).

A general structure of an IACM is represented in Figure 55, with six main components derived from the QFD (Cao, 2013):

A. Customer requirements (WHATs): summarize the customer needs or a demanded quality. Each requirement can be asserted an absolute degree of importance (according to a defined rule) regarding the others existing requirements.
B. Technical correlation (Roof) matrix: Technical correlation matrix can be made to ensure what technological necessary condition is backing or prevent one another. The idea is to assign a degree and type of correlation among the technical characteristics themselves.
C. Technical requirements (HOWs): assemble a structure of concerned and quantifiable characteristics.
D. Interrelationship matrix: Exposes a degree of interrelationship between the “what’s” and the “how’s”. Usually, this degree is represented by signs or diagrams, but it can also be a number.

E. Planning matrix: Planning matrix clarifies customer conceptions surveyed from the marketplace. It can contain a comparison of corporations' performance.
F. Technical priorities, benchmarks, and targets: It contains information about the priorities of the technical aspects and goals to achieve.

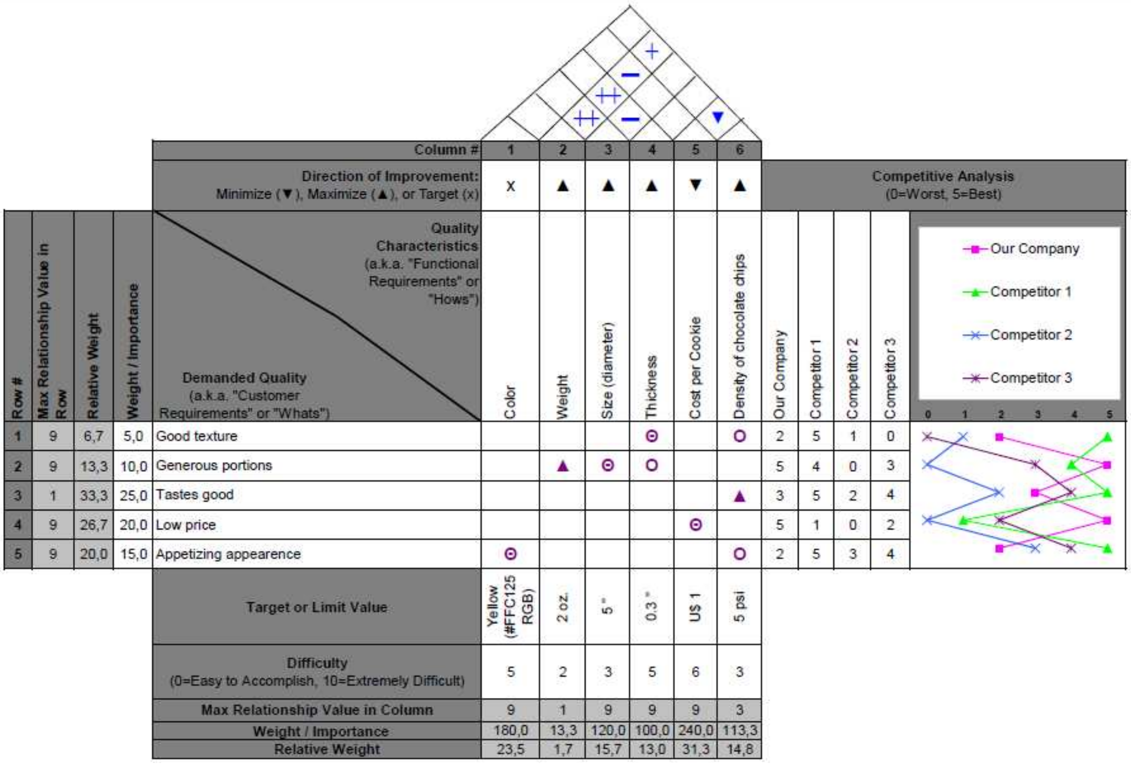
Figure 55: IACM and QFD “House of Quality” general structure



Source: The author (2015), based on Cao (2013).

Usually the interrelationship matrix and the technical correlation matrix are represented using pre-defined symbols to illustrate a “degree” of interrelationship or correlation. An example of IACM, based on QFD Online (n.d.), is exposed in Figure 56 and deals with a “Chocolate Chip Cookies” product. The IACM shows the relations of customers' requirements versus functional requirements and all the other components of the IACM.

Figure 56: Example of a QFD House of Quality



Source: The author (2015), based on QFD Online (n.d.).

The Figure 56 example shows a series of information relating the "Chocolate Chip Cookies" product and other analysis. The components of the example can be described as follows (according to each numbered circles):

1. Customer requirements ("what's") regarding the "Chocolate Chip Cookies". It is possible to find the demanded quality regarding the product, such as good texture, generous portions, taste and others.
2. This column contains the absolute weight/importance of each customer requirements. The degree and the scale can be defined and explained according to each application, product or need. In this example, the degree goes from to 5 (less importance) up to 25 (most important), incrementing from 5 to 5.
3. This column is a complement of the previous column 2 stated before and contains the relative weight of the requirements. That is, considering the total absolute weight (75), the relative weight of the "Good texture" requirement is 6.7 (5÷75). In this example, the "Good texture" requirement has 6.7% of the total weight; "Low Price" has 26.7% and so on. The labels 1, 2 and 3 are within the "A" structure represented in Figure 55.

4. This line represents the same quality characteristics of the product depicted in this example, such as color, size, cost, and others.
5. This line complements the information on the previous label 4. Here it is possible to find the direction of improvement that the project searches. According to each symbol (descriptions in Figure 57), it is possible to represent if the objective is to “hit the target”, “maximize” or “minimize” the quality characteristics. In this case, two examples of objectives are to maximize the size and minimize the cost per cookie. The labels 4 and 5 are within the “C” structure represented in Figure 55.
6. The “roof” represents a correlation matrix, indicating the degree of correlation among the characteristics. The blank cells indicate that there are no kind of correlations and, if there are any correlations, they are represented according to the symbols detailed in Figure 57. In this example, there is a strong positive correlation between weight and thickness. This label (6) is within the “B” structure represented in Figure 55.
7. This area represents the interrelationship degree analysis among the customer requirements and the characteristics. The idea is to insert a symbol that represents the degree (weight) of relationship. In this example, the “Low price” requirement has a strong relationship with “Cost per cookie” characteristic, and the “Tastes good” has a weak relationship with the “Density of chocolate chips”. The weight can be defined and explained according to each application, product or need. In this example, the values are 9 (strong relationship), 3 (moderate relationship) and 1 (weak relationship). Depending on the weights, degrees of importance and other choices, the values of some calculation will change. This label (7) is within the “D” structure represented in Figure 55.
8. This line is more informational and has the target or limit value for the characteristics or functional requirements. That is, what do the project wants to achieve. In this example, some of the values are as follows: for the color characteristics, the target is yellow, the size is 5 inches, and the cost per cookie is U$1.
9. This area contains information regarding the degree of “difficulty” of accomplishment of each characteristic or functional requirements. It also

has a degree interval that can be defined according to the needs. In this case, the interval goes from “0” (easy to accomplish) to “10” (extremely difficult).

10. Similar to label 2, this line contains the weight/importance of each functional requirements or characteristics. The difference from the area 2 is that, in this case, the weight/importance are calculated (not inserted) as a sum of all multiplications of the relative weight/importance of the customers’ requirements by the weight of the relationship in the interrelationship matrix (for each line of the same column). In this example, the “Color” characteristic has an absolute weight/importance of 180 (20 * 9) and the “Thickness” has an absolute weight/importance of 100 ((6.7 * 9) + (13.3 * 3)), considering all the rounding defined for each cell value.
11. This area is similar to label 3, and complements the previous label 10 stated before, containing the relative weight of the functional requirements or characteristics. That is, considering that the total absolute weight is 766.7 (180+13.3+120+100+240+113.3), the relative weight of the “Color” characteristic 23.5 (180 ÷ 766.7). In this example, the “Color” characteristic has 23.5% of the total weight; “Cost per cookie” has 31.3%, “Thickness” has 13% and so on. The labels 8, 9, 10 and 11 are within the “F” structure represented in Figure 55.
12. This area contains information regarding a performance comparison among competitors, considering a degree of achievement of each customer requirement (what’s) on a predefined scale. In this case, the scale goes from 0 (worst) to 5 (best) and, as stated before, these values can be changed according to the need and measurement references. This example shows that the “Competitor 1” (with a score of 5) is better than “Our Company” (with a score of 2) regarding the achievement of the “Good texture” requirement. That is, for each requirement; a performance score is given for a competitor, creating a kind of competitive analysis.
13. This area simply complements the label 12, creating a comparative graph based on the values of the performance analysis, giving a more intuitive and friendly view of the competitive analysis and comparison.

Figure 57: Symbols descriptions according to the qualitative correlation and relationship

Symbols description		Weight
⊝	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	

Source: QFD Online (n.d.).

It is important to remind that the QFD tool and its derivation IACM, as exposed here, has a qualitative approach and helps the organization and prioritization of requirements, characteristics, correlations and other aspects. Most of the fields must be fulfilled manually, according to the previous analyzes made by the stakeholders. In this example, the only fields that are calculated “automatically” are the light gray ones. There are also several possible derivations of the IACM based on the QFD example of Figure 56, that is, it is possible to adapt it according to the needs, once not all the fields and cells may be useful do use for a particular purpose.

4.7 CONSIDERATIONS AND CHAPTER SYNTHESIS

This extensive chapter provided an overview regarding a series of topics, definitions and theoretical aspects of tools and methods adopted in this research. The information must be considered as a kind of “pre-requirement” general knowledge needed for the “execution” of the research framework (Figure 4), providing a minimum background needed to better comprehend the framework and research development and outputs. Nevertheless, it is certain that some of the concepts and knowledge can also be gained and/or reviewed during the activities represented within processes A1 and A2 (Figure 4) themselves.

Some of the subsections (e.g., interoperability, public administration – eGovernment) have a strong relation to the contextualization of the research problem space (section 1.4, Figure 2). Other subsections (e.g., CMMI, MCDM, concepts similarity, quality function deployment) are more related to the contextualization of the solution space (section 1.4, Figure 2). It is important to remember that Figure 2 exposes the problem space (EI domain, eGovernment) and solution space (EIA domain, related works, tools, and techniques).

Among the exposed items, the CMMI and SCAMPI, for example, are related to the proposal of the models PAICM and PAIDM (detailed in sections 6 and 7), represented within the research framework in the processes A7, A8 and A9 (Figure 4).

The subsections regarding the concepts similarity and quality function deployment also have a connection with the models PAICM and PAIDM (processes A2, A5 and A6 in Figure 4).

The subsections related to the multi-criteria decision-making (AHP/ANP) are related to the organization of the PAIDM and execution of the diagnosis itself, mostly represented by the processes A9 and A11 in the research framework (Figure 4)

In summary, all the items exposed have a direct or indirect connection to the models proposition (PAICM and PAIDM) and the diagnosis event itself, once these are the major goals of the research.

5 RELATED WORKS – MODELS AND FRAMEWORKS

One of the results of the literature review (processes A0 and A1 in Figure 4) is the theoretical support related to the subjects of the research. Nevertheless, it is important to remind that not all of the theoretical knowledge comes directly from the systematic literature review *per se*, once there are, for example, some background and contextualization information previously needed, as briefly illustrated in section 4). One of the differences between this section and section 4 is that this section exposes some instantiated knowledge extracted from the literature review, while some information exposed in section 4 are used to understand the contextualization of this section 5.

This section provides information about related works regarding this research domain and application, exposing some interoperability models and frameworks, eGovernment frameworks within the public administration and other information that helped the construction of this thesis proposition (PAICM and PAIDM).

5.1 INTEROPERABILITY ASSESSMENT – MODELS AND FRAMEWORKS

Interoperability involves two (or more) organizations (or units) and, usually, these enterprises are different, with different systems, models or organizational structure. Enterprise Interoperability Assessment (EIA) provides a company with the opportunity to know its strengths, weaknesses and prioritize actions to improve its performance and maturity level assessment. Assessing interoperability implies the establishment of measures to evaluate the degree of interoperability between enterprises.

5.1.1 Interoperability Maturity Models

One of the measures that can be used and defined is the maturity level that is (intend to be) achieved. There is a large amount of interoperability maturity models (IMMs), presented in the literature, which describes and graduates the degree of interoperation potentiality considering, basically, two aspects of measurement (Guédria et al., 2011b):

- Measure relating to the potentiality of a system to be interoperable with a possible future partner whose identity is not known at that moment of evaluation. This approach is known as *a priori*.
- Measure relating to the compatibility between two (or more) known systems willing to interoperate, known as *a posteriori*.

Another measurement aspect also considers some other characteristics, such as potentiality, compatibility and performance (Elmir & Bounabat, 2011). Potentiality can be analyzed as an internal characteristic that reflects the readiness and preparation to interoperate. Compatibility can be analyzed as an external characteristic and the ability of interact, and performance can be analyzed regarding the quality issues, monitoring indicators related to the interoperability performance (i.e., how fast is the communication? How secure is the data exchange?).

An assessment, for example, may be used to provide a map of the relationship degree between two companies (A and B) trying to create a relationship based on their interoperability concerns and barriers. Table 33 shows an example of a possible high barrier level of interoperability regarding the technological aspect (inside the business concern) between company A and B. The interoperability assessment and diagnosis is a relatively new subject, although has been a subject of several research works such as (Chen & Shorter, 2008), (Elmir & Bounabat, 2011), (Cornu et al., 2012) and (Yahia et al., 2012).

Table 33: Examples of interoperability degree between two companies

A	Conc.	Tech.	Organ.	B
Business	LOW	HIGH	MEDIUM	Business
Process	MEDIUM	MEDIUM	NONE	Process
Service	NONE	MEDIUM	HIGH	Service
Data	NONE	LOW	LOW	Data

Most of the IMMs uses the CMMI (as seen in section 4.3) as a structural reference, including the organization and ratings in maturity degrees, using a scale from a lower to a higher level. For example, an organization at a low level of interoperability means that the work usually is *ad hoc* or even inconsistent, also with a sort of isolation from other companies. An organization with a high level assessed is rated as being able to work with other enterprises in a way that can explore the benefits of this collaboration. Among others, some of these IMMs are:

- LISI (Levels of Information System Interoperability) (C4ISR, 1998).

  Provides a reference frame for discussing system-to-system interoperability issues, focusing mainly on technical interoperability. The levels and some description are in Table 34:

Table 34: LISI levels and basic description

Level	Brief description
Enterprise-Based	Systems are capable of operating using a distributed global information space across multiple domains. Multiple users can access and interact with complex data simultaneously. Data and applications are fully shared and can be distributed. Data has a common interpretation regardless of the form. Decision-making takes place in the context.
Domain-Based	Systems are capable of being connected via wide area networks (WANs), allowing multiple users accessing the data. Information shared among independent applications. A domain-based data model is present, understood, accepted, and implemented across a functional area or group of organizations. Individual applications may share central or distributed data repositories. Decision-making is supported by merged information from a localized domain.
Functional	Systems are in local networks (allowing some data exchange). Formal data models (logical and physical) are present. Data is generally heterogeneous and may contain information from many simple formats merged together. Decision-makers are able to share information between systems.
Connected	Systems are capable of being linked electronically and provide some simple electronic exchanges, usually using homogeneous data types. Little capability to put information together to support decision-making.
Isolated	Isolated, or stand-alone, systems. No direct electronic connection is available. Manual (or sharing media) interface between these systems.

- OIMM (Organizational Interoperability Maturity Model) (Clark & Jones, 1999).

  Does not address technical, semantic or syntactical issues, but focuses on the business and organizational areas of concern, dealing with the ability of organizations to interoperate. The levels and some description are in Table 35.

Table 35: OIMM levels and basic description

Level	Brief description
Unified	The organizational goals, value systems, command structure/style, and knowledge bases are shared across the system. The organization is interoperating on continuing basis.
Integrated	There are shared value systems and shared goals, a common understanding and readiness to interoperate. The frameworks are in place and practiced, however, there are still residual attachments to a home organization.
Collaborative	Recognized frameworks exist to support interoperability, and shared goals are recognized and roles and responsibilities are defined as part of on-going responsibilities. However, the organizations are still distinct.
Ad hoc	Very limited organizational frameworks that could support ad hoc arrangements. Some guidelines describing how interoperability will occur. Some shared goal but individual organization aspirations take precedence, and the organizations remain entirely distinct.
Independent	Usually, work without any interaction other than that provided by personal contact. Do not normally share common goals. Essentially the arrangements are unplanned and unanticipated. Although there are no formal frameworks in place, they are able to communicate for example via telephone, e-mail and personal contact in meetings.

- LCIM (Levels of Conceptual Interoperability Model) (Tolk & Muguira, 2003).

  Explores the idea that interoperability goes beyond technical implementations. The levels and some description are in Table 36.

Table 36: LCIM levels and basic description

Level	Brief description
Harmonized data	Semantic connections between data that are not related concerning the execution code are made obvious by documenting the conceptual model underlying the component. Beyond the implemented parts of the concept, the important relations that are NOT captured in the implementation are captured. It is more than a white box.
Aligned dynamic data	The use of the data is well-defined using standard software engineering methods. It is usually a white box.
Aligned static data	Data is documented using a common reference model based on a common ontology. It is possible to use metadata or standard reference models. The component is a black box with a standard interface.
Documented data	Data is documented using a common protocol. The component is a black box with an interface.

Level	Brief description
System specific data	No interoperability among systems. Data is used within each system in a proprietary way with no sharing. The component is a black box.

- EIMM (Enterprise Interoperability Maturity Model) (ATHENA Consortium, 2003).

  The EIMM helps to assess an organization's maturity level concerning the use of enterprise models as well as the capability of these models to enable the company to be part of a collaboration. There are six areas covered in the assessment using EIMM: business strategy and processes, organization and competencies, products and services, systems and technology, legal environment, security and trust, and enterprise modeling. The levels and some description are in Table 37.

Table 37: EIMM levels and basic description

Level	Brief description
Optimizing	Enterprise models allow the organization to react and adapt to changes in the business environment in an agile, flexible and responsive manner. The use of enterprise modeling can contribute to reaching the overall goals of the organization, unit, or persons involved.
Interoperable	Support dynamic interoperability and adaptation to changes and evolution of external entities. The workplaces of the people are seamlessly adapted to the enterprise model. Results (for organizations and individuals involved) and process metrics are defined as a basis for continuous improvement.
Integrated	The enterprise modeling process has been formally documented, communicated and is consistently in use. The organization uses a defined methodology and infrastructure for enterprise modeling; the different dimensions are integrated among themselves, and the model is traceable to the enterprise systems. There is a knowledge base used to improve the models, and business collaboration is facilitated through interoperability technologies.
Modelled	Enterprise modeling and collaboration is done in a similar way each time. Defined meta-models and approaches are applied, responsibilities are defined, and people understand the enterprise model and know how to execute it. Network technologies are used to collaborate.
Performed	Enterprise modeling and collaboration is done but in an ad-hoc and chaotic manner. The organization collaborates with external entities, but the relationships are not planned thoughtfully. Collaborative tasks and processes usually exceed budget and schedule, their past success (generally based on the people) cannot be repeated.

- MMEI (Maturity Model for Enterprise Interoperability) (Guédria et al., 2009).
  Integrates aspects (such as the four concerns and the three barriers) which are usually dealt in a fragmented way by separated maturity models. In each level, there is an explanation of how is the behavior of that level considering the matrix of concerns and barriers. The levels and some description are in Table 38.

Table 38: MMEI levels and basic description

Level	Brief description
Adapted	Organizations are able to adjust dynamically and accommodate 'on the fly'. There exist in general shared domain ontologies. Organizations are able to interoperate with multi-lingual and multicultural heterogeneous partners. At this level, all information and interoperability itself become a subject of continuous improvement.
Organized	Organization is well organized to deal with interoperability challenges. Interoperability capability is extended to heterogeneous systems/partners, and often in a networked context. Organization and decision-making are usually decentralized. Companies are able to interoperate with multiple heterogeneous partners. The development of an ontology, reference or standardized meta-models is required.
Aligned	The organization must be able to make changes in its system to adhere to common formats (imposed by a partner). Relevant standards are used as much as possible. Some flexibility has been achieved in the organization structure. IT infrastructure and platform are connected. Tools remain platform dependent, but they are used not only for modeling but also for executions at runtime. The efforts to make changes in systems are big and in general not easily reversible. The achieved interoperability by aligning to a common format or standard is limited in the sense that it is confined to certain fixed and homogenous partners or situations.
Defined	Although the systems are still entirely distinct, some ad hoc interoperations can take place, but the interoperability remains very limited. Some basic IT devices are connectable. Simple electronic data exchange becomes possible. Systems and organizations are in general defined and modeled. Modeling tools are in place and used for design time (specifying systems), but these tools are technology dependent and can only run on some specific platforms. Responsibility and authorities to model, update and maintain data, services, processes are explicitly defined.
Unprepared	Proprietary or closed systems. Resources are not shared. System modeling and description are not complete or even inexistent. Communication remains mainly manual

Level	Brief description
	exchange. Systems run stand-alone and are not prepared for interoperability.

Usually, these models try to focus on some type of assessment (e.g., *a priori*, *a posteriori*, potential and intrinsic) or in some combination of these items, as shown in Table 39, retrieved from (Cornu et al., 2012).

Table 39: Types of assessment combinations

<table>
<tr><th colspan="2"></th><th colspan="2">Objective of the assessment</th></tr>
<tr><th colspan="2"></th><th>Intrinsic
(considers only one entity)</th><th>Extrinsic
(considered a couple of entities)</th></tr>
<tr><td rowspan="2">Type of interoperability assessed</td><td>Potential (before collaboration)</td><td>Evaluate the ability to interoperate with any partner, where the part is unknown.</td><td>Evaluate the future interoperability of the couple during collaboration. The partners know each other but have not started a collaboration.</td></tr>
<tr><td>Effective (during or after collaboration)</td><td>Evaluate the effective ability to interoperate with a partner. The partner is known, but only the interoperability of one entity is assessed.</td><td>Evaluate the effective interoperability of the couple during their collaboration. The partners know each other and interact.</td></tr>
</table>

Table 40 shows a brief comparison of the models presented previously along with a basic description of each maturity level associated.

Table 40: Examples of models, maturity levels, and macro characteristics

Models	Level 1	Level 2	Level 3	Level 4	Level 5
LISI	Level names and macro characteristics				
	Isolated	Connected	Functional	Domain based	Enterprise based
	Manual gateway (CD, DVD, flash drives).	Homogeneous product exchange (e-mails, files).	Minimal functions. Heterogeneous product exchange.	Shared databases. Sophisticated collaboration.	Distributed information. Simultaneous interactions.
OIMM	Level names and macro characteristics				
	Independent	Ad hoc	Collaborative	Combined	Unified
	Communication via personal contacts. Limited shared purpose.	General guidelines. Basic electronic shared information.	General frameworks. Shared some knowledge.	Shared communications. Shared culture influenced by the home organization.	Organization is interoperating on a daily basis.
LCIM	Level names and macro characteristics				
	System Specific Data	Documented Data	Aligned Static Data	Aligned Dynamic Data	Harmonized Data
	Isolated systems. Black box.	Black box with a documented interface.	Black box with a standard interface.	White box. Common Ontology.	Common conceptual model. Beyond a white box.
EIMM	Level names and macro characteristics				
	Performed	Modeled	Integrated	Interoperable	Optimizing
	Some collaboration. Ad hoc.	Defined collaboration. Repetition occurs.	The process is formal and frequently used.	Dynamic. Adaptation to changes and evolution.	Integrating systems, models and technologies.
MMEI	Level names and macro characteristics				
	Unprepared	Defined	Aligned	Organized	Adapted
	No capability for interoperation.	Very limited. Simple electronic data exchange.	Able to adhere to common formats or standards.	Interoperate with multiple heterogeneous partners.	Dynamically adjustments. Shared domain ontologies.

There are also other important characteristics regarding the models and the measures they offer. Table 41 shows some models and a description of what type of measure may be obtained (qualitative and/or quantitative) and if the model covers an *a priori* or *a posteriori* assessment and evaluation.

Table 41: Other characteristics of the frameworks, adapted from Yahia (2011)

Framework	**Type of measure**	**A priori/ a posteriori**
LISI	Qualitative	A priori
OIMM	Qualitative	A priori
LCIM	Qualitative	A priori
EIMM	Qualitative	A priori
MMEI	Qualitative/quantitative	A priori

Considering some common aspects of the presented models, Table 42, retrieved and adapted from Guédria et al., (2008), shows the relation and “adherence degree” of the models regarding these other properties. The ‘+++’ indicate that there is a strong concern, and the model meets better the criteria, ‘+’ denotes some kind of a weak relation and ‘++’ is in between. The ‘-’ symbols indicate that the model does not meet or address the criteria.

Table 42: Relations of the models with disciplines

	LISI	**OIMM**	**LCIM**	**EIMM**	**MMEI**	**CMMI-DEV**
Computer science	+++	-	++	+	+	+++
Production engineering	-	-	-	+++	+++	+
Management and organization	-	+++	-	+++	+++	+++
System theories	-	-	-	-	-	-
Flexibility to adapt	++	-	-	++	++	+
Agility to react	+	-	-	-	-	-
Openness	-	-	-	-	-	-
Use of standards	+++	+++	+++	+++	+++	+++
Reconfigurability	-	-	-	-	-	-
Technological	+++	-	++	-	-	+++
Organizational	-	+++	-	+++	+++	+
Conceptual	+	-	+++	++	++	+
Business	-	+++	-	+	+	+
Process	-	-	-	+++	+++	+++
Service	+++	-	-	++	++	+
Data	+++	-	+++	++	++	+

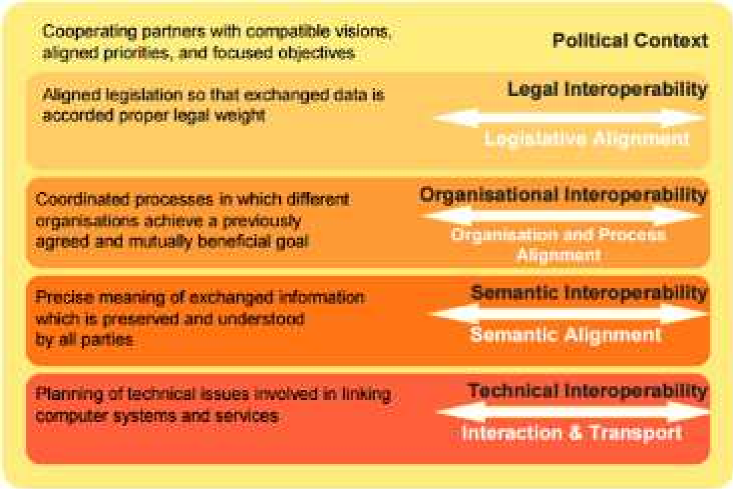
5.1.2 Interoperability Frameworks

In addition to studies of IMMs, the mapping of the interoperability frameworks (IFs) allows identifying structural characteristics in the definition of concerns and barriers studied; some of which are related to the public administration domain with the adoption of legal and political perspectives.

According to European Commission (2004), an interoperability framework can be defined as a set of standards and guidelines that describe the way in which organizations have agreed, or should agree, to interact with each other. Therefore, it is not a static document and may have to be adapted over time as technologies, standards and administrative requirements change.

- EIF 1.0 (European Interoperability Framework for Pan-European eGovernment services) (European Commission, 2004).
  Developed in the context of a research program funded by the European Commission for the interoperability development. Provides a set of recommendations and specifications to connect systems, which could be used also for eGovernment services so that public administrations, enterprises, and citizens can interact across borders, in a Pan-European context (Guédria, 2012). The framework identifies the three classical dimensions of interoperability: semantic, organizational and technical.
- EIF 2.0 (European Interoperability Framework for European public services) (European Commission, 2010).
  A review of the EIF 1.0, with underlying principles of European public services, similar to the recommendations defined in the previous version. There is an increment in the interoperability levels/dimensions, including a legal interoperability level and a political context, which covers the other levels, as, illustrated in Figure 58.

Figure 58: Interoperability levels/barriers in EIF 2.0



Source: European Commission (2010).

- AIF (Athena Interoperability Framework) (Berre et al., 2007) (Ruggaber, 2006).

  Structured in three levels:

  - Conceptual integration: identifying concepts, models, meta-models, languages and relationships required to develop interoperability.
  - Applicative integration: methodologies, standards, and domain models. It provides guidelines, principles and patterns that can be used to solve interoperability problems.
  - Technical integration: technical development and ICT environments (including tools and platforms).

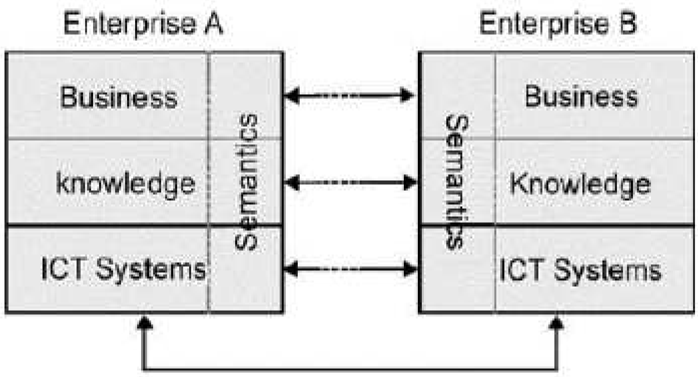
  The framework states that interoperations can take place at the various levels:

  - Enterprise/business level: organizational and operational ability of a company to cooperate with other external organizations in spite of different working practices, legislations, cultures and commercial approaches.
  - Interoperability of processes: aims to make various processes work together. Connecting internal processes of two companies to create the cross-organizational business process.
  - Interoperability of services: identifying, composing and executing various applications (designed and implemented independently).

- Interoperability of information/data: related to the management, exchange and processing of different documents, messages, and/or structures by different collaborating entities.

- IDEAS (Interoperability Developments for Enterprise Application and Software) (Chen & Doumeingts, 2003).
  Identifies three levels of interoperability: business, knowledge and ICT systems. These three levels are connected by a common semantic layer (as shown in Figure 59). To achieve meaningful interoperation between enterprises, interoperability must be reached in all layers of an enterprise.

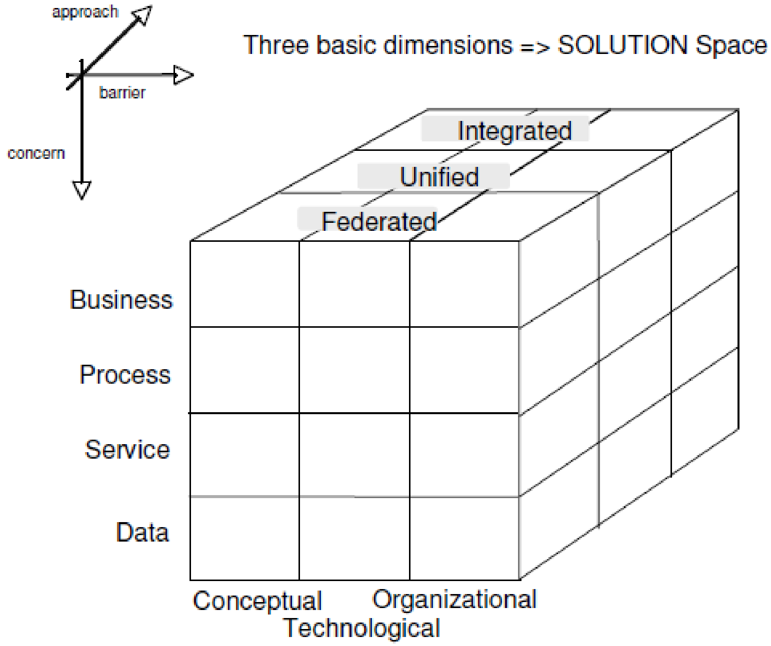
Figure 59: Interoperability considering the layers



Source: Chen & Doumeingts (2003).

- FEI (Framework for Enterprise Interoperability) (Chen & Daclin, 2006).
  The framework defines the research context of the enterprise interoperability and help to identify and to structure the knowledge in this domain. Figure 60 shows the three dimensions of the solution space (considering the approach, barriers, and concerns).

Figure 60: Framework for Enterprise Interoperability (FEI)



Source: Chen & Daclin (2006).

5.2 EGOVERNMENT INTEROPERABILITY DOMAIN

The previous sections of this document exposed perspectives of interoperability models and frameworks (IMMs and IFs). To put these perspectives together with the public administration/eGov domain, this section provides definitions and information related to the combination of these views. I.e., dealing with enterprise interoperability aspects of the public administration, more specifically regarding government agencies and similar, considering specific aspects such as risks, concerns, barriers related to government and eGovernment. Some definitions and statements about eGovernment interoperability are exposed in Table 43.

Table 43: Definitions regarding eGovernment interoperability

Source	Statements
Charalabidis et al., (2007)	"Since the late 90s, most countries have faced the interoperability challenge with the adoption of national e-Government Interoperability Frameworks covering areas, such as data integration, metadata, security, confidentiality and delivery channels, which fall into the technical interoperability facet. Such interoperability frameworks have issued "sets of documents" guiding systems' design - but have not developed to date appropriate infrastructures, such as repositories of XML schemas for the exchange of specific context".
Archmann & Nielsen (2006)	"The ability of public authorities' information communication technology (ICT) systems and business

Source	Statements
	processes to share information and knowledge within and across organizational boundaries to better support the provision of public services as well as to strengthen support to public policies and to democratic processes". "Interoperability is not an end in itself, but a tool to solve the problems of different stakeholders. The manner in which interoperability solves a given problem varies according to the type of eGovernment area and services".
CEPA (2007)	"Governance in this context refers to agreements between governments and other actors involved in interoperability, and ways of achieving them, including the creation for establishing such agreements. Governance activities are designed to provide government entities the institutional structures needed to establish interoperability standards and ensure that they are."
UNDP (2008)	"The ability of constituencies to work together." "At a technical level, it is the ability of two or more government information and communications technology (ICT) systems or components to exchange information and use the information that has been exchanged to improve governance. E-Government interoperability has become a crucial issue because recent ICT investments have reinforced the old barriers that made government decision-making, not to mention citizen access to public services, difficult. In some governments, agencies are deploying new ICT systems with specifications and solutions relevant to their particular needs but without adequate attention to the need to connect, exchange and re-use data with other agencies' ICT systems. The result is a patchwork of ICT solutions that are not always compatible with each other and an e-government programme that does not meet its goals."
Pardo & Burke (2008b)	"The creation of systems that facilitate better decision making, better coordination of government agency programs and services to provide enhanced services to citizens and businesses, the foundation of a citizen-centric society, and the one-stop delivery of services through a variety of channels."
Pardo & Burke (2008a)	"The ability of two or more diverse government information and communications technology systems or components to meaningfully and seamlessly exchange information and use the information that has been exchanged."
Pankowska (2008)	"Can be considered on community level (policies, rules); administration level (processes, architecture); service level (structure, semantics) and technology level (connectivity, communication)"
Vogel et al., (2008)	"The capability for direct machine-to-machine interaction in Business-to-Government (B2G) as well as Government-to-Government (G2G)."
Shvaiko et al., (2009)	"The capability of (two or more) systems to exchange seamlessly data, information and knowledge, thereby

Source	Statements
	enabling efficient and effective services offered by the government organizations (G) to the citizens (G2C), to the business sector (G2B) and to the other government organizations (G2G)".
Da Silva (2009)	"The interoperability of e-Gov systems is not a goal in itself, but a pathway to reach the real objectives for these systems."
Saekow & Boonmee (2009a)	"EGovernment interoperability can be achieved through the adoption of standards or through architecture to each other and to the environment, and the principles guiding, its design and activity."
New Zealand Government (2008)	"The ability of government organizations to share information and integrate information and business processes by use of common standards. Government adopting and using common standards to ensure agencies and their partners can work together, and users can access government services and information."
Pardo et al., (2012)	"Set of multidimensional, complementary, and dynamic capabilities that are specific to a defined network of organizations with particular goals and a common environment."

5.2.1 eGovernment Interoperability Models and frameworks

Although the models already presented in the interoperability section can be used for various types of organizations, in an abstract way, there are few models regarding specifically government issues. Such models have a strong connection to eGovernment issues, considering it as a key strategy for improving the effectiveness of public policies and programs (Pardo et al., 2012).

According to UNDP (2007), a Government Interoperability Framework (GIF) is a set of standards and guidelines that a government uses to specify the preferred way that its agencies, citizens and partners interact with each other, being one way to achieve eGovernment interoperability. A GIF includes context, technical content, process documentation and, among other things, the basic technical specifications that all agencies relevant to the eGovernment strategy implementation should adopt.

Charalabidis et al., (2007) states that an eGIF (eGovernment Interoperability Frameworks) is in the core of eGovernment initiatives and strategies, constituting the cornerstone of electronic services provision and, since 2000, has become a crucial issue (Saekow & Boonmee, 2009a). Some government interoperability models and/or frameworks are exposed in Table 44.

Table 44: Government interoperability frameworks and models

Source	Brief description	Focus	Process oriented	Levels
Sarantis et al. (2008)	Government Interoperability Maturity Matrix (GIMM). Provides an accessible, comprehensive and complete way for administrations to evaluate their status on eGovernment issues. The structure is very similar to other models (presented in this document) and is based on the CMMI. There are maturity levels defining the characteristics of the formalism degree and the way of exchanging data and information. The GIMM works with interoperability attributes, such as connectivity with central government gateways, single sign-on facilities for user authentication, the existence of web-service interfaces, interoperability with external enterprise systems, and the existence of common XML-based data schemas. The maturity levels are as follows: • Level 1: Independent. Interaction between independent organizations. • Level 2: Ad hoc. Very limited organizational frameworks exist which could support ad hoc arrangements. • Level 3: Collaborative. Frameworks exist. Shared goals are recognized, roles and responsibilities are allocated. Organizations are still distinct. • Level 4: Integrated. There are shared systems, goals, and a common understanding and readiness to interoperate with other organizations. • Level 5: Unified. The organizational goals, systems, command structure/style and knowledge bases are shared among organizations.	G2B G2C	Yes	5
Laskaridis et al., (2007)	The model proposed presents important issues related to government interoperability, taking into account that eGovernment actions may decrease bureaucracy. The need for a more effective service providing public service requires a well-defined ICT infrastructure of support. The model proposed has a focus regarding technical aspects of information exchange, especially considering the necessity of a single and common language to be adopted, which, in this case, is the XML.	G2B G2G	No	NA
Usero et al., (2006)	The model for interoperability evaluation in eGovernment services identifies some aspects to guarantee information and knowledge interoperability in eGovernment services, especially focused on public websites contents. The authors proposes three basic approaches that must be taken into account: (i) information and	G2B G2G G2C	No	NA

Source	Brief description	Focus	Process oriented	Levels
	knowledge management (e.g., markup languages, open software and formats, and electronic document processing), (ii) metadata for knowledge representation in electronic resources, and (iii) web accessibility to improve access for all users.			
Solli-Saether (2011)	Two government e-services in Norway are presented as a case study. The authors propose a study based on a four-staged framework (aligning work processes, knowledge sharing, joining value creation and aligning strategies) crossing with organizational, semantic and technical interoperability issues.	G2B G2C	Yes	4
Pardo et al., (2012)	A framework that structures eGovernment interoperability in terms of dynamic and interactive policy, management, and technology dimensions. The framework proposes a structure formed by basic categories and dimensions.	NA	Yes	NA
Saekow & Boonmee (2009b)	Interoperability Practical Implementation Support (IPIS) presents a practical approach for implementing electronic government interoperability. The approach consists of three main components: support tools, interoperability repositories, and a knowledge-based system. The authors show a methodology to tie all three elements together in a very technical approach.	NA	Yes (as a tool)	NA
Staden & Mbale (2012)	Information Systems Interoperability Maturity Model (ISIMM) defines levels and degrees of interoperability evolution, focusing on technical aspects regarding data exchange and sharing. The authors present an application case of the ISIMM regarding the Government of Namibia to establish its interoperability level considering, mostly, technical issues. Although the ISIMM was not built to deal with government issues specifically, it is mentioned in this section, given that, in this case, it was applied for government assessment.	G2B G2G G2C	Yes	5
Ministério do Planejamento (2012)	The e-PING is a Brazilian Government (framework) effort that defines a minimum set of premises, policies, and technical specifications to regulate the use of ICT in the interoperability of services regarding the eGovernment. e-PING stands, in Portuguese, for "Padrões de Interoperabilidade de Governo Eletrônico", which can be freely translated into English as "eGovernment Interoperability Patterns". Establishes conditions and interactions with other government agencies and the society, covering aspects such as interconnection, security, access, and organization and data interchange. The Brazilian e-PING (and other countries Government Interoperability Frameworks) addresses technical interoperability	G2B G2G G2C	Yes	Yes (in some aspects)

Source	Brief description	Focus	Process oriented	Levels
	(UNDP, 2008) defines protocols that must be used, hypertext interchange format, databases, image extensions, BPMN notations and other issues. Cover areas such as interconnection, security, ways to access, organization and information exchange and electronic government integration areas. The framework does not recommend tools or defines presentations patterns for information, and considers that there are technical, semantic and organizational elements that must be covered in the interoperability.			
Marques et al., (2011)	The General Interoperability Architecture for e-Government based on Agents and Web Services is a generic interoperability architecture for eGovernment based on Software Agents and Web Services where the main objective is to provide a secure way for delivering integrated services from the client's (citizens, businesses or Public Administration) perspective. The framework has a strong focus on security aspects, and the fundamental principle of the architecture consists of agents that publish services and that work together, requesting and providing services, to fulfill services that are more complex.	G2B G2G G2C	No	NA
Malaysian Government (2003)	MyGIF defines the minimum set of collection of ICT standards and technical specifications governing the communication of systems, the flow of information, as well as the exchange of data and business processes that relate to Government Ministries, agencies and departments. MyGIF basically covers five interoperability areas: interconnection, data integration, information access, security, and metadata. Instead of creating new standards or specifications, MyGIF adopts internationally recognized open and de facto ICT standards as well as technical specifications for all the interoperability areas mentioned.	G2G G2C G2B G2Og	Yes	NA
Mozambique Government (2010)	The eGIF4M define an essential framework to integrate technical and organizational aspects using existing technical frameworks and models, such as PMBoK, CMMI, SOA and others. Adopts practices and concepts of service delivery architecture and propose the implementation of world known standards. The eGIF4M also propose a form of maturity model and the assessment of software development, based on the LISI levels. To evaluate the organizations eGIF4M adopts the vision of PAID attributes also retrieved from LISI. Suggests four maturity	G2G G2C G2B	Yes	4 or 5

Source	Brief description	Focus	Process oriented	Levels
	levels for process and infrastructure maturity and five levels for system and technology maturity levels.			
German Government (2008)	SAGA pursues a comprehensive standardization approach for Germany's administrations to achieve the goals such as defining technical standards and architectures for eGovernment applications and standardizing processes and data in administrations. SAGA pursues the following aims: (i) interoperability, (ii) reusability, (iii) openness, (iv) reduction of costs and risks and (v) scalability.	G2C G2B G2G	Yes (also)	NA
Indian Government (2013)	The Indian government has a set of standards related to e-governance applications and which are part of a National e-Governance Plan (NeGP) with the intent to support the growth of e-Governance within the country. The standards are divided into categories such as policy, frameworks, guidelines and best practices. A government portal provides a platform for sharing the documents among the members of various committees involved in standards formulation process.	G2B G2G G2B	Yes (in some ways)	NA
Australian Government (2011)	The intent of the Australian Government Architecture (AGA) framework is to assist in the delivery of more consistent and cohesive services to citizens and support cost-effective delivery of ICT services by government, providing a framework that provides a common language, enhances collaboration, assists in describing and analyzing IT investments, assists in transforming government to a citizen-centric and results-oriented base. The AGA contains a set of interrelated reference models such as Performance Reference Model, Business Reference Model, Service Reference Model, Data Reference Model, and Technical Reference Model.	G2G G2C G2B G2Og	Yes	NA
Estonian Government (2011)	A collection of requirements, standards and instructions, handling the interoperability of information systems and services of the Estonian public sector, which ensures serving public sector institutions, enterprises and citizens both in Estonia and all over Europe. The framework is a guideline for preparing public sector IT legal acts, designing IT solutions and organizing IT related public procurements. The objectives of the framework are to contribute to the development of a service-oriented society, to bring more transparency into information related political decisions of the information system, to support co-development of the state information system, to create conditions free competition and to reduce public sector IT costs. It is guided by the European Interoperability	G2C G2G G2Og G2B	Yes (in some ways)	NA

Source	Brief description	Focus	Process oriented	Levels
	Framework and its 12 principles: (i) subsidiarity and proportionality, (ii) user-centricity, (iii) inclusion and accessibility, (iv) security and privacy, (v) multilingualism, (vi) administrative simplification, (vii) transparency, (viii) preservation of information, (ix) openness, (x) reuse, (xi) technological neutrality and adaptability and (xii) effectiveness and efficiency. Although the fundamental principles have been taken from the European framework, it is not a repetition of the European angle, but peculiarities and specifications of the application of these principles in the Estonian context.			
US Government (2013)	Federal Enterprise Architecture Framework consists of a set of interrelated “reference models” that describe six sub-architecture domains in the framework: strategy, business, data, applications, infrastructure, and security. These are designed to facilitate cross-agency analysis and the identification of duplicative investments, gaps and opportunities for collaboration within and across agencies. “Helps to accelerate agency business transformation and new technology enablement by providing standardization, analysis and reporting tools, an enterprise roadmap, and a repeatable architecture project method that is more agile and useful and will produce more authoritative information for intra and inter-agency planning, decision-making, and management”.	G2G	Yes	NA
United Kingdom Government (2005)	Sets of the government’s technical policies and specifications for achieving interoperability and ICT systems coherence across the public sector. Define the essential prerequisites for the joined-up and web-enabled government. Adopts XML and XSL as the core standards for data integration and management and sets out policies for establishing and implementing metadata across the public sector. The UK e-GIF defines the minimum set of technical policies and specifications governing information flows across government and the public sector.	G2C G2B G2Org G2Og G2G	NA	NA
New Zealand Government (2008)	Consists of standards, policy and resources. It covers ways to achieve interoperability of public sector data and information resources, ICT, and electronic business processes. It enables any agency to join its information, ICT or processes with those of any other agency using a predetermined framework based on “open” (i.e., non-proprietary) international standards. The standards define very technical aspects regarding network (data transport, protocols), data integration, business	G2G G2C G2B	Yes (in some aspects)	More or less

Source	Brief description	Focus	Process oriented	Levels
	services, security, best practices, web services and others. There is a kind of maturity assessment related to the stage of the implementation of some standard or practice and the “levels” are (i) adopted, (ii) recommended, (iii) under development and (iv) future consideration.			
Kingdom of Saudi Arabia Government (2005)	Set of policies to be adopted by government institutions that standardize the way the information is being exchanged and shared services are being used. Defines data types, schemas, metadata element, dictionaries, integration approach, standards, connectivity standards, security standards, information access, and delivery standards.	G2B G2C G2Og G2Foreign Employees G2G	Yes (in some aspects)	NA
Hong Kong Government (2012)	Supports the Government’s strategy of providing client-centric joined-up services by facilitating the interoperability of technical systems between Government departments, as well as between Government systems and systems used by the public (including citizens and businesses). Define a collection of specifications aimed at facilitating the interoperability of Government systems and services. Adopting these interoperability specifications, system designers can ensure interoperability between systems while at the same time enjoy the flexibility to select different hardware, and systems and application software to implement solutions. In addition, the framework promotes and fosters the adoption of XML to enable the exchange of data between applications.	G2C G2G G2B	NA	NA

NA: not applicable.

Table 45 shows other complementary maturity eGovernment models as identified in Huijsman et al., (2012). They all follow the fundamental characteristics of having some “maturity stages”, focusing on one or another aspect of the relation between government and its stakeholders.

Table 45: eGovernment maturity models. Retrieved and adapted from Huijsman et al., (2012)

Authors	Year	Main focus	Process oriented	# stages
Baum and Di Maio, Gartner	2000	G2C/G2B	No	4
Layne and Lee	2001	G2C/G2B	Yes	4
Hiller and Bélanger	2001	G2C/G2B	No	5
Silcock, Deloitte	2001	G2C/G2B	No	6
Ronaghan, UN	2001	G2C/G2B	No	5
Wescott	2001	G2C/G2B	No	6
Netchaeva	2002	G2C/G2B	No	5
Chandler and Emanuels	2002	G2C/G2B	No	4
Peristeras, Tsekos, and Tarabanis	2002	G2G	No	4
West	2004	G2C/G2B	No	4
Siau and Long	2005	G2C/G2B	No	5
Wauters, EU Commission	2006	G2C/G2B	No	4
Andersen and Henriksen	2006	G2C/G2B	No	4
Papantoniou et al.	2001	G2C/G2B	Yes	4
Klievink and Janssen	2009	G2G	Yes	5
Janssen	2010	G2G	Yes	4

5.2.2 eGovernment Interoperability benefits and difficulties

Some of the benefits of dealing with eGovernment interoperability are already exposed in section 1.2, but the literature review collects a few other advantages and statements (see Table 46) that worth mention.

Table 46: Other eGovernment interoperability benefits

Source	Statements
UNDP (2007)	Interoperability will allow data compiled by different agencies to be used together to make better decisions. Germany’s Federal Foreign Minister, Frank-Walter Steinmeier stated it well: “An open, unhindered exchange of information in all areas of life is of fundamental importance for today’s knowledge-based society. It is an important foundation for our shared objective: a peaceful, democratic, pluralistic society. If information about government is easier to obtain, policy makers can design better projects and can more easily avoid redundant or similar projects. Policy and decision-makers would have more information by which to evaluate the performance of agencies and the public services they deliver.

Source	Statements
	Interoperability among governments can help create the infrastructures necessary to solve cross-border problems such as drug trafficking, environmental pollution, money laundering and illegal arms trade. Interoperability among governments can also mean delivery of eGovernment services to citizens and businesses across a region (as in the case of the European Union) and facilitate trade between a group of countries and their trading partners.
UNDP (2008)	Interoperability will allow data compiled by different agencies to be used together to make faster and better decisions. The seamless flow of data from one government office to another provides the policy maker with the information needed to draft sound policy and deliver better services. It is fundamental to invest in the development of an eGovernment interoperability framework, recognizing that eGovernments should be transformative and become more citizen-oriented and focused on delivering public services. EGovernment interoperability enables one-stop, comprehensive online services for citizens and businesses by linking the diverse services that are offered by different agencies. Increasing the ease at which information is shared among individual agencies (up to the point allowed by law) makes for better and/or new services. Interoperability also allows governments to manage their internal operations better. Increases transparency and accountability. Governments are better able to justify their programs and citizens are better informed, both prerequisites for a vibrant democracy. Even governments that are not yet fully automated and are beginning to digitize data should focus on interoperability. For them, setting standards and getting the architecture right in advance of full-scale informatization will be a way of avoiding the problems described above and of preparing the ground for better governance using ICT.
De Angelis (2009)	Is a large opportunity to (i) transform organizations of public sector reaching innovative and user-centered PAs; (ii) provide high quality services with low cost promoting economic development; (iii) improve governance allowing an efficient access to information through flexible and transparent institutions
Soares & Amaral (2011)	Streamlined data management contributes to information infrastructure.

Source	Statements
	Supports problem solving, expands professional networks. Supports domain-level action, improves public accountability, faster's program, and service coordination.
Novakouski & Lewis (2012)	Improve the efficiency of service delivery, access to the services, coordination among existing services (resulting in further efficiency gains), and technology management and maintenance. Improve data gathering and parsing techniques, which will lead to more efficient decision-making that is based on information that is more accurate. Enhance transparency and accountability, resulting in better overall governance.

Obstacles and barriers detected are exposed in Table 47:

Table 47: Barriers and difficulties extracted from database documents

Source	Statements
Saekow & Boonmee (2009b)	The main obstacles and barriers to eGovernment interoperability are derived from technical, semantic and human issues. The technical one refers to the great variety of legacy systems. The systems already installed and running within involved agencies. The semantic obstacle is concerned on the difference of data/information standards used within organizational services. Another important obstacle to the spread of interoperable solutions in eGovernment is that of adoption of any new systems by officers. […] cultural differences between governmental departments, issues of trust, timing, collaboration between agencies, unsatisfactory workflows, legal matters and also the importance of political support and funding.
De Angelis (2009)	Private sector suffers only a little of politicization while eGovernment (for its nature) is more government-centric. Due to this, eGovernment appear to be a difficult domain in which the success or the failure of initiatives and projects is related to managerial considerations, political decision and to technological skills. Forcing government managers into private sector thinking usually causes more problems than benefits. It is not a good idea to transfer concepts [without adaptations] from the private sector to the public one. The sectors differ starting from their objectives.
Saekow & Boonmee (2009a)	Bureaucratic challenges due to the nature of bureaucracy and the lack of accountability of different agencies; ensuring compliance or

Source	Statements
	enforcement of the adopted standards; capacity development; and using the right metrics to measure the success of the eGIF. The bigger and more complex the bureaucracy, the more difficult it is to implement an eGIF.
Rosa (2010)	[…] There is a high number of failure incidents in the public sector information systems rollout, which accounts for the hesitant reporting. This can result in a failure to appreciate the impact that Interoperability has on the success of eGovernment service delivery. The organizational interoperability study field lags behind in the development of good practices and effective application tools that can support the government on their systems projects. Initiatives of services interoperability and organizational change have failed to support the user take-up of eGovernment. They tend not to offer effective integration of facilities, passing, in turn, onto the citizens, the image of a public service that lacks modernity, stability, security, clarity and value.
Santos & Reinhard (2012)	There are barriers in the political, organizational, economic and technical aspects. There are potential barriers coming from segments such as constitutional, jurisdictional, collaborative, organizational, informational, managerial, costs, technological and performance.
Novakouski & Lewis (2012)	Interoperability is a fundamental barrier to achieving the benefits of e-government. A better understanding of the context and relevant issues will help resolve the difficulties many governments have in achieving these benefits.
Soares & Amaral (2011)	Technical barriers: incompatible technologies and inconsistent data structure. Organizational barriers: organizational self-interest, dominant professional frameworks. Political obstacles: external influences on decision-making, the power of agency discretions, the primacy of programs.

5.2.3 Countries engaged with eGovernment interoperability

To evaluate the country (and region) distribution of the researchers regarding eGovernment and public administration interoperability, an analysis was made considering the 150 documents retrieved from the literature review. The objectives are, among others:

- Verify and map where (which regions) these authors are providing their researchers, building a world scenario of eGovernment interoperability.
- Verify (and justify) possible opportunities of researchers in the "weakest" regions.

The distribution considers where the authors are working (which university, laboratory, country), because it is a measure of importance/investment of that country, even though the research may be related to other country or organization (the author's birthplace are not considered). The information was collect in each of the 150 documents, considering the following aspects:

- If a document has more than one author, and two or more of them are related to the same country, this country was considered only once.
- If a document has more than one author and they are all related to different countries, each country is considered once.
- After the detection of countries, they were grouped into regions (e.g., Asia, Europe, North America)

The review detected 62 different countries in the 150 documents analyzed, with a distribution as shown in Table 48. Each of the 62 countries is associated at least once to a researcher but some of them are cited more times (considering the different documents) and, because of this, there are 192 references to countries within the 150 documents (e.g., Greece appears 12 times considering only one appearance per document). Table 49 shows the distribution considering the total amount of references to the countries.

Table 48: Distribution of region and countries

Region	# Detected countries	%
Europe	30	48.39%
Central America	10	16.13%
South America	6	9.68%
Asia	6	9.68%
Africa	5	8.06%
North America	2	3.23%
Oceania	2	3.23%
Asia/Oceania	1	1.61%

Table 49: Distribution according to the amount references

Region	%
Europe	53.13%
Asia	9.22%
South America	8.59%
North America	6.84%
Central America	5.05%
Africa	4.35%
Oceania	2.53%
Asia/Oceania	0.52%

In both cases, it is possible to verify the enormous difference between Europe and the other regions but, in Table 49, the difference is even “higher”, indicating that, besides the large number of countries detected in Europe (Table 48), there are also a higher number of references to these countries. Despite the North America region has two detected countries (USA and Canada), considering the quantity of citations in the database (Table 49), the region appears almost in the same percentage of South America (which has 6 detected countries according to Table 48).

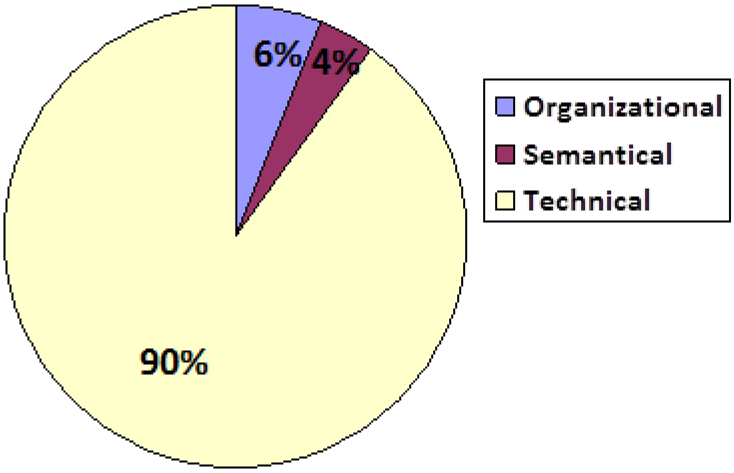
Another interesting view in public administration and eGovernment domain around the world is concerning the focuses. CSTRANSFORM (2010), a specialist global consulting business, focused on delivering Citizen Service Transformation in the public sector, conducted a survey analyzing 30 published eGIFs, related to 30 countries. The study identifies three common pitfalls regarding the frameworks, also detecting that eGIFs focus 90% in the technical domain (Figure 61). Table 50 summarize the results presented in CSTRANSFORM (2010), also considering statements regarding some principles for success in the development of policies and implementation of eGIFs.

Table 50: Results of 30 countries eGIFs.

Countries	Pitfalls	Principles for success
Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Denmark, Egypt, European Interoperability Framework, Estonia, Ethiopia, France, Germany, Greece, Hong Kong, Hungary, India, Malaysia, Malta, Mauritius, Netherlands, New Zealand, Norway, Philippines, Poland, Saudi Arabia, South Africa, Spain, UK, USA.	• Over-engineering • Lack of focus on government-wide business transformation • Inadequate implementation	• Ensure top-level ownership. • Focus on business change, not technology. • Ensure cross-government coordination. • Map the current environment. • Prioritize. • Do not re-invent wheels.

Countries	Pitfalls	Principles for success
		• Promote competition and innovation in the IT supply market. • Do not assume you have all the skills in-house. • Drive change. • Be prepared for the long haul.

Figure 61: eGIFs domain focus



Source: CSTRANSFORM (2010).

5.3 CONSIDERATIONS AND CHAPTER SYNTHESIS

This section exposes knowledge extracted from the literature review, presenting some related works and definitions regarding the research domain and application. Existent models and frameworks, type of diagnosis and maturity levels as also an overview of the subject around the world were also covered in the subsections of the chapter. The models, frameworks and other information presented helped, among other things, in the identification of aspects related to the relevance, complexity and originality of this research, as exposed in the introductory section 1.

Aspects regarding eGovernment interoperability were presented, considering the models and frameworks available in some countries. Two important surveys were analyzed, one focusing in the eGovernment maturity in the world and other related to the eGIFs of 30 countries. Both surveys, among other studies and documents collected in the literature review, helps to evidence that the research of public administration interoperability (and related themes) are important in Brazil, once the country can increase its position in the public administration “ranking”, adopting good practices to improve the performance using interoperability characteristics. Most of the models and frameworks presents regional characteristics (e.g., particularities from Europe or the USA), but this research thesis considers that the proposed models (PAICM and PAIDM, sections 6 and 7) have an applicability in Brazil, once it uses methods (e.g., survey with Brazilian researchers and practitioners, AHP/ANP) that support that.

This section also exposed the benefits and the difficulties of dealing with public administration/eGovernment interoperability and an overview (based on the 150 documents analyzed) of the countries engaged in the research area (by publications) and its related author’s distribution.

After all the analysis and data collected and exposed in this chapter, some issues are important to mention:

- There are not so many works in the non-technical layers as in the technical ones (approximately 90% of the frameworks deals with technical aspects).
- The Brazilian e-Ping (Ministério do Planejamento, 2012), and other government frameworks, deals mostly with protocols, data exchange, code standards and other technical issues.
- The non-technical dimensions of the public administration interoperability are important once the frameworks consider, above the technological layer, processes, business, legal and political perspectives. Treat all these issues in an integrated way is a gap in the literature regarding interoperability assessment.

6 CAPABILITY MODEL PROPOSITION (PAICM)

The objective of this section is to propose and describe a capability model called **Public Administration Interoperability Capability Model (PAICM)**, regarding its structure, levels and organization. The PAICM definition and use are related to the research framework, Figure 4, process A8 and A9. Generally, PAICM defines capability levels and measurable aspects (attributes), including, within those attributes, guidelines related to "best practices" regarding the application domain. A capability model is an abstract representation of the reality, and it is not a process, although it can suggest some practices and/or examples. Additionally, describes “what to do”, but not necessarily “how to do it”.

The definition of capability adopted in this research is based on Princeton University (2010), CMMI Product Team (2010) and ISO/IEC (2015), and can be described as:

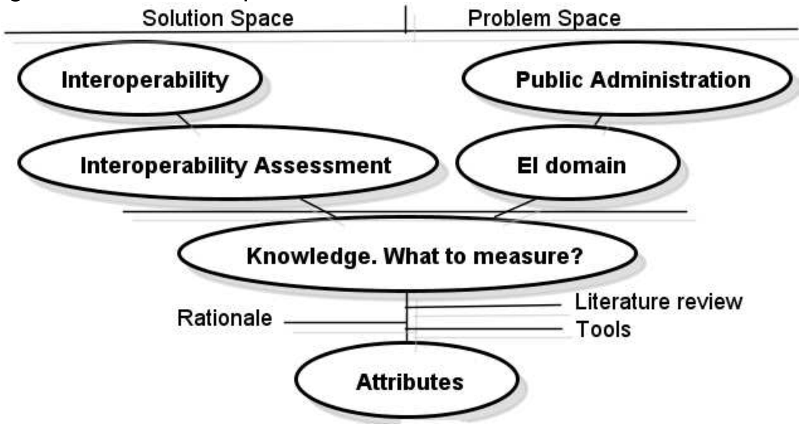
(i) The measure of the ability of an entity to achieve its objectives;

(ii) The ability to perform or achieve certain actions or outcomes through a set of controllable and measurable faculties (e.g., features, functions, processes, or services)

(iii) The degree of how good is the implementation or achievement of some faculty.

In complement, a capability level describes an interval of expected results within an entity (i.e., what is the capability degree of certain measurable faculties regarding an organizational entity?). In this research context, the measurable items are the attributes, as illustrated in Figure 62, which exposes a general structure of the components adopted as the basis for the attributes extraction process, taking into account that the solution space helps to provide information in order to solve issues related to the problem space.

Figure 62: Abstract representation for definition of measurement items



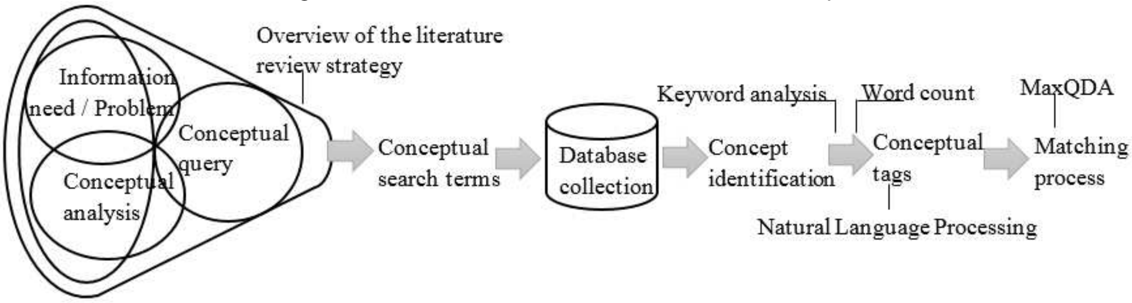
Source: The author (2015).

6.1 ATTRIBUTES

According to Nonaka (1994), knowledge is a justified belief that increases an entity's capacity for taking effective action. In Swan et al. (1999) the authors define knowledge as experience, facts, rules, assertions and concepts about their subject areas that are crucial to the business. There are two basic dimensions of knowledge: tacit and explicit (Nonaka, 1994), which can be combined with an ontological dimension. In complement, knowledge management is a process of identifying, capturing and leveraging collective knowledge to help the organization compete (Von Krogh, 1998). The creation of knowledge can be achieved through (i) socialization; (ii) externalization; (iii) combination and (iv) internalization (Nonaka, 1994). Knowledge can be represented using different formal forms (e.g., semantic nets, rules, ontologies, mind maps and conceptual maps). A general model, based on Keeling (2012), of the knowledge retrieval process is exposed in Figure 63, illustrating that information (literature) regarding the problems of the domain and the concepts involved were processed with conceptual queries and searches in order to create a database collection of 150 documents containing papers, technical reports, white papers and presentations.

In summary, the steps to extract the attributes are: (i) concept identification; (ii) keyword analysis and word count as support mechanisms; (iii) tagging words to identify groups of knowledge and (iv) matching process to search for relations among the words found and root concepts of the research.

Figure 63: Overview of attributes extraction steps



Source: The author (2015).

As the goal is to define the capability levels of each attribute, it is important to define and characterize what is an attribute and its relations. Table 51 exposes definitions adopted for this research, based on Princeton University (2010) and other sources.

Table 51: Attributes definitions

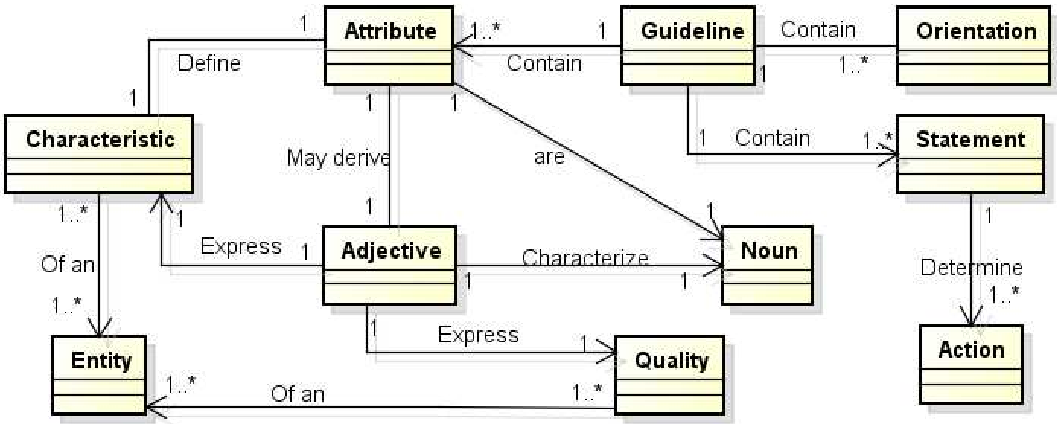
Definitions	References
A quality or characteristic that is given to a person, group, or some other thing. An abstraction belonging to or characteristic of an entity.	Vocabulary Dictionary (n.d.)
A quality or feature of a person or thing, especially one that is an important part of its nature.	Cambridge Dictionaries Online (n.d.).
A quality or feature regarded as a characteristic or inherent part of someone or something	Oxford Dictionaries (n.d.)
Regarding class diagrams, an attribute represents a data definition for an instance of a classifier. An attribute describes a range of values for that data definition and may describe the structure and value of an instance of a class.	Object Management Group (n.d.)

In the domain of interoperability (models and frameworks), attributes can be also mapped to best practices, requirements or desired interoperability characteristics within public administration entities.

Although the grammar structure is a specific body of knowledge (and not the focus of this research), it is relevant to mention that attributes are nouns and/or adjectives that modify a noun (e.g., collaboration (noun), collaborationist (adjective)), and guidelines are suggestions to show how to behave and usually derives action from its statements Vocabulary Dictionary (n.d.).

Guidelines can contain, or suggests, attributes and they (guidelines) will be used to assess the interoperability of the entities, with a similar approach exposed in Deschamps (2013). Figure 64 illustrates the relation among important concepts for the research, which is useful in the attributes extraction process (described in section 6.2.2), besides exposing the components that are connected, somehow, primarily with an attribute and secondly with a guideline.

Figure 64: Attributes concept model



Source: The author (2015).

The connections exposed in Figure 64 represents that an “Attribute” can be an adjective that expresses some sort of quality, or defines characteristics of an entity. Guidelines contain attributes, once they have orientation and/or statement that can determine action regarding the achievement or measurement of that attribute cited by the guideline. In fact, as the research and representation of the model evolved, and for measuring and diagnosing capability levels aspects, the attributes contain measurable items in the form of guidelines.

6.1.1 ATTRIBUTES EXTRACTION

Considering the database collection, a keyword counting and analysis was made as a first attempted to derive some attributes. The idea behind that is that if a document deals with important issues of the government interoperability aspects, there is a chance that qualification words (attributes) could be cited in the keywords section of the papers. This strategy is adopted in some research initiatives such as in Chen & Shorter (2008) and Lee & Segev (2012).

Keywords are not only “one word”, but may be also considered a group of words separated by commas or other symbols. The MaxQDA software (MaxQDA,

2014) was used to count and organize the keywords of the documents, and a summary of the results are presented in Table 52. The highest number of occurrences are the words “interoperability” (55 times) and “e-government” (53 times) and this was expected because of the search rules adopted during the literature review (these two words were one of the most important composing the search strings) (Cestari et al., 2014). As an illustration, 178 words occur only once.

Table 52: Quantitative overview of keywords (number of occurrences)

Number of occurrences	Number of words
1	178
2	21
3	6
4	4
6	1
7	2
8	1
10	1
55	1
53	1

Nevertheless, as the idea is not to have a “sample” approach, the quantity and distribution of the keywords are not as important as their meaning in terms of creating knowledge (Nonaka, 1994). However, after the analysis of all keywords retrieved, it was detected that most of them are related only to general aspects of the paper. That is, the keywords contain words with generic meanings to introduce main points to the reader. Because of this, it was not possible to identify words that could be used (directly or indirectly) to compose the preliminary set of attributes.

As the keyword analysis did not bring information about possible attributes, the research continued following a process based on a word counting and Natural Language processing analysis. According to Pierce (1980), an average English word has from 4.5 to 7 characters and, using the MaxQDA software (MaxQDA, 2014), the whole database collection was scanned searching for words with a minimum of six characters’ length. In a first round, 44,111 words were found and, after the second round of execution (with the elimination of authors names, symbols, irrelevant words and words that appeared less than 10 times) a total of 21,644 words were selected. The quantitative analysis by itself does not solve the problem of finding attributes, so it was necessary to investigate some of the semantic meaning of this large group of words. That is, as a next step, there was a need to discover the lexical linguistic category (e.g., verbs, adjectives, nouns, adverbs) of the words, searching specially for adjectives (considering the relations already exposed in Figure 64).

As an attribute may define (or derives to/from) adjectives and also because of the high number of existent words (21,644), a Natural Language Processing Software was used to detect the adjectives in the word's database. The software adopted was the Stanford POS Tagger (The Stanford Natural Language Processing Group, (n.d.)) maintained by the Stanford Natural Language Processing Group and built based on the research of a log-linear part-of-speech taggers described in Toutanova et al. (2003). A Part-Of-Speech Tagger (POS Tagger) is a software that reads a text in some language and assigns parts of speech to each word (and other token), such as noun, verb, and adjective. The tool was also used in Keeling (2012) within the natural language processing approach. The list of 21,644 words was processed with the Stanford POS Tagger, and the results were 3,739 words tagged as adjectives.

At this point, considering that the set of words identified as adjectives could contain a subset of attributes, there is a need to search for a connection among each of the identified words with the concept words that represents the research subject domain (interoperability within public administrations/government). In this research case, this process was done using a lexical matching functionality of MaxQDA tool. This software has an option of "within 'z' paragraphs" inside the lexical search mechanism. "Within 'z' paragraphs" means that when the "and" option is checked the search strings must be found within "z" number of paragraphs. If selected to search within one paragraph, only the paragraph in which the first string is found will be searched. For example, if the option is checked to search within two paragraphs, and the first string is found in paragraph 12, the search for the second string will occur in paragraphs 11, 12, and 13.

This research adopts the option of "within 2 paragraphs", considering the words interoperability and government as the "control" words. That is, for every word detected as an adjective (3,739), a search was executed considering the other two control words (e.g., "Adjective_Word_1 AND interoperability AND government Within 2 paragraphs"). After the whole process, and the elimination of words nonrelated to the context, the extracted "raw" attributes are presented in Table 53:

Table 53: Preliminary list of attributes

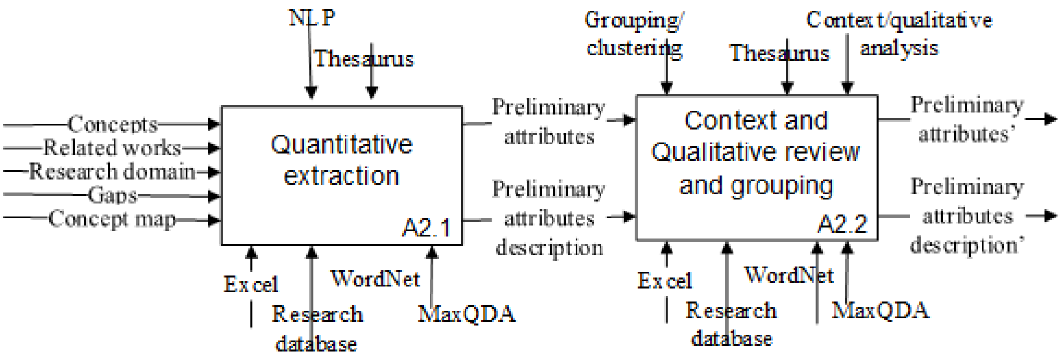
Preliminary list of attributes
Adaptability (Adaptable)
Collaboration (collaborative)
Commitment
Communication (communicational, semantic)
Conflicts (conflictive, conflictual)
Cooperation
Economical (economy, financial)
Efficiency
Historical
Integration (integrate)
Legality (legal)
Loyalty (loyal)
Politic (politic, politics)
Process
Responsibility (responsible)
Senior management support (supportable, supporting, supportive)
Sociological
Standardization (standard, standardizable)

As it is possible to notice, some of the words are not adjectives itself, but the idea is that they are based on adjectives aspects. For instance, the attribute "historical" means that the "historical aspects of that entity are important for the interoperability".

To review the preliminary list of extracted attributes according to the context and the literature review, the research did a qualitative analysis of all related issues and terms that could complement the initial attributes. The idea was to collect all the pertinent structure, influence factors, requirements, parameters, principles, areas, perspective or categories that could be considered an attributional aspect for the capability measurement, as a kind of detail for process A2, exposed in Figure 4 and Figure 7, as illustrated in Figure 65.

.

Figure 65: Detailing process A2



Source: The author (2015).

In order to execute the process A2.2, the frameworks, models and other material selected during the literature review and regarding interoperability, public administration, eGovernment and related subject were revisited with the purpose to collect their influence factors, requirements, parameters, principles, areas, perspective and categories in order to compare and grouping with the initial quantitative attributes extraction. This approach strength the attributes extraction, once that applies two techniques (one more quantitative oriented and other more qualitative oriented) to corroborate and complement the information. Table 54 exposes the information retrieved from the literature as a basis for the qualitative/context analysis.

Table 54: Possible measurable characteristics from literature review

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
European Commission (2004) - EIF 1.0.	• Accessibility. • Multilingualism. • Security. • Privacy. • Subsidiarity. • Use of Open Standards. • Assess the benefits of Open Source Software. • Use of Multilateral Solutions.
European Commission (2010) - EIF 2.0.	• Technological Neutrality and Adaptability. • Multilingualism. • Effectiveness and Efficiency. • Subsidiarity and Proportionality. • User Centricity. • Inclusion and Accessibility. • Security and Privacy. • Administrative Simplification. • Transparency. • Preservation of Information.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Openness. • Reusability.
AIF (Athena Interoperability Framework). Berre et al., (2007). Ruggaber (2006).	• Collaborative enterprise modelling • Cross-organizational business processes • Flexible execution and composition of services • Information interoperability • Ontologies and semantics.
Whitman & Panetto (2006).	• Linguistic. • Language. • Syntax. • Ontology. • Culture. • Behavior.
Soares & Amaral (2011).	• Experience of Institutional Collaboration. • Interagency. • Involvement and Commitment of Agencies • Semantic Incompatibility. • Transparency of Public Agencies. • Domain Ontology for Public Administration. • Conflict of Interests. • Partnerships with Private/Public Entities. • Financial Resources. • Net benefits perceived by Agencies. • Technological Incompatibility. • Political will. • Political and Budgetary Cycles. • Monitoring and Reconstruction of Cross-Agency Processes. • Responsibility for the Execution of Cross-Agency Processes. • Statutory Authority and Responsibility of Agencies. • Human Resources. • Peoples Attitude Toward Change. • Intra and Interagency. • Leadership. • Disturbance in the Autonomy (Power and Prestige) of Agencies. • Changes in the Status Quo of Agencies. • Standards for Interoperability. • Constitutional Principles. • National Structure for Interoperability Governance. • Control of Interoperability Initiatives. • Methodological Frameworks for Interoperability. • Information Security.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Enterprise Architecture of Public Administration. • Electronic Signature. • Privacy and Protection of Personal Data. • The condition of Member State of the European Union.
Tambouris et al. (2007).	• Flexibility/transferability/reconfigurability of the interoperability solutions. • Multilingualism and multiplatform devices. • Broad commitment, participation, and communication • Consensus on and visibility of the ownership, management, and responsibility for cross-organizational processes/services. • Common and global definitions/representations for e-government semantics. • Promotion/dissemination and maturity of common definitions. • Maintenance and evolution of common definitions. • Modeling perspective and formalism for documenting the common definitions. • Partnering with the private sector in interoperability projects • Adoption/switching costs inherent to interoperability solutions • Development of national e-government interoperability strategy and programs • Promotion of organizational federalism as a model for organizing the divergent administrative space into a cooperative environment • Public procurement policies and financing for interoperability projects. • Modeling and visualization of PA services/processes • Identification and documentation of common service functionality and features across PA agencies Support of multi-channel service delivery. • Reuse of knowledge and experience related to the execution of internal and cross-agency business processes/services from the private sector. • Clear interoperability leadership/ownership/sponsorship/management.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Administrative level of definitions development. • Willingness for cultural change. • Involvement of the users by setting up communities of practice in the process of new service design. • Adoption of any relevant available standard and proposal of new standards in areas where standardization is missing. • Open Standards. • Legal alignment to address the new requirements posed by the intensive cooperation of PA agencies. • Significance of international interoperability aspects • Protection of intellectual properties in multi-partners projects and developments • Diffusion of digital signature and electronic identity • Citizen privacy and data protection • Staff training related to interoperability projects. • A Clear link between cross-organizational processes/services and the business strategies of the broader agencies. • Suitable technologies to handle Structure of Information (XML, Data models). • Suitable technologies to handle Structure of Services (Web, Services, SOA, WSDL, UDDI, Workflows). • Suitable technologies to handle Semantics of Information (RDF, OWL). • Suitable technologies to handle Semantics of Service (OWL-S and WSMO, Semantic Web Services). • Accessibility. • Security and Privacy. • Subsidiarity. • Open Source Software. • Trust, reliability, and the supportive technical interoperability layer.
BIF (Business Interoperability Framework) within ATHENA Project. Ruggaber (2006). Berre et al., (2007).	• Governance. • Behavioral. • Operational. • Management of external relationships. • Employees and Culture. • Information Systems.
EIMM (Enterprise Interoperability Maturity Model).	• Enterprise modeling. • Business strategy. • Processes.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
ATHENA Consortium (2003). Berre et al., (2007).	• Organization. • Competences. • Products and Services. • Systems & Technology. • Legal environment. • Security & trust.
BIQMM (Business Quotient Measurement Model). Zutshi et al., (2012).	• The impact of collaboration breakdown. • Semantic conversion. • Linguistic barriers. • Communication. • Conflicting Terminologies. • Contact points. • Clarity in Strategic Goals. • Conflict resolution. • Conflicts. • Cooperation contracts. • Partner selection. • Partner assessment. • Efficiency. • Clarity in the business process. • Visibility. • Responsibility. • Shared responsibility. • Cross-organizational role mapping. • Motivation. • Honesty. • Background IPR (Intellectual Property Rights) protection. • Foreground IPR (Intellectual Property Rights). • Data exchange tools. • Speed. • Application interoperability. • Security.
IDEAS (Interoperability Developments for Enterprise Application and Software). Chen & Doumeingts (2003).	• Business. • Knowledge. • ICT Systems. • Semantics.
Rohatgi & Friedman (2010).	• Data. • Network. • Service. • Application. • Infrastructure. • Security. • Platform. • System. • Culture. • Programmatic.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Constructive. • Operational. • Policy. • Semantic (Conceptual). • Coalition. • Organizational.
da Cruz (2012).	• Supplier relationships. • Customer relationships. • Information sharing. • Logistic integration. • Operational performance. • Economic performance. • Environment performance. • Quality. • Customer service. • Price/Cost. • Time to market. • Production information. • Delivery.
The E-health interoperability framework. NEHTA (2007).	• Business processes. • Standards. • Security policies. • Privacy. • Foundations. • Structures. • Assemblies. • Certification. • Interoperability architecture.
Enterprise Interoperability-Framework and knowledge corpus-Advanced report. Chen et al. (2006).	• Communication.
MMEI (Maturity Model for Enterprise Interoperability). Guédria (2012).	• Business model modeled or documented. • Basic IT infrastructure in place. • Organization structure defined and in place. • Use of standards for alignment with other business models. • Standard and configurable IT infrastructures. • Human resources trained for interoperability. • Business models for multi-partnership and collaborative enterprise. • Open IT infrastructure. • Flexible organization structure. • Adaptive business model. • Adaptive IT infrastructure. • Agile organization for on-demand business.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Process models modeled or documented. • IT support for processes. Ad hoc exchange for process information. • Processes responsibilities/authorities defined and in place. • Use of standards for alignment with other process models. • Standard Process tools & platforms. • Procedures for processes interoperability. • Meta-modeling for multiple process model mappings. • Platform & tool for the collaborative execution of processes. • Cross-enterprise collaborative processes management. • Modeling for dynamic process re-engineering. • Dynamic and adaptive tools and engines for processes. • Real-time monitoring of processes, adaptive procedures. • Service models modeled or documented. • Applications/services connectable. • Services responsibilities/authorities defined and in place. • Use of standards for alignment with other service models. • Standard and configurable architecture & interface. • Procedures for services interoperability. • Meta-modeling for multiple service model mappings. • Automated services discovery and composition, shared applications. • Collaborative services and application management. • Adaptive service modeling. • Dynamically composable services, networked applications. • Dynamic management rules and methods of services and applications. • Data models modeled or documented. • Data storage devices connectable, simple electronic exchange possible. • Data responsibilities/authorities defined and in place. • Use of standards for alignment with other data models. • Automated access to data, based on standard protocols.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Rules and methods of data management. • Meta-modeling for multiple data model mappings • Remote access to databases possible for applications shared data. • Personalized data management for different partners. • Adaptive data models (both syntax and semantics). • Direct database exchanges capability and full data conversion tool. • Adaptive data management rules and methods.
GIMM (Government Interoperability Maturity Matrix). Sarantis et al. (2008).	• Government Process Alignment. • Compatibility with eGovernment legislation issues. • Interoperability at the local level. • Interoperability at National Level. • Interoperability at International Level. • The existence of common XMLbased data schemas. • The existence of XML-based common code lists. • Common Service Categorization. • The existence of Service Metadata. • The existence of Documents Metadata. • Interoperable front and back office systems. • The existence of Web-service interfaces. • The existence of Web-Service discovery mechanisms. • Interoperability with payment systems and services. • Single sign-on facilities for user authentication. • Connectivity with central government gateways. • Interoperability with external enterprise systems.
Laskaridis et al., (2007).	• Web services to exchange XML.
Usero et al., (2006).	• Markup languages. • Open software. • Format. • Electronic document processing. • Metadata for knowledge representation in electronic resources. • Web accessibility to improve access for all.
Solli-Saether (2011).	• Strategy. • Business process and lateral links. • Formal structure. • Informal structure.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Human resource management. • Meaning of data. • The role of infrastructure. • The role of information systems. • Data. • Data exchange. • Information security.
Pardo et al., (2012).	• Business architecture. • Governance. • Leaders and champions. • Stakeholder engagement. • Strategic planning. • Project management. • Resource management. • Information policy. • Data requirements. • Cross organization collaboration. • Collaboration readiness. • Organizational compatibility. • Secure environment. • Technology acceptance. • Technology knowledge. • Technology compatibility.
Interoperability Practical Implementation Support (IPIS). Saekow & Boonmee (2009b).	• Business process model. • Data standardize set. • XML scheme standard. • E-Services. • Technical standards.
ISIMM (Information Systems Interoperability Maturity Model). Staden & Mbale (2012).	• Data. • Software. • Communication. • Physical.
Interoperability Governance Model (IGM). Mbale & Staden (2012).	• Legal. • Policy. • Monitoring and evaluation. • Collaboration. • Standards. • Architecture. • Data. • Functionalities. • Infrastructure. • Planning and Organize.
e-PING. Ministério do Planejamento, Orçamento e Gestão (2012).	• Interconnection. • Security. • Access means. • Organization and Exchange of Information. • Integration Areas for Electronic Government.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
General Interoperability Architecture for e-Government based on Agents and Web Services. Marques et al., (2011).	• Mutable. • Adaptable. • Versatile. • Secure.
Malaysian Government Interoperability Framework (MyGIF). Malaysian Government (2003).	• Interconnection. • Data Integration. • Information Access. • Security. • Metadata.
eGIF4M. Mozambique Government (2010). Shvaiko et al., (2009).	• Human capacity. • Infrastructure. • Private sector Governance. • Policy and regulations. • Content and applications. • Governance. • Skills. • Sustainability. • Policies, business. • Methodology, standards, architecture. • Political endorsement. • Clear ownership and coordination. • Collaboration with PA agencies. • Incentives and monitoring. • Systemic support actions.
SAGA German Government (2008).	• Purpose, use area and rules. • System elements and interfaces. • Standards and technologies. • Hardware and infrastructure. • Data structure and semantics.
Interoperability Framework for e-Governance (IFEG). Indian Government (2013).	• Security. • Digital preservation. • Digital signature.
Australian Government Architecture (AGA). Australian Government (2011).	• Performance. • Business. • Service. • Data. • Technical.
Interoperability framework of Estonian Government. Estonian Government (2011).	• Technological Neutrality and Adaptability. • Multilingualism. • Effectiveness and Efficiency. • Subsidiarity and Proportionality. • User Centricity. • Inclusion and Accessibility. • Security and Privacy. • Administrative Simplification. • Transparency.

References	Attributes, influence factors, requirements, parameters, principles, areas, perspective, categories.
	• Preservation of Information. • Openness. • Reusability.
Federal Enterprise Architecture. US Government (2013).	• Strategy. • Business. • Data. • Applications. • Infrastructure. • Security.
e-Government Interoperability Framework. United Kingdom Government (2005)	• Alignment with the Internet. • Adoption of XML. • Adoption of the browser as the key interface. • Interconnectivity. • Data integration. • E-services access. • Content management metadata. • Market support. • Scalability. • Openness. • International standards.
New Zealand E-government Interoperability Framework. New Zealand Government (2008)	• Security. • Best practices. • Governance. • Management. • Access and presentation. • Business services. • Data integration. • Network.
Yesser Framework for Interoperability. Kingdom of Saudi Arabia Government (2005)	• Data types. • Schemas. • Metadata element. • Dictionaries. • Integration approach. • Standards. • Connectivity standards. • Security standards. • Information access. • Delivery standards.
HKSARG Interoperability Framework. Hong Kong Government (2012).	• Flexible. • Application integration. • Information access and interchange. • Security. • Interconnection.

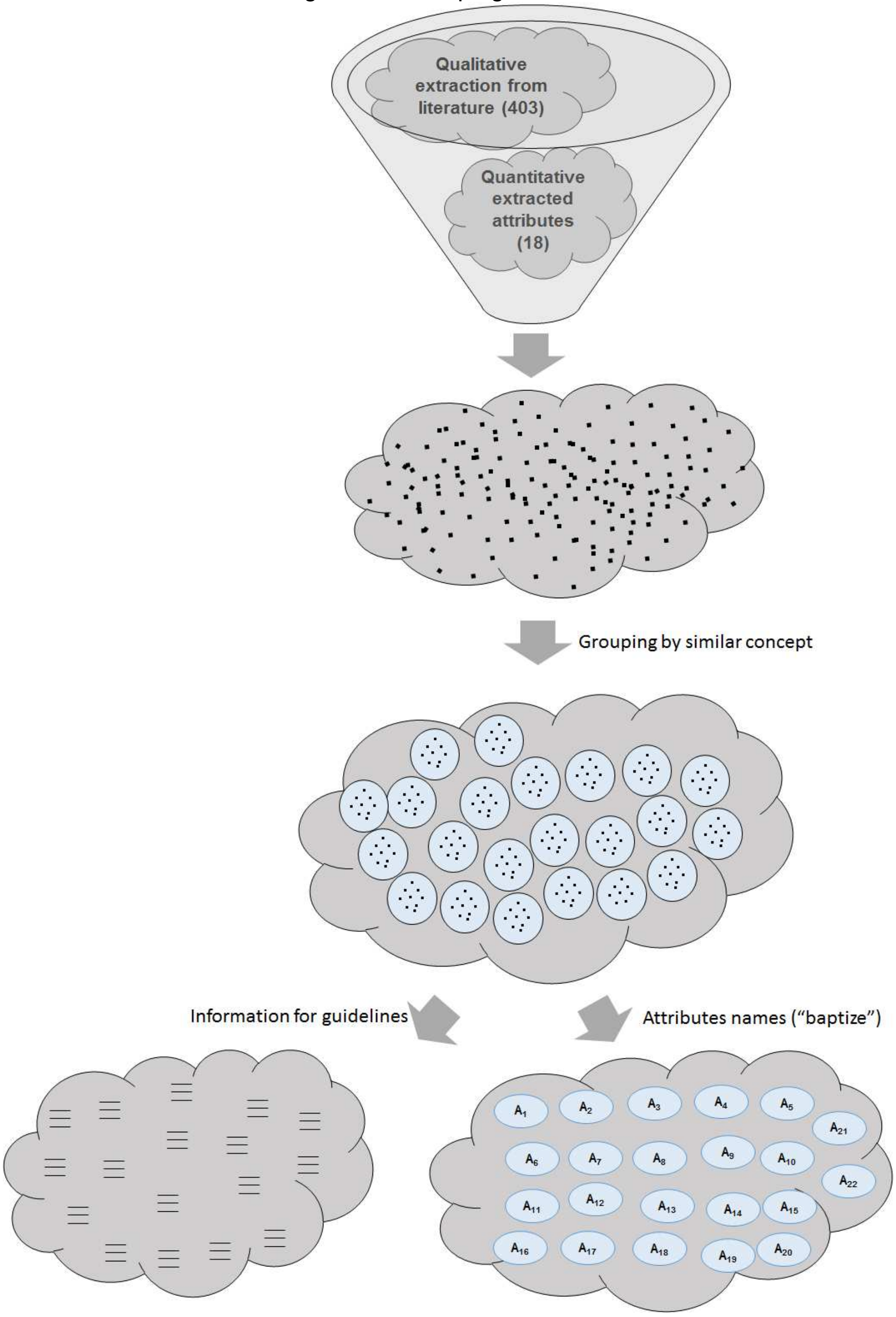
All information from Table 53 and Table 54 were structured and organized to group similar concepts and then form groups of attributes (either with a possibility of changing the initial attributes extraction, by adding new ones, changing the names, swapping others). Table 54 generated 403 items and, together with the 18 from Table 53, a context and groping analysis were made.

Firstly, similar concepts were grouped together generating 22 macro groups (named from Group A to Group V) then each group of attributes received a name. Some concepts and ideas not explicitly used to create the attributes were used to help the definition of the guidelines. These macro steps are illustrated in Figure 66 and after the whole comparison, context analysis and grouping concepts, the list of attributes generated is exposed in Table 55.

Table 55: Updated list of attributes

Preliminary list of attributes
Accessibility
Adaptable (Adaptability)
Collaboration (collaborative)
Commitment (Support)
Communication (communicational, semantic)
Conflicts (conflictive, conflictual)
Cooperation
Culture (behavior, sociological)
Economy (financial)
Efficiency
Governance (governability)
Human Resources
Infrastructure
Integration (integrate)
Legality (Legal Aspects)
Monitoring (Management)
Policy and regulations
Political (politic, politics)
Responsibility (responsible, roles)
Security
Standardization (standard, standardizable)
Tools (Technology)

Figure 66: Grouping attributes



Source: The author (2015).

6.1.2 EVALUATE PRELIMINARY LIST OF ATTRIBUTES

This subsection is related to the processes A3 and A4 of the research framework exposed in Figure 4. Despite the technical methods adopted to extract the attributes from literature (e.g., NLP) and then the application of a qualitative context analysis, another evaluation was executed considering a group of practitioners and researchers. In order to execute these activities, a confirmatory survey was applied with the support of an online questionnaire tool called Qualtrics (Qualtrics, 2015). According to Forza (2002), a confirmatory survey aims to test the adherence of the developed concepts in relation to the object of study and validate the boundaries. The survey was executed according to the description already exposed in section 3.6.

The survey went for a pilot testing (Forza, 2002), with reviews and discussions with practitioners, colleagues and researchers, to achieve an adequate format and content possible.

The main goal of the survey is the evaluation of the 22 extracted attributes using a Likert scale (Likert, 1932) from “Strongly disagree” (1), “Disagree” (2), “Neither agree nor disagree” (3), “Agree” (4), or “Strongly agree” (5) to the following question: “Do you think that the presented attributes (influence factors) can be considered relevant/pertinent regarding public administration interoperability?”. The other questions are associated with the gathering of general information regarding the respondents (e.g., years of experience, the area of experience and other suggestions).

The sample selection was non-probabilistic, considering at least three types: by convenience, most similar and typical cases (Freitas et al., 2000). Therefore, the respondents were chosen according to the following criteria:

a. All the authors with 2 or more contributions detected in the literature review and exposed here in Table 9. In this step, 42 persons were selected (according to Table 9, it should be selected 45 persons, but it was not possible to find 3 e-mail addresses).
b. Practitioners from public administration related organizations, including institutes, Curitiba municipality entities, state government entities, Non-Governmental Organizations (NGO) and others. The entities were analyzed by pertinence and personal contact of the author. In this step, 57 persons were selected.
c. Other people that did not appear in the previous criteria but with the possibility to contribute to the research (e.g., researchers not listed before and others (practitioners or researchers) with knowledge of the subject). In this step, 10 persons were selected.

An e-mail with a presentation letter (see Appendix 2A) and major explanations of the research was sent to all the previous selected possible respondents (109 persons), and it was asked that those not interested in taking part of the survey should answer the e-mail stating so within one week. This e-mail was sent two more times (for those that not answered) with an interval of 3 days. At the end of the planned schedule, the results of this first interaction are the following:

a. Twelve e-mails returned with error, stating address problems or some other type of server issue;
b. Two persons explicitly answered the presentation e-mail stating an impossibility to participate in the survey.

Therefore, at the end of this process a total of 95 respondents were selected, distributed as illustrated in Table 56. Using Qualtrics (Qualtrics, 2015), e-mails (see Appendix 2B) were sent for each one of the 95 persons, with instructions regarding the survey. It was not necessary to ask the name of the respondents, once it is possible to link the name with the e-mail directly in the Qualtrics tool. The questions are exposed in Appendix 2C of this document.

Table 56: Distribution of potential respondents

% of possible respondents	Type of institution, involvement, category
57.89%	Practitioners related to government entities (e.g., municipalities employees, state energy company, courts of law).
8.42%	Institutes (e.g., companies, universities).
33.69%	Academy (e.g., researchers, authors, professors).

The survey Qualtrics portal stayed open for about one month, and each week a reminder e-mail was sent to the participants that did not have answered until that moment.

6.1.2.1 SURVEY CONSISTENCY

To evaluate the consistency of the answers, specifically of the questions related to the attributes evaluation, the Cronbach's alpha technique was applied. This technique is one of the most used approaches (Cortina, 1993) and quantifies the reliability of the questionnaire within an interval from 0 to 1 (being 1 the higher reliability). The formula for Cronbach's alpha is illustrated in Equation 18, where

k is the number of items in the questionnaire, S_i^2 is the variance of each item, and S_{sum}^2 is the sum of all variances.

Equation 18: Cronbach's alpha

$$\alpha = \left(\frac{k}{k-1}\right) \cdot \left(1 - \frac{\sum_{i=1}^{k} S_i^2}{S_{sum}^2}\right)$$

Source: Almeida et al., (2010).

The calculation was made specifically over the attributes evaluation question, considering that there are 22 sub-questions, as exemplified in Table 57.

Table 57: “Transforming” one question into 22.

Respondents	Question 1	Question 2	...	Question 22
Respondent 1	1	3	...	4
Respondent 2	2	4	...	3
Respondent N	2	5	...	5

1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, 5-Strongly agree

The reliability of the survey was considered satisfactory, once the calculated alpha value was 0.87 and, according to Forza (2002) and Almeida et al., (2010), the minimum acceptable value is 0.7.

6.1.2.2 SURVEY RESULTS

The returned rate was 20%, and the profile distribution of the respondents (regarding interoperability involvement) are exposed in Table 58, showing an almost equally distribution of the respondents’ areas of engagement regarding involvement in interoperability aspects. This is an interesting aspect because it was possible to receive answers of all covered areas.

Table 58: Type of experience regarding interoperability

Profile	%
Professional	31.58%
Academic	36.84%
Both (professional and academic)	31.58%

Besides Table 58 and before present a qualitative analysis, some quantitative information is presented and discussed based on cross-table analysis, with a similar approach as presented in Mattioda et al. (2015) and Zanoni et al. (2013).

Considering the type of experience (or involvement, knowledge, participation) with public administration (government issues, eGovernment entities, etc.), the distribution are the same as for interoperability (Table 59), but not necessarily with the same respondents (i.e., there are respondents with professional experience in public administration and with academic experience in interoperability).

Table 59: Average years of experience (interoperability and public administration)

Profile	%	Average years of experience regarding interoperability aspects	Average years of experience regarding public administration aspects
Professional	31.58%	10.5 years.	13.16 years.
Academic	36.84%	14 years.	13.42 years.
Both (professional and academic)	31.58%	17 years.	15.33 years.

Table 60 and Table 61 synthesizes the answers distribution and provides information relating the evaluated attributes, remembering that the profile distribution is the same regarding interoperability and public administration (i.e., groups have answers with 6 professionals, 7 of academy and 6 of both).

Table 60: Distributions of the answers
Prof. (1) – Professional; Acad. (2) – Academic. There were no respondents in the "Other" category

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
Accessibility	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	2	1	3	15.79%
	Neither Agree nor Disagree	2	3	2	7	36.84%
	Agree	1	2	1	4	21.05%
	Strongly Agree	3	0	2	5	26.32%
	Total	6	7	6	19	
Adaptable (Adaptability)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	2	3	0	5	26.32%
	Agree	2	4	4	10	52.63%
	Strongly Agree	2	0	2	4	21.05%
	Total	6	7	6	19	
Collaboration (collaborative)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
	Neither Agree nor Disagree	0	1	0	1	5.26%
	Agree	5	4	1	10	52.63%
	Strongly Agree	1	2	5	8	42.11%
	Total	6	7	6	19	
Commitment (Support)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	1	0	2	10.53%
	Agree	1	4	3	8	42.11%
	Strongly Agree	4	2	3	9	47.37%
	Total	6	7	6	19	
Communication (communicational, semantics)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	0	3	0	3	15.79%
	Agree	2	4	0	6	31.58%
	Strongly Agree	4	0	6	10	52.63%
	Total	6	7	6	19	
Conflicts (conflictive, conflictual)	Strongly disagree	0	0	0	0	0.00%
	Disagree	1	1	1	3	15.79%
	Neither Agree nor Disagree	1	3	0	4	21.05%
	Agree	3	0	2	5	26.32%
	Strongly Agree	1	3	3	7	36.84%
	Total	6	7	6	19	
Cooperation	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	1	0	2	10.53%
	Agree	2	4	2	8	42.11%
	Strongly Agree	3	2	4	9	47.37%
	Total	6	7	6	19	
	Strongly disagree	0	0	0	0	0.00%

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
Culture (behavior, sociological)	Disagree	0	1	0	1	5.26%
	Neither Agree nor Disagree	2	1	1	4	21.05%
	Agree	2	4	2	8	42.11%
	Strongly Agree	2	1	3	6	31.58%
	Total	6	7	6	19	
Economy (financial)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	1	1	5.26%
	Neither Agree nor Disagree	1	1	0	2	10.53%
	Agree	4	6	4	14	73.68%
	Strongly Agree	1	0	1	2	10.53%
	Total	6	7	6	19	
Efficiency	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	1	0	1	5.26%
	Neither Agree nor Disagree	2	2	1	5	26.32%
	Agree	1	3	1	5	26.32%
	Strongly Agree	3	1	4	8	42.11%
	Total	6	7	6	19	
Governance (governability)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	0	1	0	1	5.26%
	Agree	1	2	1	4	21.05%
	Strongly Agree	5	4	5	14	73.68%
	Total	6	7	6	19	
Human Resources	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	2	1	4	21.05%
	Agree	3	4	1	8	42.11%
	Strongly Agree	2	1	4	7	36.84%
	Total	6	7	6	19	

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
Infrastructure	Strongly disagree	0	0	0	0	0.00%
	Disagree	1	0	1	2	10.53%
	Neither Agree nor Disagree	0	4	0	4	21.05%
	Agree	4	1	3	8	42.11%
	Strongly Agree	1	2	2	5	26.32%
	Total	6	7	6	19	
Integration (integrate)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	0	1	0	1	5.26%
	Agree	1	3	2	6	31.58%
	Strongly Agree	5	3	4	12	63.16%
	Total	6	7	6	19	
Legality (Legal Aspects)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	1	1	5.26%
	Neither Agree nor Disagree	0	1	0	1	5.26%
	Agree	0	1	3	4	21.05%
	Strongly Agree	6	5	2	13	68.42%
	Total	6	7	6	19	
Monitoring (Management)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	4	0	5	26.32%
	Agree	4	3	3	10	52.63%
	Strongly Agree	1	0	3	4	21.05%
	Total	6	7	6	19	
Policy and regulations	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	0	1	0	1	5.26%
	Agree	1	1	3	5	26.32%
	Strongly Agree	5	5	3	13	68.42%

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
	Total	6	7	6	19	
Political (politic, politics)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	0	1	1	2	10.53%
	Agree	1	4	1	6	31.58%
	Strongly Agree	5	2	4	11	57.89%
	Total	6	7	6	19	
Responsibility (responsible, roles)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	2	0	3	15.79%
	Agree	1	3	2	6	31.58%
	Strongly Agree	4	2	4	10	52.63%
	Total	6	7	6	19	
Security	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	1	1	5.26%
	Neither Agree nor Disagree	0	2	1	3	15.79%
	Agree	2	4	2	8	42.11%
	Strongly Agree	4	1	2	7	36.84%
	Total	6	7	6	19	
Standardization (standard, standardizable)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	1	1	0	2	10.53%
	Agree	5	5	4	14	73.68%
	Strongly Agree	0	1	2	3	15.79%
	Total	6	7	6	19	
Tools (Technology)	Strongly disagree	0	0	0	0	0.00%
	Disagree	0	0	0	0	0.00%
	Neither Agree nor Disagree	2	2	1	5	26.32%
	Agree	2	5	3	10	52.63%

Attributes	Options	Answers (quantity)			Total	Total (%)
		Prof. (1)	Acad. (2)	Both (1 & 2)		
	Strongly Agree	2	0	2	4	21.05%
	Total	6	7	6	19	

Table 61: Mean and median for each attribute

Attributes	Mean	Median	Mode
Accessibility	3.58	3	3
Adaptable (adaptability)	3.95	4	4
Collaboration (collaborative)	4.37	4	4
Commitment (support)	4.37	4	5
Communication (communicational, semantics)	4.37	5	5
Conflicts (conflictive, conflictual)	3.84	4	5
Cooperation	4.37	4	5
Culture (behavior, sociological)	4.00	4	4
Economy (financial)	3.89	4	4
Efficiency	4.05	4	5
Governance (governability)	4.68	5	5
Human Resources (human aspects)	4.16	4	4
Infrastructure	3.84	4	4
Integration (integrate)	4.58	5	5
Legality (legal aspects)	4.53	5	5
Monitoring (management)	3.95	4	4
Policy and regulations	4.63	5	5
Political (politic, politics)	4.47	5	5
Responsibility (responsible, roles)	4.37	5	5
Security	4.11	4	4
Standardization (standard, standardizable)	4.05	4	4
Tools (technology)	3.95	4	4

The mean and median were calculated based on the "values" of the options (1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, 5-Strongly agree).

The following considerations can be extracted from Table 60 and Table 61:

a. All attributes have at least 84.21% of answers positioned in a higher than/equal "Neither Agree nor disagree" status.
b. The higher percentage of some kind of "disagreement" is 15.79% (only in two attributes: Accessibility and Conflicts). Only six other attributes have some percentage of certain disagreement (one with 10.53% and the other five with 5.26%).
c. Almost all attributes have at least 73% for higher than/equal "Agree" status. There are only four attributes with a lower percentage.

d. Considering all the averages, they are all higher than 3.5, showing that the sensibility is always “higher” than “Neither Agree nor Disagree” status.
e. There is only one attribute (Accessibility) with a median value of 3. Other 14 has a median value of 4, and the rest (7 attributes) have the median value of 5.
f. There is only one attribute (Accessibility) with a mode value of 3. Other 10 has a mode value of 4, and the rest (11 attributes) have the mode value of 5.

Besides the Cronbach’s test, it was also applied a hypothesis test based on the values of the p-value regarding each answer individually and all the answers as a group. It was adopted the one-sample Wilcoxon test (Portal Action, 2015), which is a non-parametric statistical hypothesis test. Considering the answer’s options (from 1 to 5), the null hypothesis (H0) were defined as being 3 (i.e., the respondent “neither agrees nor disagrees” with the proposal), the alternative hypothesis is a “higher than” 3 and the reliability degree is 0.95. All the p-values for the alternatives (separately) were lower than 0.05, which is the maximum reference to discard the null hypothesis. The higher p-value found was 0.0160 (for the “Accessibility” attribute). Taking all the answers as one group and increasing H0 to 4, the p-value is still lower than 0.05. In all scenarios, (considering the variables above exposed), it is possible to reject the null hypothesis.

Considering all the exposed results and presented analysis and the considerations related to the open questions with comments and suggestions (some of them will be incorporated in the guidelines of the attributes), the decision is to keep the attributes as proposed in Table 55 as the final list. These results conclude the Processes A3 and A4, represented in Figure 4, and now that all the attributes were evaluated, it is possible to better descript them, verify the relationship degree among them (for future use during the diagnosis process) and categorize them into the interoperability structure of concerns and barriers.

6.1.3 ATTRIBUTES DESCRIPTION

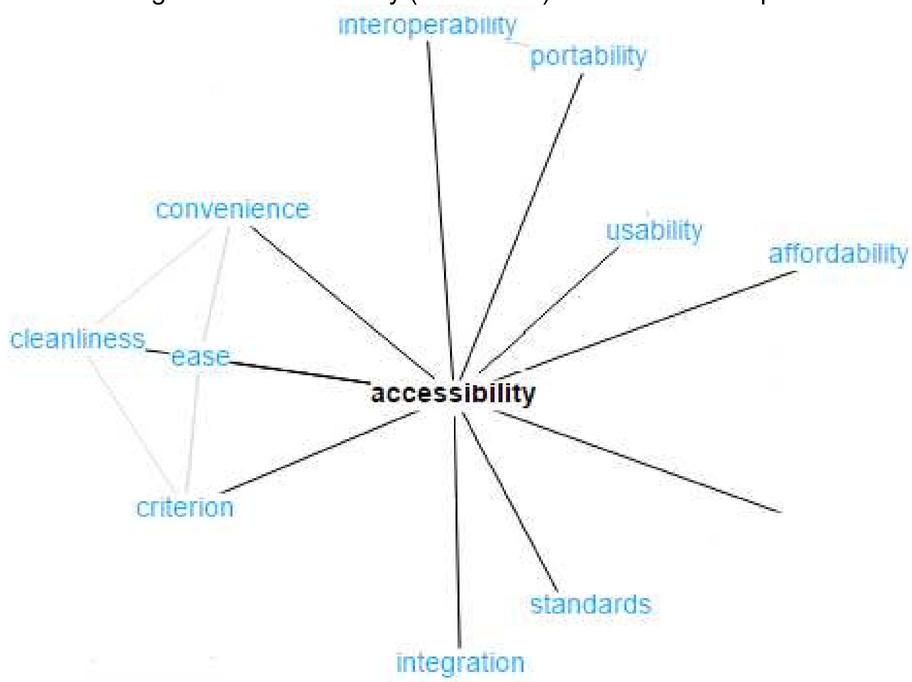
Now that the attributes were evaluated, it is necessary to better descript them to provide their interpretation and comprehension during the diagnosis process. The attributes detailing is based on three aspects: (i) thesauri and lexical aspects (Princeton University, 2010), (Oxford Dictionaries, n.d.), and (Cambridge Dictionaries Online, n.d.), (ii) lexico-semantic engine (Panchenko et al., 2013b) and (iii) context/qualitative analysis within interoperability aspects. The results of the analysis are exposed in the following subsections.

6.1.3.1 Accessibility (accessible)

Brief description and context:

- Able to be used, obtained, reached or approached.
- Easy to communicate or deal with (accessible people or system).
- Capable of being used or seen (available).
- Capable of being understood or appreciated.

Figure 67: Accessibility (accessible) connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.2 Adaptable (adaptability)

Brief description and context:

- Able to adjust to new conditions.

- Able to change or be changed to fit or work better in some situation or for some purpose.

Figure 68: Adaptable (adaptability) connected concepts

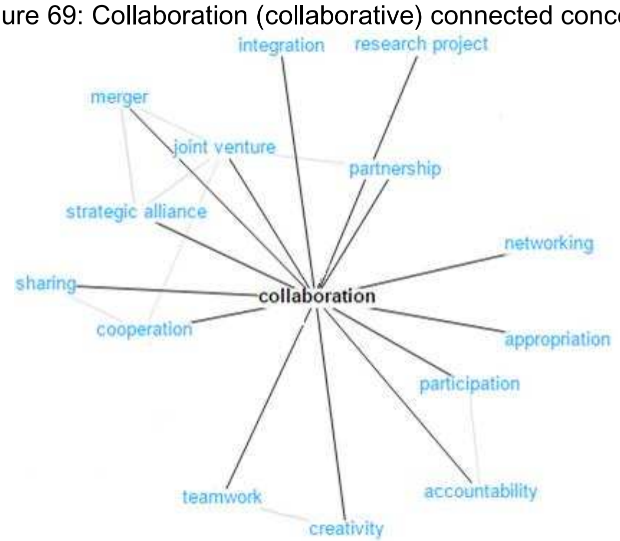
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.3 Collaboration (collaborative)

Brief description and context:

- Produced or conducted by two or more parties working together.
- To work jointly with others or together.
- To cooperate with an agency or instrumentality with which one is not immediately connected.

Figure 69: Collaboration (collaborative) connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

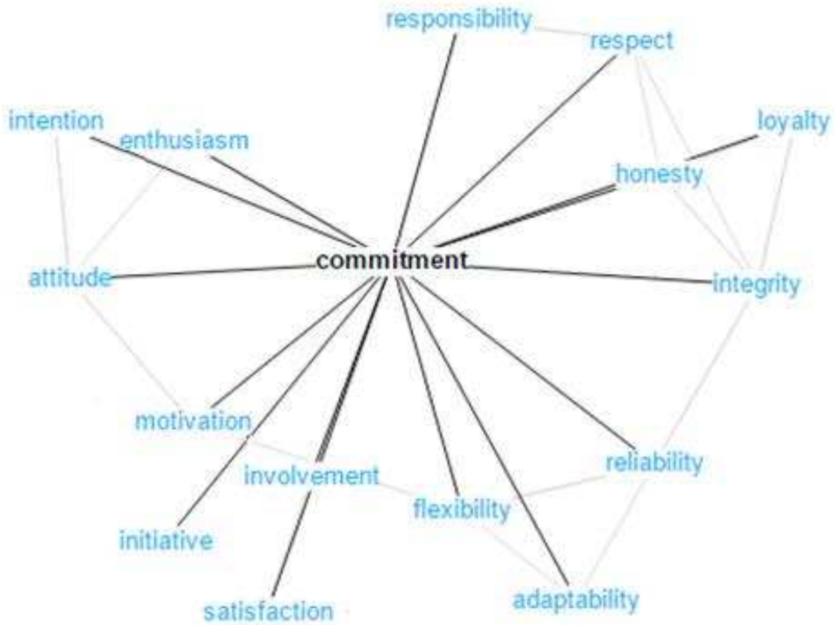
6.1.3.4 Commitment (support)

Brief description and context:

- The state or quality of being dedicated to a cause, activity, etc.

- The attitude of someone who works very hard to do or support something.

Figure 70: Commitment (support) connected concepts



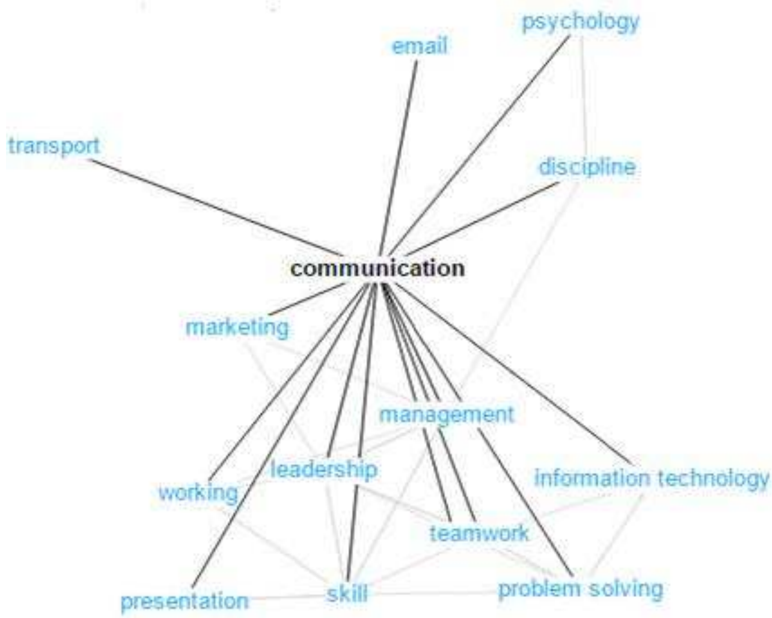
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.5 Communication (communicational, semantic)

Brief description and context:

- The imparting or exchanging of information.
- The successful conveying or sharing of ideas and feelings.
- Tries to minimize different semantics and syntax problems.

Figure 71: Communication (communicational, semantic) connected concepts



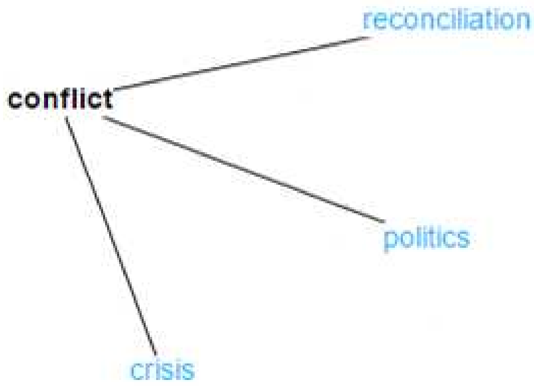
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.6 Conflicts (conflictive, conflictual)

Brief description and context:

- An incompatibility between two or more opinions, principles, or interests.
- Strong disagreement between people, groups, etc.
- Competitive or opposing action. Antagonistic state or action (as of divergent ideas, interests, or persons).

Figure 72: Conflicts (conflictive, conflictual) connected concepts



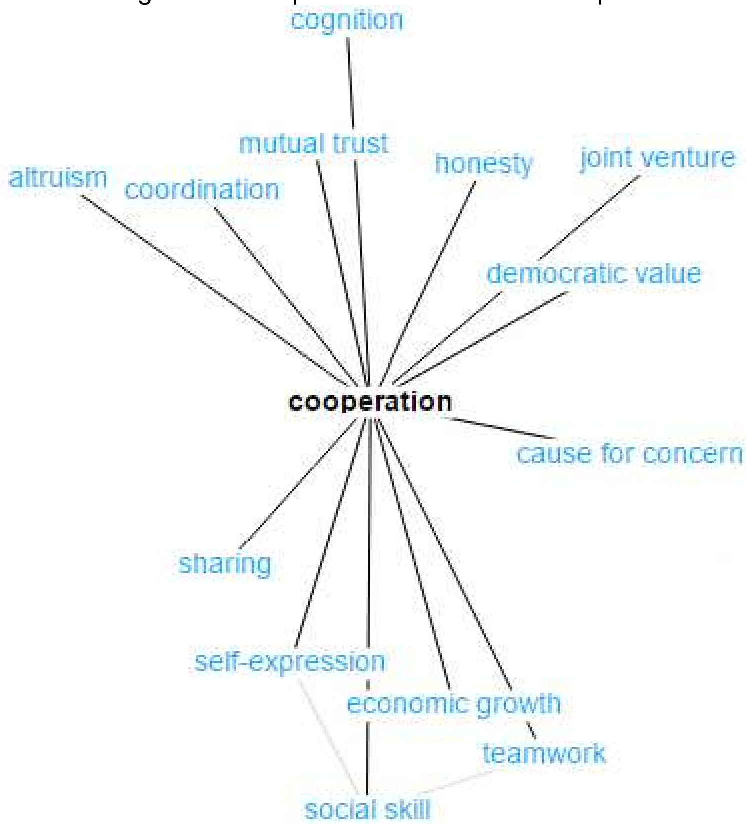
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.7 Cooperation

Brief description and context:

- The process of working together to the same end.
- The actions of someone who is being helpful by doing what is wanted or asked for.
- Association of persons for a common benefit.

Figure 73: Cooperation connected concepts



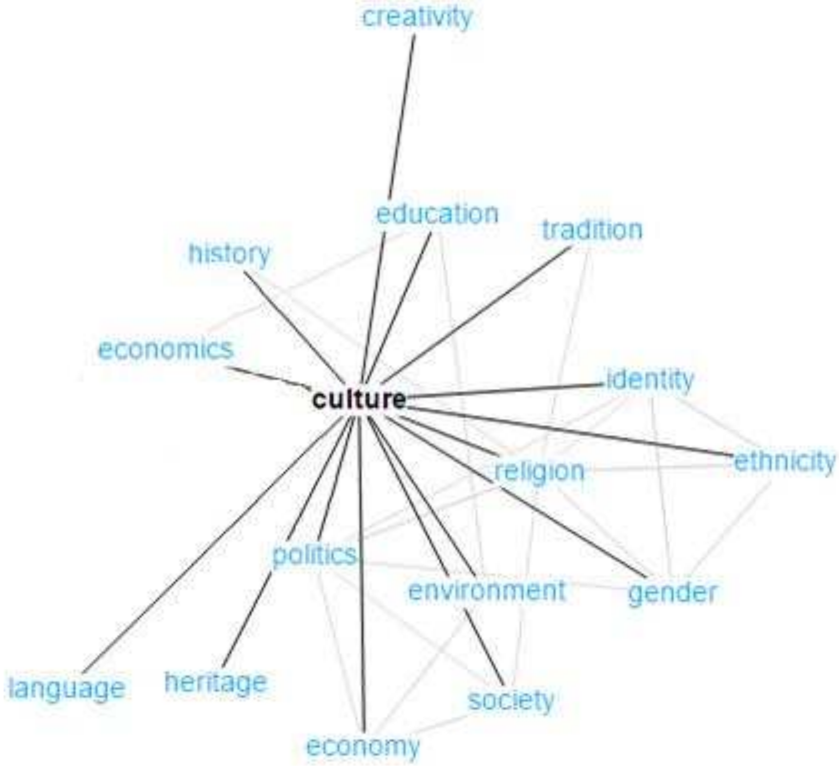
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.8 Culture (behavior, sociological)

Brief description and context:

- The set of shared attitudes, values, goals, and practices that characterize an institution or organization (corporate culture).
- A way of thinking, behaving, or working that exists in a place or organization (such as a business).
- The characteristic features of everyday existence (as diversions or a way of life) shared by people in a place or time.
- The set of values, conventions, or social practices associated with a particular field, activity, or societal characteristic.

Figure 74: Culture (behavior, sociological) connected concepts



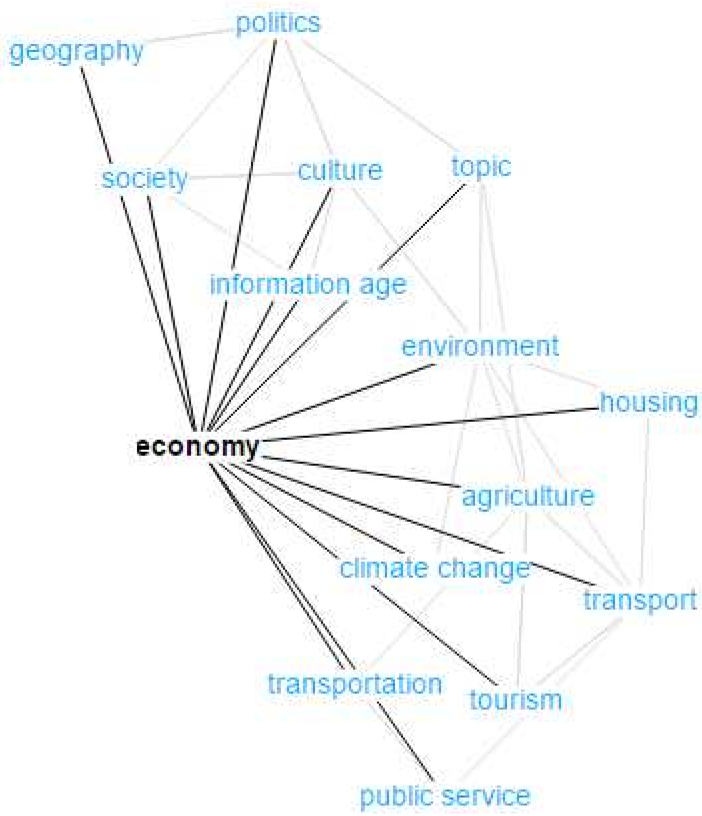
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.9 Economy (economical)

Brief description and context:

- The wealth and resources of a country or region, especially regarding the production and consumption of goods and services.
- The process or system by which goods and services are produced, sold, and bought in a country or region.
- A particular system or stage of an economy.
- The structure or conditions of economic life in a country, area, company or period.

Figure 75: Economy (economical) connected concepts



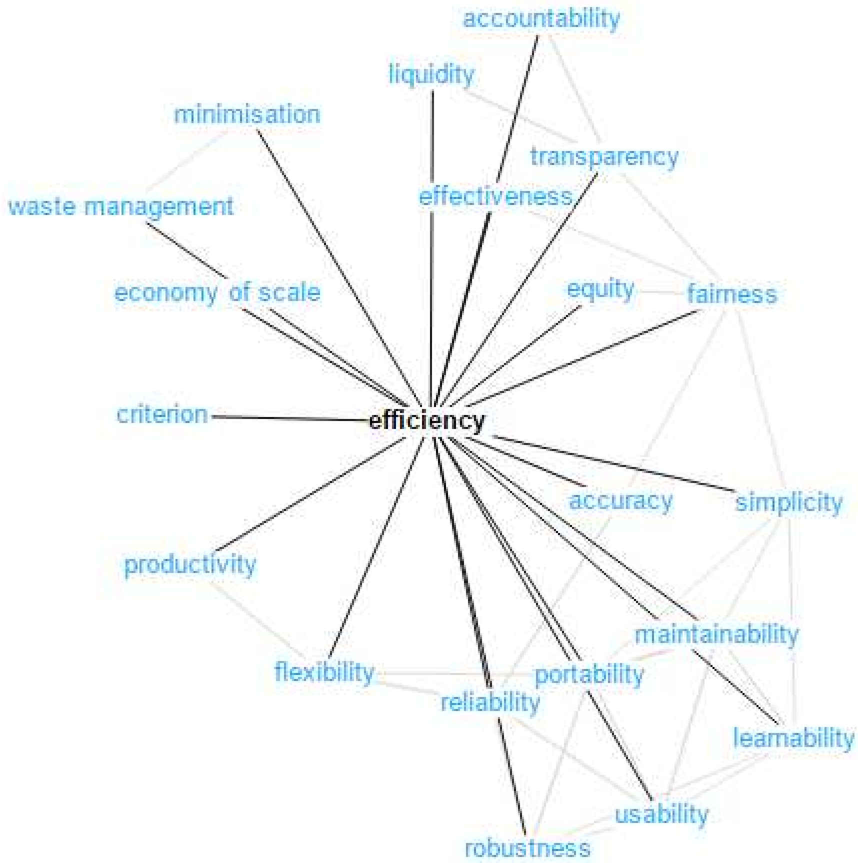
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.10 Efficiency

Brief description and context:

- The ability to do something or produce something without wasting materials, time, or energy.
- Seek to optimize all the means used in pursuit of achieving excellence.
- Relationship between the results obtained and the resources used.

Figure 76: Efficiency connected concepts



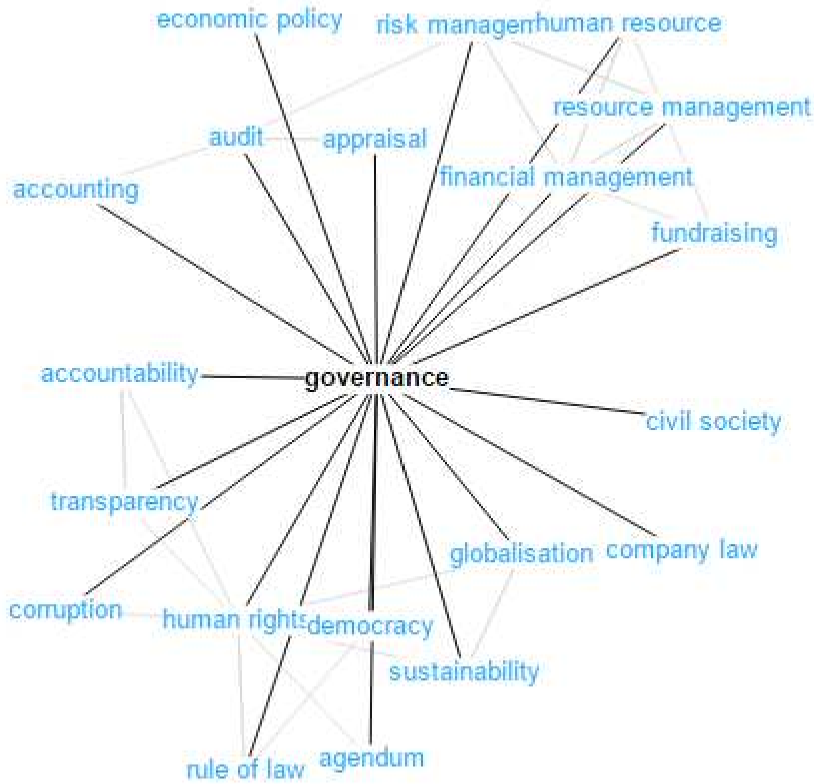
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.11 Governance (governability)

Brief description and context:

- In this context, the way a company (or government unit) is controlled by the people who run it.
- Administration, authority, rule, government, jurisdiction, regimen.
- The organization, machinery, or agency through which an entity exercises authority and performs functions and which is usually classified according to the distribution of power within it.
- The way the rules, norms and actions are produced, sustained, and regulated. The degree of formality depends on the internal rules of a given organization.

Figure 77: Governance (governability) connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.12 Human resources (human aspects)

Brief description and context:

- Related do personnel aspects (training, maturity, skills, work force).
- Concerned with the relations among the employees (and employer.
- Aligning with business strategy, re-engineering organization processes, listening and responding to employees, and managing transformation and change.

Figure 78: Human Resources (human aspects) connected concepts

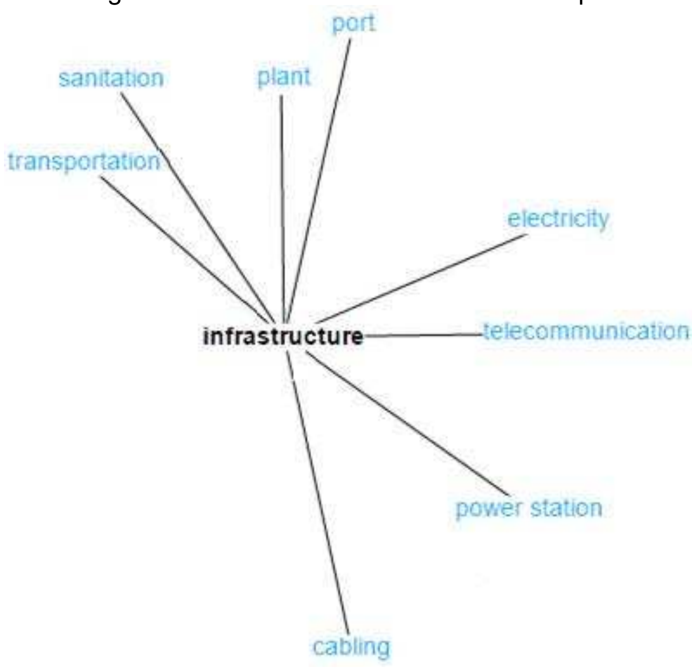
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.13 Infrastructure

Brief description and context:

- The resources required for an activity.
- Basic physical and organizational structure (or services) needed for the operation.
- Facilitates the production of goods and services.

Figure 79: Infrastructure connected concepts



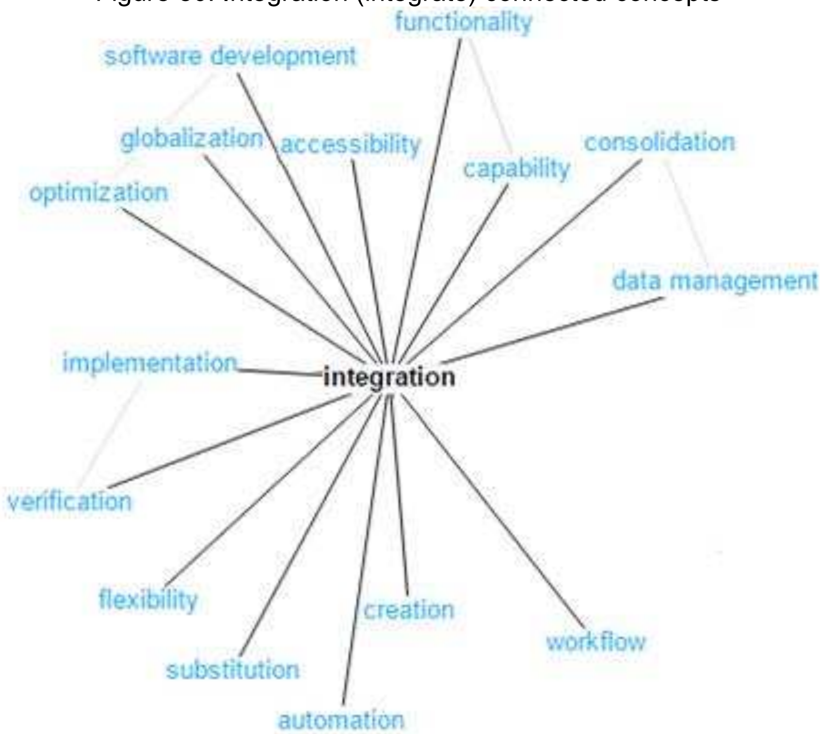
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.14 Integration (integrate)

Brief description and context:

- Coordination of mental processes with the environment.
- The combining and coordinating of separate parts or elements into a unified whole.
- The process by which the different parts of an organism are made a functional and structural whole.

Figure 80: Integration (integrate) connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.15 Legality (legal aspects)

Brief description and context:

- Adherence to the legislation.
- Attachment to or observance of the law.

Figure 81: Legality (legal aspects) connected concepts

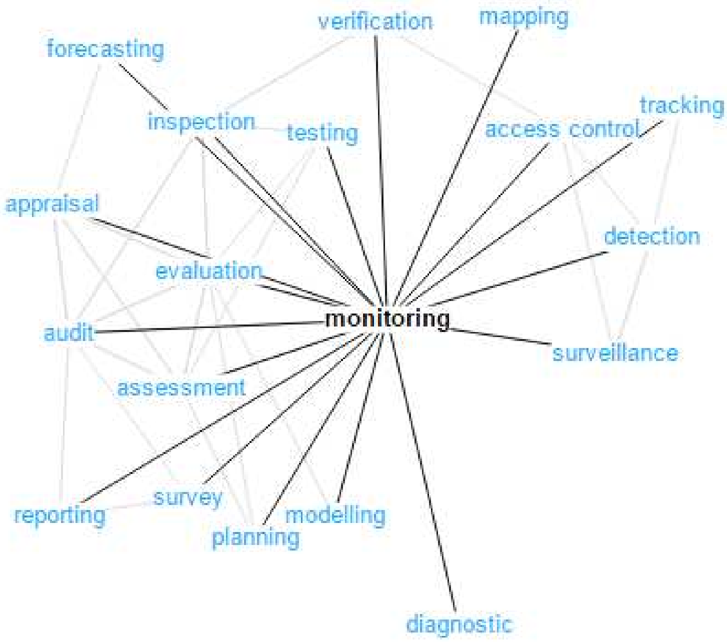
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.16 Monitoring (management)

Brief description and context:

- Watch, observe, keep track of, listen to, or check (something) for a special purpose over a period.
- Observe a situation for any changes that may occur over time.
- Observes a process or activity to check that it is carried out fairly or correctly.

Figure 82: Monitoring (management) connected concepts



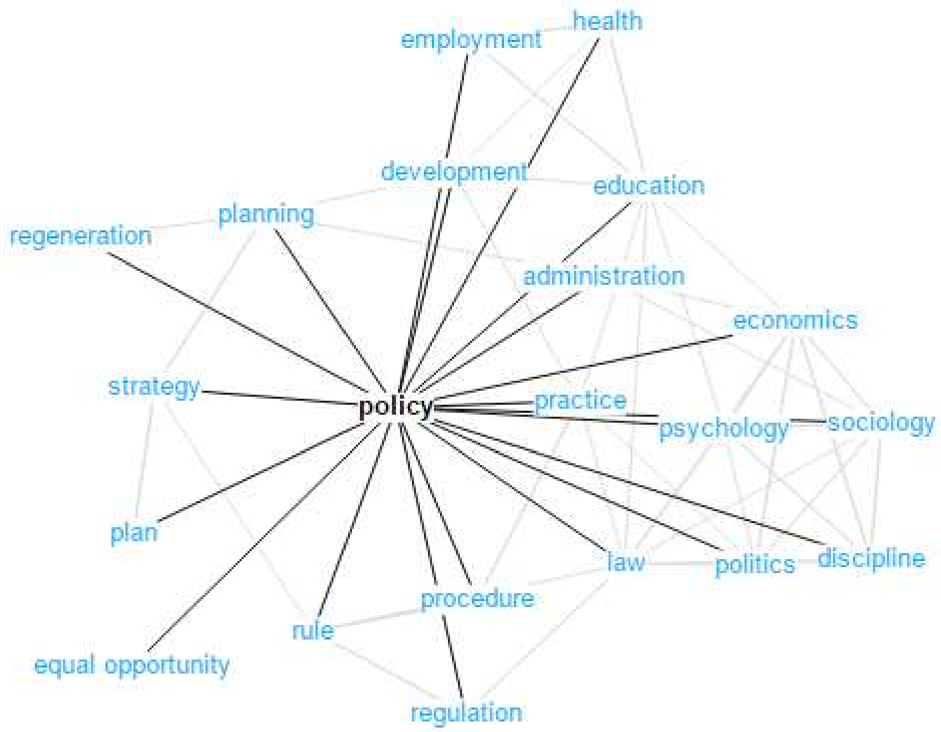
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.17 Policy and regulations

Brief description and context:

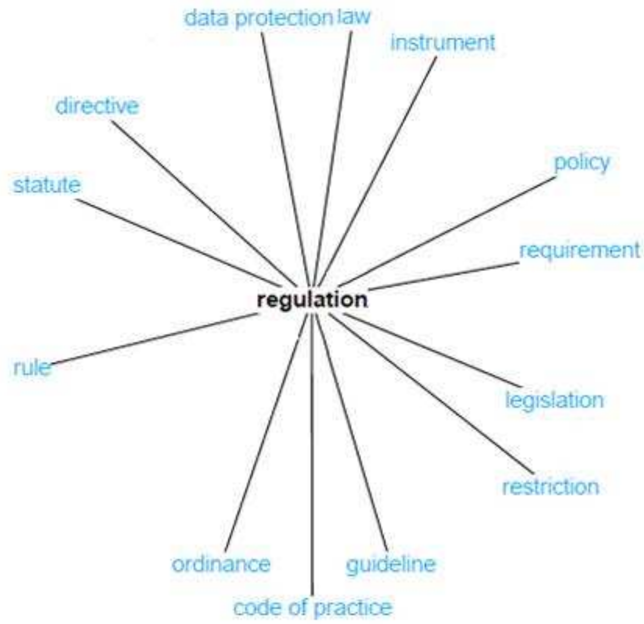
- Define a course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions.
- A general plan involving the general goals and acceptable procedures especially of a governmental body.
- System of principles to guide decisions and achieve rational outcomes.
- Rule, directive or order issued by an executive authority or regulatory agency of a government and having the force of law.

Figure 83: Policy connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

Figure 84: Regulations connected concepts



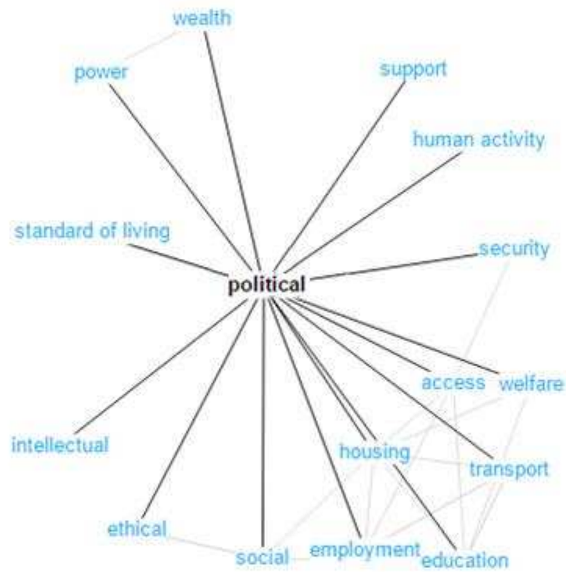
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.18 Political (politic, politics)

Brief description and context:

- Of or relating to the government or the public affairs of a country.
- Activities associated with the governance of a country or other area, especially the debate or conflict among individuals or parties having or hoping to achieve power.
- Activities that relate to influencing the actions and policies of a government or getting and keeping power in a government.

Figure 85: Political (politic, politics) connected concepts



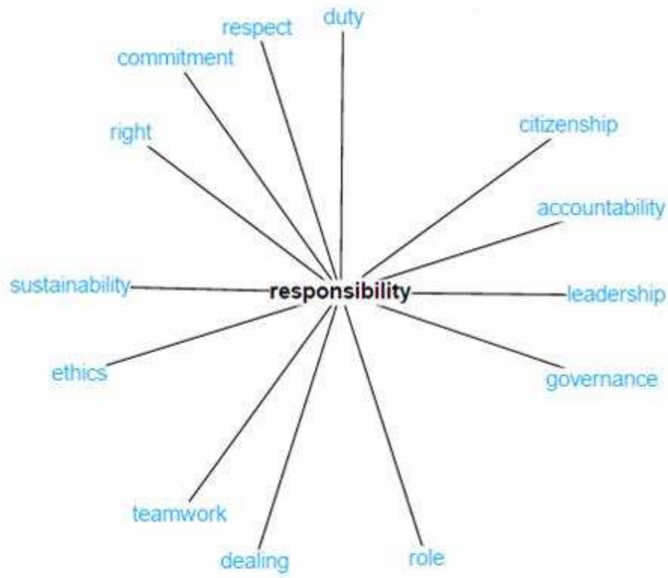
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.19 Responsibility (responsible, roles)

Brief description and context:

- The state or fact of having a duty to deal with something or of having control over someone.
- A thing that one is required to do as part of a job, role, or legal obligation.
- A duty or task that you are required or expected to do.
- Involving important duties, decisions, etc., that you are trusted to do.

Figure 86: Responsibility (responsible, roles) connected concepts



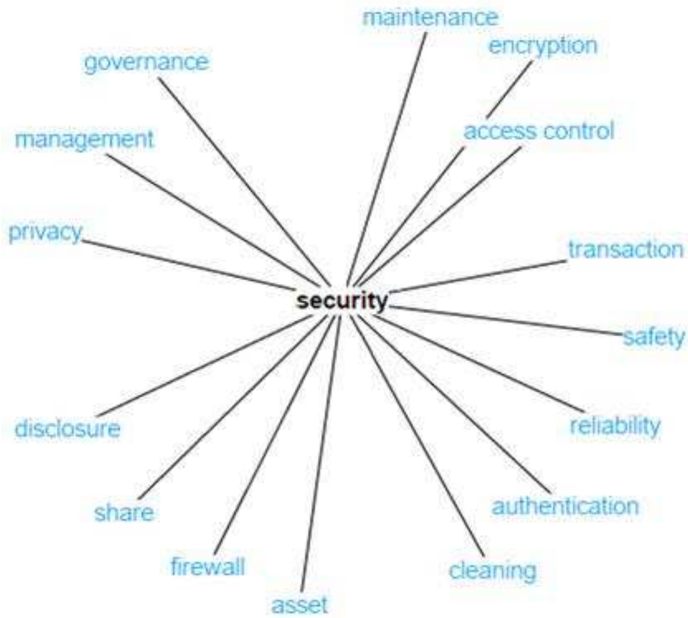
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.20 Security

Brief description and context:

- Physical and logical security.
- Procedures followed or measures taken to ensure the security of a state or organization.
- Information security: the practice of defending information from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction. It is a general term that can be used regardless of the form the data may take.
- The act of ensuring that data is not lost when critical issues arise.

Figure 87: Security connected concepts



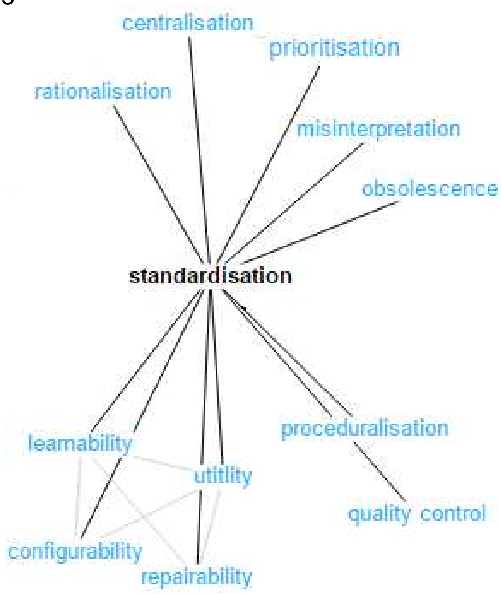
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.21 Standardization (standard, standardizable)

Brief description and context:

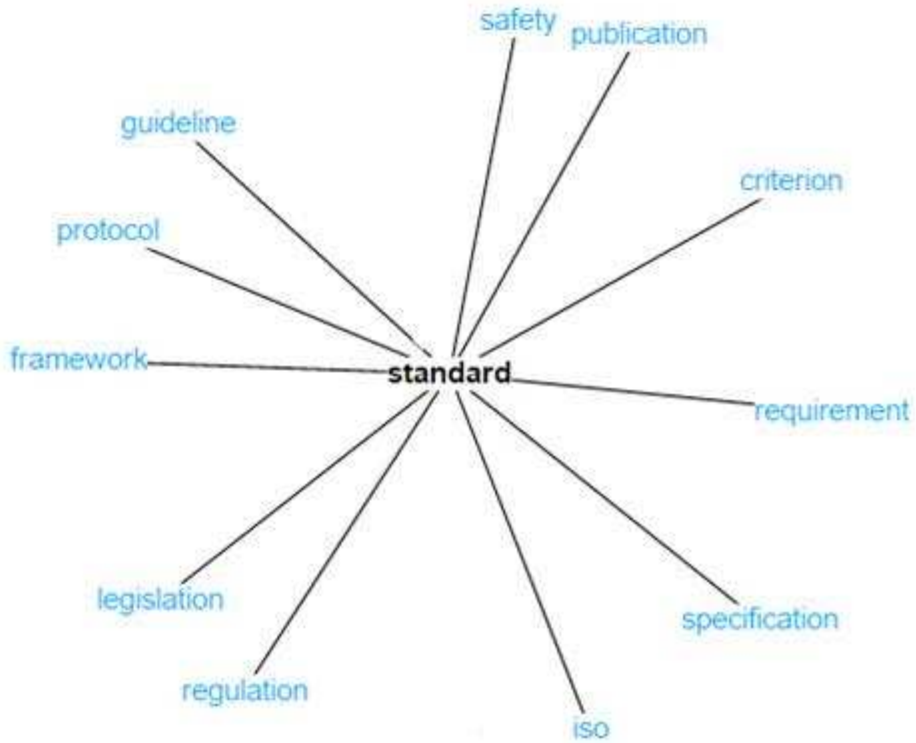
- Something set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality.
- Regularly and widely used, seen, or accepted.
- Substantially uniform and well established by usage.

Figure 88: Standardization connected concepts



Source: The author (2015). Based on Panchenko et al., (2013b).

Figure 89: Standard connected concepts



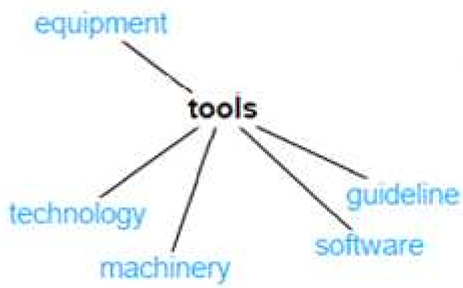
Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.3.22 Tools (Technology)

Brief description and context:

- Something (as an instrument or apparatus) used in performing an operation or necessary in the practice of an activity.
- Practical application of knowledge especially in a particular area.
- The manner of accomplishing a task especially using technical processes, methods, or knowledge.
- A collection of techniques, methods or processes used in the production of goods or services or in the accomplishment of objectives.

Figure 90: Tools (Technology) connected concepts

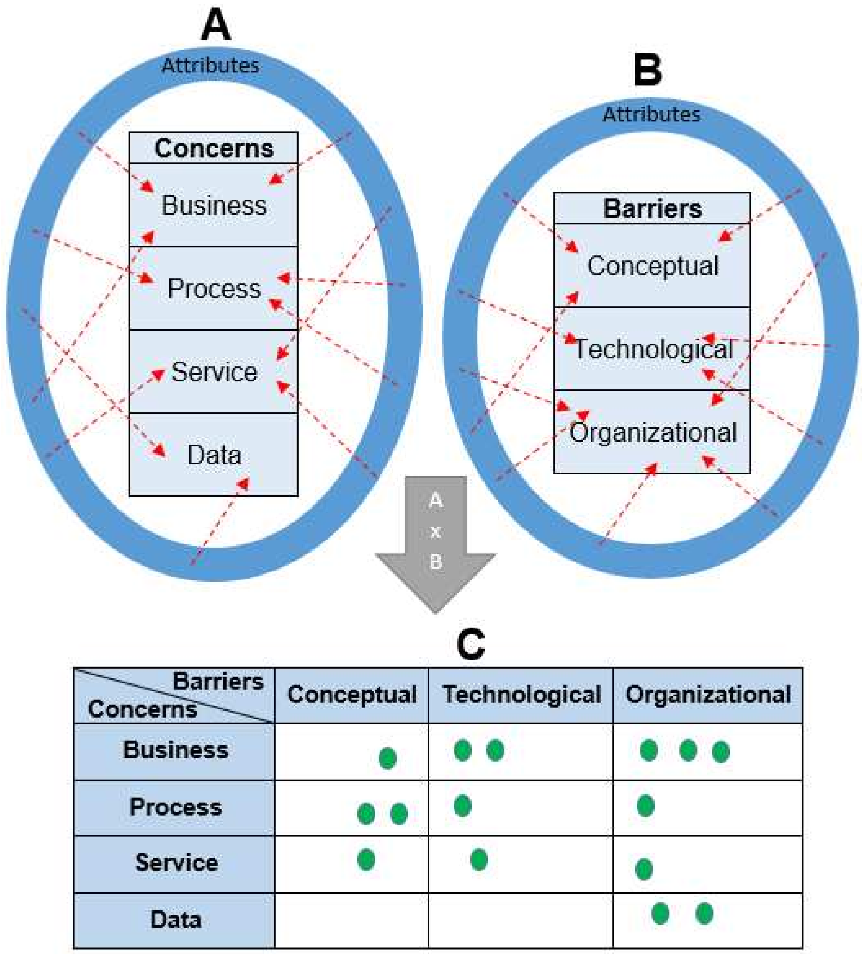


Source: The author (2015). Based on Panchenko et al., (2013b).

6.1.4 ATTRIBUTES CATEGORIZATION WITHIN INTEROPERABILITY ASPECTS

Once all the attributes were defined and detailed in the previous sections, it is necessary to classify them into the interoperability categories (i.e., concerns and barriers), initially within the concerns, then related to the barriers and finally considering the Cartesian position within the concerns x barriers quadrant. Figure 91 represents this conjunction, with random data and green bullets representing the final distribution of the attributes.

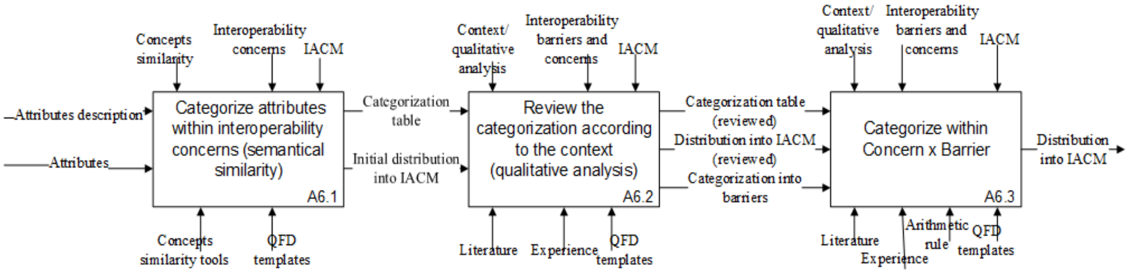
Figure 91: Mapping the attributes within interoperability structure



Source: The author (2015).

To do that, an approach with two phases (Figure 92, Process A6.1 and Process A6.2) will be adopted: the first one is based on the semantical similarity aspects, as already exposed and discussed in section 4.5. The second phase is a context and qualitative analysis (considering the literature and the pertinence regarding public administration interoperability), to review and update (if it is necessary) the results obtained from the first phase. Process A6.3 (Figure 92) consolidates and concludes the categorization.

Figure 92: Details of Process A6



Source: The author (2015).

This is the same approach adopted for the attributes extraction and strengthen the quality of information, once that applies two techniques (one more quantitative oriented and other more qualitative oriented) to corroborate and complement the evaluation of the items.

As a starting point to categorize the attributes into interoperability aspects (especially into concerns), a UMBC Semantic Similarity Service (The UMBC Ebiquity Research Group, 2013) was adopted. The process consisted of comparing all the attributes with all the concerns, and then obtain a value (from 0 to 1, being 1 the highest) for a semantical similarity. This value (and further analysis) provides an initial reference for a decision of where is the most appropriate concern to insert each attribute. After obtaining the raw data, the values were normalized (with four decimal places) and are presented in Table 62.

Table 62: Semantical comparison (attributes x concerns)

#	Attributes	Concerns			
		Business	Process	Service	Data
1	Accessibility	0.0000	0.5497	1.0000	0.2066
2	Adaptable (adaptability)	1.0000	0.0000	0.5548	0.0000
3	Collaboration (collaborative)	0.0000	0.4265	0.3967	1.0000
4	Commitment (support)	0.0000	0.0167	1.0000	0.2407
5	Communication (communicational, semantics)	0.6478	0.0000	1.0000	0.7636
6	Conflicts (conflictive, conflictual)	0.1612	1.0000	0.0000	0.0177
7	Cooperation	0.0000	0.5194	1.0000	0.6461
8	Culture (behavior, sociological)	0.8777	1.0000	0.0000	0.1335
9	Economy (financial)	1.0000	0.4647	0.1183	0.0000
10	Efficiency	0.4124	1.0000	0.3568	0.0000

#	Attributes	Concerns			
		Business	Process	Service	Data
11	Governance (governability)	0.9305	1.0000	0.0000	0.0620
12	Human Resources (human aspects)	0.0000	1.0000	0.0000	0.0000
13	Infrastructure	0.1695	0.0000	1.0000	0.0444
14	Integration (integrate)	0.0000	0.5542	0.8455	1.0000
15	Legality (legal aspects)	0.7459	1.0000	0.5771	0.0000
16	Monitoring (management)	0.0598	0.5171	0.0000	1.0000
17	Policy and regulations	0.8848	1.0000	0.0000	0.0000
18	Political (politic, politics)	1.0000	0.3631	0.0000	0.0000
19	Responsibility (responsible, roles)	0.0171	0.3568	1.0000	0.0000
20	Security	1.0000	0.0000	0.8605	0.1368
21	Standardization (standard, standardizable)	0.2441	0.7182	0.0000	1.0000
22	Tools (technology)	0.0000	1.0000	0.6671	0.7982

It is important to remember that, as the values are normalized, the value “1” does not mean that the pair (attribute x concern) have 100% of semantical similarity, but indicates that they have the higher value among the other words. The next step was to define an interval of distribution (based on the values of Table 62), preparing to organize the information in terms of Interoperability Attributes Correlation Matrix (IACM) structure and symbology of its relations and correlations (see section 4.6). Table 63 presents the interval, the type of relationship, the symbols and the weight of the relationship, preparing to insert into an IACM structure. In addition, derived from Table 62 and Table 63, Table 64 exposes the relationship connection already represented as IACM symbols.

Table 63: Types of relationships, interval, weights and symbols (considering the concerns)

Type of relationship	Interval	IACM symbols	Weight
Weak	<= 0.3333	▲	1
Moderate	> 0.3333 and < 0.6666	O	3
Strong	>= 0.6666	Θ	9

Table 64: Relationship between attributes and concerns

#	Attributes	Concerns			
		Business	Process	Service	Data
1	Accessibility	▲	O	Θ	▲
2	Adaptable (adaptability)	Θ	▲	O	▲
3	Collaboration (collaborative)	▲	O	O	Θ
4	Commitment (support)	▲	▲	Θ	▲

#	Attributes	Concerns			
		Business	Process	Service	Data
5	Communication (communicational, semantics)	▲	▲	Θ	Θ
6	Conflicts (conflictive, conflictual)	▲	Θ	▲	▲
7	Cooperation	▲	O	Θ	O
8	Culture (behavior, sociological)	Θ	Θ	▲	▲
9	Economy (financial)	Θ	O	▲	▲
10	Efficiency	▲	Θ	O	▲
11	Governance (governability)	Θ	Θ	▲	▲
12	Human Resources (human aspects)	▲	Θ	▲	▲
13	Infrastructure	▲	▲	Θ	▲
14	Integration (integrate)	▲	O	Θ	Θ
15	Legality (legal aspects)	Θ	Θ	O	▲
16	Monitoring (management)	▲	O	▲	Θ
17	Policy and regulations	Θ	Θ	▲	▲
18	Political (politic, politics)	Θ	O	▲	▲
19	Responsibility (responsible, roles)	▲	O	Θ	▲
20	Security	Θ	▲	Θ	▲
21	Standardization (standard, standardizable)	▲	Θ	▲	Θ
22	Tools (technology)	▲	Θ	Θ	Θ

Considering Table 64 as a starting point for the classification of the public administration attributes into the interoperability concerns, a qualitative and context analysis was executed to review and, if it is necessary, update the type of relationships. This analysis was made based on the literature review, including interoperability frameworks, models (some of them exposed in sections 4 and 5) and with informal support of interoperability academic researchers, considering the most pertinent connection between the concepts regarding the context applicability. After the analysis, the reviewed relationships are presented in Table 65.

Table 65: Reviewed attributes x concerns

#	Attributes	Concerns			
		Business	Process	Service	Data
1	Accessibility	O	O	Θ	Θ
2	Adaptable (adaptability)	Θ	O	O	▲
3	Collaboration (collaborative)	Θ	O	O	▲
4	Commitment (support)	Θ	O	O	▲

#	Attributes	Concerns			
		Business	Process	Service	Data
5	Communication (communicational, semantics)	Θ	Θ	Θ	Θ
6	Conflicts (conflictive, conflictual)	Θ	O	▲	O
7	Cooperation	Θ	O	O	▲
8	Culture (behavior, sociological)	Θ	O	▲	▲
9	Economy (financial)	Θ	O	▲	▲
10	Efficiency	Θ	Θ	O	▲
11	Governance (governability)	Θ	Θ	▲	▲
12	Human Resources (human aspects)	Θ	▲	▲	▲
13	Infrastructure	O	▲	Θ	O
14	Integration (integrate)	O	O	Θ	Θ
15	Legality (legal aspects)	Θ	Θ	O	▲
16	Monitoring (management)	Θ	Θ	▲	▲
17	Policy and regulations	Θ	Θ	▲	▲
18	Political (politic, politics)	Θ	O	▲	▲
19	Responsibility (responsible, roles)	Θ	Θ	▲	▲
20	Security	O	▲	O	Θ
21	Standardization (standard, standardizable)	O	Θ	▲	▲
22	Tools (technology)	O	Θ	Θ	Θ

The same approach (qualitative/context analysis) were executed to analyze the relationship with the interoperability barriers, considering that it was not applied semantical similarities as a first step, once it was not possible to infer or obtain significant relationship information when comparing the attributes with such extensive terms as “Conceptual” or “Technological”).

Similar to Table 63, Table 66 presents the type of relationship, the symbols and the weights of the relationship, also preparing to insert into an IACM structure (see section 4.6). As it possible to notice, the symbols and the weights are different from the concerns relationship, and this was done to facilitate the visualization when working with the IACM and to differentiate the values in a future arithmetic operation regarding concerns x barriers. Either way, the “rule” of the weights are similar: regarding the concerns, the weak relationship begins with 1, growing up to times 3 for each level (i.e., moderate=weak * 3 and strong=moderate * 3). Regarding the barriers, the weak relationship begins with

1, growing up to times 2 for each level (i.e., moderate=weak * 2, and strong=moderate * 2).

Table 66: Types of relationships, interval, weights and symbols (considering the barriers)

Type of relationship	IACM symbols	Weight
Weak	□	1
Moderate	●	2
Strong	◊	4

Table 67 exposes the relationships connections between barriers and the attributes.

Table 67: Attributes x barriers relationship

#	Attributes	Barriers		
		Conceptual	Technological	Organizational
1	Accessibility	□	◊	□
2	Adaptable (adaptability)	□	●	◊
3	Collaboration (collaborative)	□	●	◊
4	Commitment (support)	□	□	◊
5	Communication (communicational, semantics)	◊	□	◊
6	Conflicts (conflictive, conflictual)	●	●	◊
7	Cooperation	□	●	◊
8	Culture (behavior, sociological)	□	□	◊
9	Economy (financial)	□	□	◊
10	Efficiency	□	●	◊
11	Governance (governability)	□	●	◊
12	Human Resources (human aspects)	□	□	◊
13	Infrastructure	□	◊	●
14	Integration (integrate)	□	◊	◊
15	Legality (legal aspects)	□	□	◊
16	Monitoring (management)	□	□	◊
17	Policy and regulations	●	□	◊
18	Political (politic, politics)	●	□	◊
19	Responsibility (responsible, roles)	□	□	◊
20	Security	□	◊	◊
21	Standardization (standard, standardizable)	□	◊	◊
22	Tools (technology)	□	◊	●

As a final step for this attributes categorization into the interoperability aspects, a simple arithmetic rule was created inspired by a risk management approach (Project Management Institute, 2013) to provide the final distribution of the attributes. The rule maps the product between the barriers values with the concerns values, to define and select in with quadrant each attribute will occur and, consequently, what will be the approach (i.e., what are the aspects or the views) that each attribute will receive during the diagnosis. Table 68 shows the product regarding the weights, with colors representing the strength of the derived relationship (i.e., green for the strongest connections, yellow for the moderate and red for the weakest connections).

Table 69, derived from Table 68, shows the product result using the same symbols as the concerns' relationships.

Table 68: Product of concerns and barriers considering the weights

			Barriers		
			◊	●	□
		Weights	**4**	**2**	**1**
Concerns	**Θ**	**9**	36	18	9
	O	**3**	12	6	3
	▲	**1**	4	2	1

Table 69: Product of concerns and barriers (with proper symbols)

		Barriers		
		◊	●	□
Concerns	**Θ**	Θ	Θ	O
	O	O	O	▲
	▲	▲	▲	▲

Table 69 propose relations as such: if the relationship between concerns and attributes are strong, and the relationship between barriers and concerns are strong or moderate, the result is a strong relationship between the attribute and the specific pair concerns x barriers. The other cells are interpreted in the same way. Again, as exposed in previous evaluation, after the product operation, a new qualitative review was executed and, according to the results, some of the relationships strengths were updated.

The operation produces a 264 cells matrix (4 concerns x 3 barriers x 22 attributes) considering all types of relationship ("weak", "moderate" and "strong"). In this particular scenario (already after the qualitative review), there are 116 "weak", 85 "moderate" and 63 "strong" relationships, as detailed in Figure 93 (as the initial construction of the IACM, as seen in Figure 55, item “D”: interrelationship matrix).

Considering the aspects of this research, it was defined that, for diagnosing purposes, only the cells with strong relationship will have their attributes evaluated during the diagnosis phase, resulting in the final representation within the interoperability aspects illustrated in Figure 94.

Figure 93: Resulted product matrix (IACM interrelationship matrix)

Attributes / Concerns x Barriers	Accessibility	Adaptable (adaptability)	Collaboration (collaborative)	Commitment (support)	Communication (communicational, semantics)	Conflicts (conflictive, conflictual)	Cooperation	Culture (behavior, sociological)	Economy (financial)	Efficiency	Governance (governability)	Human Resources (human aspects)	Infrastructure	Integration (integrate)	Legality (legal aspects)	Monitoring (management)	Policy and regulations	Political (politic, politics)	Responsibility (responsible, roles)	Security	Standardization (standard, standardizable)	Tools (technology)
Business x Conceptual (BC)	▲	O	O	O	Θ	Θ	O	O	O	O	O	O	O	▲	O	O	Θ	Θ	O	▲	▲	▲
Business x Technological (BT)	O	Θ	Θ	O	Θ	Θ	Θ	O	O	Θ	Θ	O	Θ	O	O	O	O	O	O	O	O	Θ
Business x Organizational (BO)	▲	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	O	Θ	Θ	Θ	Θ	Θ	Θ	O	O
Process x Conceptual (PC)	▲	▲	▲	▲	Θ	O	▲	▲	▲	O	O	▲	▲	▲	O	O	Θ	O	O	▲	O	O
Process x Technological (PT)	O	O	O	▲	O	O	O	▲	▲	Θ	Θ	▲	▲	O	O	O	O	▲	O	▲	Θ	Θ
Process x Organizational (PO)	▲	O	O	O	Θ	O	O	O	O	Θ	Θ	▲	▲	O	Θ	Θ	Θ	O	Θ	Θ	Θ	▲
Service x Conceptual (SC)	O	▲	▲	▲	Θ	▲	▲	▲	▲	▲	▲	▲	O	O	▲	▲	▲	▲	▲	▲	▲	Θ
Service x Technological (ST)	Θ	O	O	▲	Θ	▲	O	▲	▲	O	▲	▲	Θ	Θ	▲	▲	▲	▲	▲	O	▲	Θ
Service x Organizational (SO)	O	O	O	O	▲	▲	O	▲	▲	O	▲	▲	Θ	Θ	O	▲	▲	▲	▲	O	▲	▲
Data x Conceptual (DC)	O	▲	▲	▲	Θ	O	▲	▲	▲	▲	▲	▲	▲	O	▲	▲	▲	▲	▲	O	▲	Θ
Data x Technological (DT)	Θ	▲	▲	▲	O	O	▲	▲	▲	▲	▲	▲	O	Θ	▲	▲	▲	▲	▲	O	▲	Θ
Data x Organizational (DO)	O	▲	▲	▲	Θ	O	▲	▲	▲	▲	▲	▲	O	Θ	▲	▲	▲	▲	▲	Θ	▲	▲

Source: The author (2015), based on QFD Online (n.d.).

Figure 94: Attributes distribution within interoperability structure

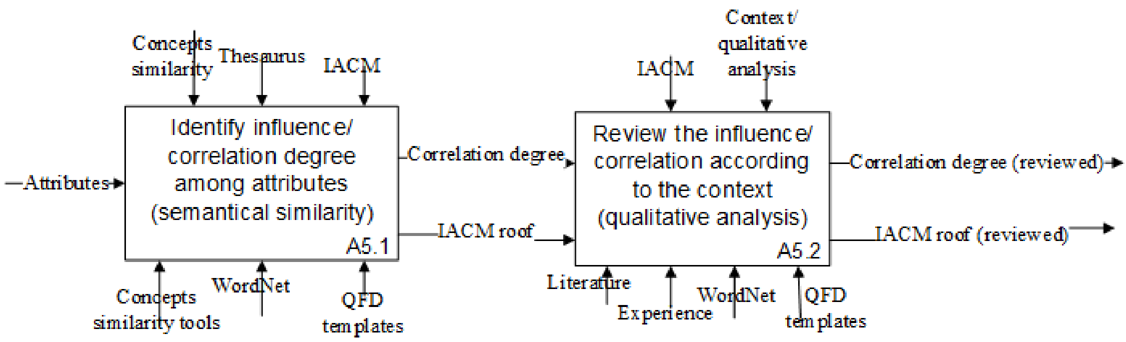
Concerns x Barriers \ Attributes	Accessibility	Adaptable (adaptability)	Collaboration (collaborative)	Commitment (support)	Communication (communicational, semantics)	Conflicts (conflictive, conflictual)	Cooperation	Culture (behavior, sociological)	Economy (financial)	Efficiency	Governance (governability)	Human Resources (human aspects)	Infrastructure	Integration (integrate)	Legality (legal aspects)	Monitoring (management)	Policy and regulations	Political (politic, politics)	Responsibility (responsible, roles)	Security	Standardization (standard, standardizable)	Tools (technology)
Business x Conceptual (BC)					Θ	Θ											Θ	Θ				
Business x Technological (BT)		Θ	Θ		Θ	Θ	Θ			Θ	Θ		Θ									Θ
Business x Organizational (BO)		Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ	Θ		Θ	Θ	Θ	Θ	Θ	Θ		
Process x Conceptual (PC)					Θ												Θ					
Process x Technological (PT)										Θ	Θ										Θ	Θ
Process x Organizational (PO)					Θ					Θ	Θ				Θ	Θ	Θ		Θ	Θ	Θ	
Service x Conceptual (SC)					Θ																	Θ
Service x Technological (ST)	Θ				Θ								Θ	Θ								Θ
Service x Organizational (SO)													Θ	Θ								
Data x Conceptual (DC)					Θ																	Θ
Data x Technological (DT)	Θ													Θ								Θ
Data x Organizational (DO)					Θ									Θ						Θ		

Source: The author (2015), based on QFD Online (n.d.).

6.1.5 ATTRIBUTES CORRELATION/INFLUENCE (IACM ROOF)

Besides the attributes extraction and classification, it is important to map the influence that each attribute can have over another attribute. The process is represented in Figure 10 and Figure 4 (Process A5) and it was adopted the same approach as described in section 6.2.5. That is, a semantical similarity as a starting point and then a context and qualitative analysis (considering the literature and the pertinence regarding public administration interoperability), to review and update (if it is necessary) the results obtained from the first phase. Figure 95 illustrates the details of Process A5.

Figure 95: Details of Process A5



Source: The author (2015).

As said before, this kind of approach strength the quality of information once that applies two techniques (one more quantitative oriented and other more qualitative oriented) to corroborate and complement the evaluation of the items. As a starting point, the UMBC Semantic Similarity Service (The UMBC Ebiquity Research Group, 2013) was adopted. The process consisted of comparing all the attributes with all others, and then obtain a value (from 0 to 1, being 1 the highest) for a semantical similarity. This value (and further analysis) provides an initial reference for a decision related to the influence/correlation degree between the attributes themselves. After obtaining the raw data, the values were normalized (with four decimal places) and are presented in Figure 96, generating a kind of bi-directional and traceability matrix, with both parts (left/under-diagonal/bright blue and right/upper-diagonal/white) having the same values. From now on, for representation purposes, only “one side” of the diagonal will be shown.

Figure 96: Attributes correlation factor (based solely on semantical similarity)

	Accessibility	Adaptable (adaptability)	Collaboration (collaborative)	Commitment (support)	Communication (communicational, semantics)	Conflicts (conflictive, conflictual)	Cooperation	Culture (behavior, sociological)	Economy (financial)	Efficiency	Governance (governability)	Human Resources (human aspects)	Infrastructure	Integration (integrate)	Legality (legal aspects)	Monitoring (management)	Policy and regulations	Political (politic, politics)	Responsibility (responsible, roles)	Security	Standardization (standard, standardizable)	Tools (technology)
Accessibility		0.1294	0.1217	0.0690	0.4027	0.1788	0.1245	0.0000	0.0824	0.9941	0.0845	0.2251	0.5971	0.6884	0.9449	0.0398	0.1267	0.0000	0.0716	0.8069	1.0000	0.1952
Adaptable (adaptability)	0.1294		0.7377	0.0000	0.1734	0.0725	0.2266	0.2800	0.5067	0.4350	0.2955	0.3920	0.0493	0.5752	0.0000	0.0000	0.1077	0.6075	0.0228	0.5653	1.0000	0.2942
Collaboration (collaborative)	0.1217	0.7377		0.1945	0.2452	0.1351	1.0000	0.0875	0.0506	0.0935	0.0515	0.0752	0.1278	0.4675	0.0000	0.0652	0.0577	0.0251	0.1020	0.0000	0.2861	0.1017
Commitment (support)	0.0690	0.0000	0.1945		0.0096	0.1425	1.0000	0.0265	0.0358	0.0115	0.0316	0.1077	0.1071	0.1872	0.0085	0.0697	0.1610	0.0289	0.3452	0.0738	0.0029	0.0000
Communication (communicational, semantics)	0.4027	0.1734	0.2452	0.0096		0.2364	0.8013	0.2130	0.2994	0.1385	0.0346	0.3529	0.8657	1.0000	0.0468	0.4598	0.2140	0.2217	0.4375	0.6983	0.0140	0.4045
Conflicts (conflictive, conflictual)	0.1788	0.0725	0.1351	0.1425	0.2364		0.5420	0.3895	0.3904	0.0000	0.3175	0.4412	0.0122	0.3636	0.2449	0.0374	0.5032	1.0000	0.4438	0.5760	0.2350	0.0000
Cooperation	0.1245	0.2266	1.0000	1.0000	0.8013	0.5420		0.0868	0.1306	0.1428	0.0800	0.0623	0.1007	0.3902	0.0000	0.0560	0.0838	0.0739	0.1408	0.0755	0.2939	0.0539
Culture (behavior, sociological)	0.0000	0.2800	0.0875	0.0265	0.2130	0.3895	0.0868		1.0000	0.2047	0.3608	0.2158	0.1287	0.1770	0.0662	0.0743	0.4794	0.8810	0.1503	0.2864	0.2287	0.0194
Economy (financial)	0.0824	0.5067	0.0506	0.0358	0.2994	0.3904	0.1306	1.0000		0.0428	0.8402	0.5200	0.9751	0.3096	0.3470	0.0000	0.7177	0.8928	0.0744	0.4253	0.0309	0.0143
Efficiency	0.9941	0.4350	0.0935	0.0115	0.1385	0.0000	0.1428	0.2047	0.0428		0.0640	0.3196	0.2793	0.5955	0.6191	0.0537	0.3138	0.0501	0.1122	0.2689	0.5841	0.2119
Governance (governability)	0.0845	0.2955	0.0515	0.0316	0.0346	0.3175	0.0800	0.3608	0.8402	0.0640		0.3162	0.1669	0.0441	0.1808	0.0000	0.8087	1.0000	0.2308	0.5410	0.0935	0.1091
Human Resources (human aspects)	0.2251	0.3920	0.0752	0.1077	0.3529	0.4412	0.0623	0.2158	0.5200	0.3196	0.3162		1.0000	0.5440	0.0985	0.2641	0.6017	0.7743	0.6345	0.4967	0.0000	0.9102
Infrastructure	0.5971	0.0493	0.1278	0.1071	0.8657	0.0122	0.1007	0.1287	0.9751	0.2793	0.1669	1.0000		0.9597	0.1150	0.0000	0.1527	0.0518	0.1891	0.9679	0.6732	0.4333
Integration (integrate)	0.6884	0.5752	0.4675	0.1872	1.0000	0.3636	0.3902	0.1770	0.3096	0.5955	0.0441	0.5440	0.9597		0.0000	0.3159	0.1375	0.0091	0.0883	0.3298	0.7484	0.2360
Legality (legal aspects)	0.9449	0.0000	0.0000	0.0085	0.0468	0.2449	0.0000	0.0662	0.3470	0.6191	0.1808	0.0985	0.1150	0.0000		0.1771	0.3136	0.3891	0.1845	0.1980	0.4660	0.0085
Monitoring (management)	0.0398	0.0000	0.0652	0.0697	0.4598	0.0374	0.0560	0.0743	0.0000	0.0537	0.0000	0.2641	0.0000	0.3159	0.1771		0.3459	0.1226	0.5597	0.6269	0.6191	0.3015
Policy and regulations	0.1267	0.1077	0.0577	0.1610	0.2140	0.5032	0.0838	0.4794	0.7177	0.3138	0.8087	0.6017	0.1527	0.1375	0.3136	0.3459		0.6816	0.4575	0.6565	0.1108	0.0000
Political (politic, politics)	0.0000	0.6075	0.0251	0.0289	0.2217	1.0000	0.0739	0.8810	0.8928	0.0501	1.0000	0.7743	0.0518	0.0091	0.3891	0.1226	0.6816		0.0528	0.3391	0.0774	0.0067
Responsibility (responsible, roles)	0.0716	0.0228	0.1020	0.3452	0.4375	0.4438	0.1408	0.1503	0.0744	0.1122	0.2308	0.6345	0.1891	0.0883	0.1845	0.5597	0.4575	0.0528		0.3242	0.0397	0.1793
Security	0.8069	0.5653	0.0000	0.0738	0.6983	0.5760	0.0755	0.2864	0.4253	0.2689	0.5410	0.4967	0.9679	0.3298	0.1980	0.6269	0.6565	0.3391	0.3242		0.1346	0.2504
Standardization (standard, standardizable)	1.0000	1.0000	0.2861	0.0029	0.0140	0.2350	0.2939	0.2287	0.0309	0.5841	0.0935	0.0000	0.6732	0.7484	0.4660	0.6191	0.1108	0.0774	0.0397	0.1346		0.1163
Tools (technology)	0.1952	0.2942	0.1017	0.0000	0.4045	0.0000	0.0539	0.0194	0.0143	0.2119	0.1091	0.9102	0.4333	0.2360	0.0085	0.3015	0.0000	0.0067	0.1793	0.2504	0.1163	

Source: The author (2015).

The next step was to define an interval of distribution (based on the values of Figure 96), preparing to organize the information in terms of IACM structure and symbology of its correlations. Table 70 presents the interval, the type of correlation and the symbols of correlation, preparing to insert into an IACM structure (roof). In addition, derived from Figure 96 and Table 70, Figure 97 exposes the correlations with the proper symbols, considering the semantical similarity aspects.

Table 70: IACM roof symbols and correlations

Type of correlation	**Interval**	**IACM symbols**
Weak	<= 0.3333	┼
Moderate	> 0.3333 and < 0.6666	╫
Strong	>= 0.6666	↑

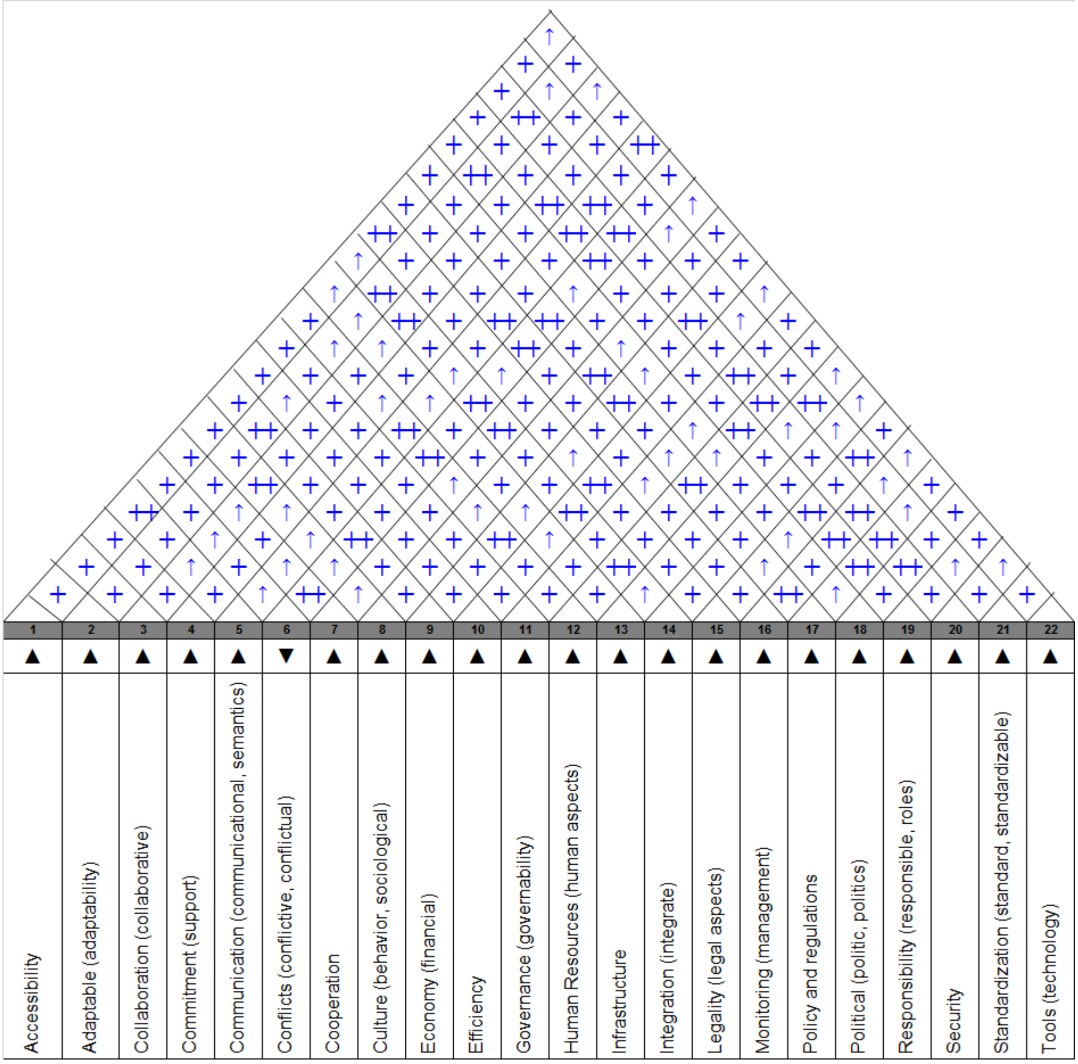
Considering Figure 97 as a starting point for the influence correlation, a qualitative and context analysis was executed to review and, if it is necessary, update the connections (Figure 95, process A5.2). This analysis was made based on the literature review, including interoperability frameworks and models (some o then exposed in sections 4 and 5) and with informal support of interoperability academic researchers, considering the most pertinent connection regarding the context applicability. After the analysis, the reviewed correlations are presented in the format of the IACM "roof", in Figure 98.

Figure 97: Attributes correlation with symbols

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		Accessibility	Adaptable (Adaptability)	Collaboration (collaborative)	Commitment (Support)	Communication (communicational, semantic)	Conflicts (conflictive, conflictual)	Cooperation	Culture (behavior, sociological)	Economy (financial)	Efficiency	Governance (governability)	Human Resources	Infrastructure	Integration (integrate)	Legality (Legal Aspects)	Monitoring (Management)	Policy and regulations	Political (politic, politics)	Responsibility (responsible), roles	Security	Standardization (standard, standardizable)	Tools (Technology)
1	Accessibility	NA	+	+	+	++	+	+	+	+	↑	+	+	++	↑	↑	+	+	+	+	↑	↑	+
2	Adaptable (adaptability)		NA	↑	+	+	+	+	+	++	++	+	++	+	++	+	+	+	++	+	++	↑	+
3	Collaboration (collaborative)			NA	+	+	+	↑	+	+	+	+	+	+	++	+	+	+	+	+	+	+	+
4	Commitment (support)				NA	+	+	↑	+	+	+	+	+	+	+	+	+	+	+	++	+	+	+
5	Communication (communicational, semantics)					NA	+	↑	+	+	+	+	++	↑	↑	+	++	+	+	++	↑	+	++
6	Conflicts (conflictive, conflictual)						NA	++	++	++	+	+	++	+	++	+	+	++	↑	++	++	+	+
7	Cooperation							NA	+	+	+	+	+	+	++	+	+	+	+	+	+	+	+
8	Culture (behavior, sociological)								NA	↑	+	++	+	+	+	+	+	++	↑	+	+	+	+
9	Economy (financial)									NA	+	↑	++	↑	+	++	+	↑	↑	+	++	+	+
10	Efficiency										NA	+	+	+	++	++	+	+	+	+	+	++	+
11	Governance (governability)											NA	+	+	+	+	+	↑	↑	+	++	+	+
12	Human Resources (human aspects)												NA	↑	++	+	+	++	↑	++	++	+	↑
13	Infrastructure													NA	↑	+	+	+	+	+	↑	↑	++
14	Integration (integrate)														NA	+	+	+	+	+	+	↑	+
15	Legality (legal aspects)															NA	+	+	++	+	+	++	+
16	Monitoring (management)																NA	++	+	++	++	++	+
17	Policy and regulations																	NA	↑	++	++	+	+
18	Political (politic, politics)																		NA	+	++	+	+
19	Responsibility (responsible, roles)																			NA	+	+	+
20	Security																				NA	+	+
21	Standardization (standard, standardizable)																					NA	+
22	Tools (technology)																						NA

Source: The author (2015).

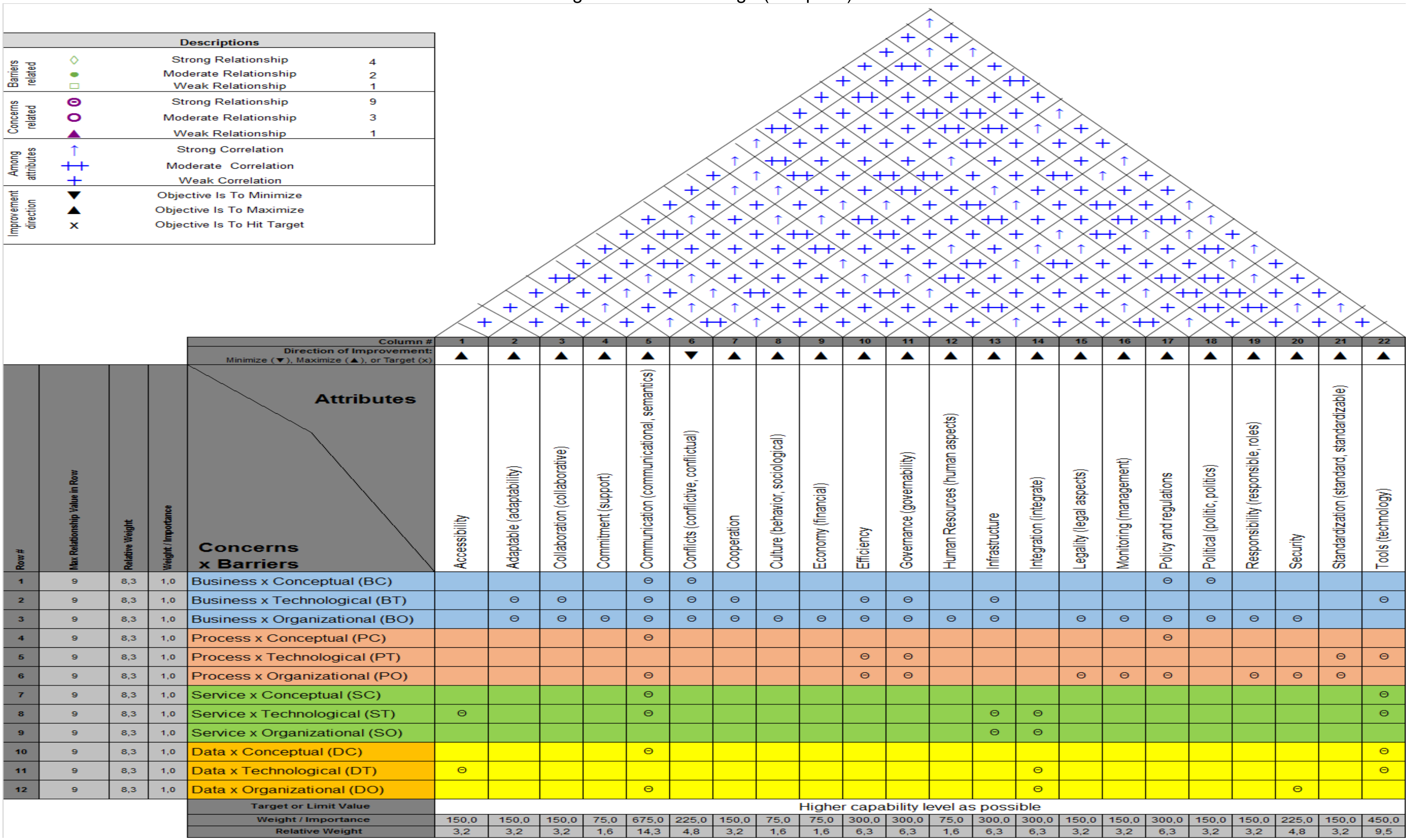
Figure 98: IACM “roof”



Source: The author (2015), based on QFD Online (n.d.).

Putting all parts together, the full IACM structure now can be represented and is presented in Figure 99.

Figure 99: IACM design (complete)



Source: The author (2015).

It is important to mention that the Interoperability Attributes Correlation Matrix (IACM), based on QFD (see section 4.6), was used to help the design of the proposed models (capability and diagnosis) in this research, and not to execute the diagnosis itself, as will be exposed forward.

Additionally, the IACM are used as a basis to analyze the diagnosis' results, inferring over the attributes priorities and supporting sensitive analysis (evaluation of the attributes weights in the definition of the capability/maturity levels within the organization). The roof of the IACM structure (see section 4.6, Figure 55, item "B") serves to map, within the AHP structure, correlations or different influence relations between attributes. Therefore, this generates a "break" in a purely hierarchical basis towards the structuring and organization oriented the ANP (see section 4.4.2 and Figure 50).

6.2 CAPABILITY LEVELS

As already exposed in section 4.3 (CMMI), capability levels describe ways for incrementally improving the activities corresponding to a given activity. A capability describes and defines how good an entity executes an activity or how good some processes are implemented and/or followed (ISO/IEC, 2015). Regarding this research, a capability level indicates the level of evolution and implementation of certain guidelines related to attributes. In fact, as will be seen in section 6.3 (model structure) and section 7 (diagnosis method), it will be possible to diagnose the capability level of guidelines, attributes and interoperability area, according to the model design based on AHP/ANP. This research defines four capability levels, as exposed in Table 71.

Table 71: Proposed capability levels

Capability levels and characteristics
Level 1: Ad hoc
• The guideline (or attribute) is not performed or partially performed in the manner that its implementation is done in such a way (according to the aspects of the level) that characterizes an ad hoc implementation. • One or more aspects of the attributes guidelines are not executed or present in a satisfactory way. • There is very poor documentation (or none) and no management or institutionalization. No (or only a few) processes or activities are documented. • Although interoperability within capability level "ad hoc" can perform with a kind of success in some ways, it can be lost over time if they are not defined, managed and institutionalized. • Somewhat chaotic tasks and actions.

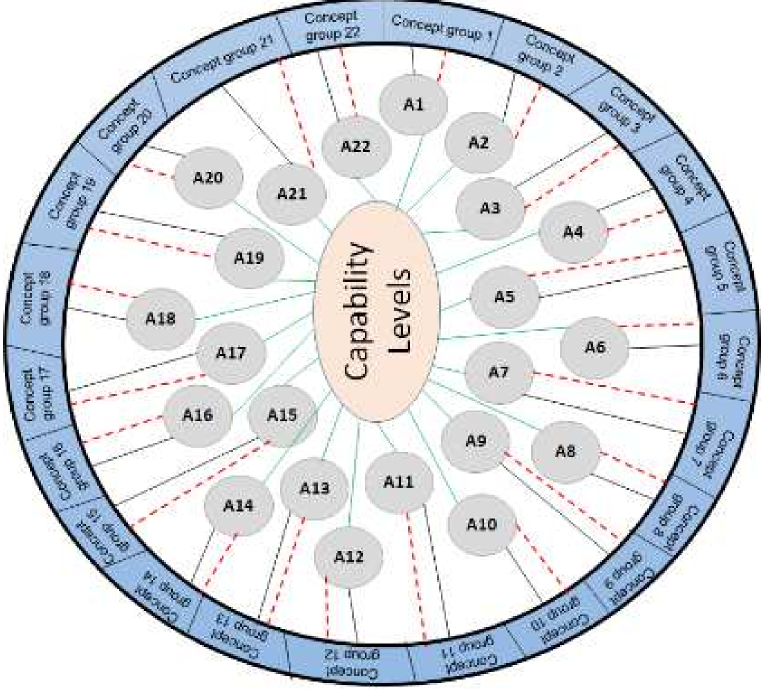
Capability levels and characteristics
• Entities usually do not have a stable environment. • Success depends on the "heroism" and competence of the people and not of consolidated processes. • Entities still produce goods and services that work, but usually do not meet budgets and deadlines. • Entities tend to make commitments beyond their means, abandon processes (when it exists) in times of crisis and are hardly able to repeat past successes. • Systems are capable of performing some ad-hoc interoperations with other systems. • Interoperability is very limited and occurs almost for “lucky”. • Some basic IT devices are connectable and some electronic data exchange becomes possible. • The IT infrastructure (generally ad-hoc) is in place, providing support for some entity information exchange.
Level 2: Defined
• The guideline (or attribute) is performed or partially performed in a manner that its implementation is in such a way (according to the aspects of the level) that characterizes a defined implementation. • The activities and processes (related to the guidelines) are executed and documented. • Interoperability is limited and occurs mostly because of the existence of documents, processes and formal proceedings. • Well-characterized and understood processes are described using standards, procedures, tools and methods. • The activities are performed in a planned way, and executed in accordance with certain definitions. • There are few (or none) controls and no (or very few) management regarding the guidelines’ aspects. • People are trained to execute the guidelines and meet the attributes goal in an event-based way (i.e., according to some specific need). There is no (or very few) managed training plan with a strategic approach (e.g., yearly planning, strategic needs for training).
Level 3: Managed
• There are controls and formal management regarding the guidelines execution and attributes aspects. • The management and control measurement occurs in a project and/or area/department level, but it is not yet institutionalized for all the entity or for all the attributes, guidelines or processes. • People are formally trained regarding the execution and implementation of the guidelines to increase the performance of the interoperability attributes. • There are adequate resources to produce controlled outputs. • The processes discipline helps to ensure that existing practices are retained during times of stress. • The involvement of stakeholders is monitored, controlled, and reviewed. • Interoperability occurs as a management strategy (and not on an ad hoc or people dependent way). It is not yet institutionalized, but it is managed. • Decision-makers are able to share information between systems. • There is measurement, control, execution and planning of the activities and/or execution of the guidelines. • Practices are maintained even in times of difficulties, with management techniques that support decision-making.

Capability levels and characteristics
• Measures on the guidelines, attributes and/or processes are collected and analyzed (especially for quantitative control). • Quantitative objectives for quality and process performance are established and used as criteria for managing the processes and/or guidelines. • There are shared value systems and shared goals, a common understanding and readiness to interoperate. • Systems allow data exchange. • The guideline (or attribute) is performed in a manner that its implementation is in such a way (according to the aspects of the level) that characterizes a managed structure.
Level 4: Institutionalized
• The processes, attributes and guidelines practices are institutionalized in the entity. • Interoperability is a strategic focus and is embedded within the entity's strategic plan. • Interoperability and the entity in general can adapt to changes in the business environment in an agile, flexible and responsive manner. • Support dynamic interoperability and adaptation to changes and evolution of external entities. • The entity seeks for qualitative and continuous improvements. • Interoperability occurs on continuing basis. • Entities are able to adjust dynamically and accommodate 'on the run'. • The work is performed and there are commitment and consistency to performing it. • Entities are able to interoperate with multi-lingual and multicultural heterogeneous partners. • Entities are well organized to deal with interoperability challenges. • Interoperability capability is extended to heterogeneous systems/partners. • Data and applications are fully shared and can be distributed. • Data has a common interpretation regardless of the form. • The processes are institutionalized. • During stress times, the entity retains its processes and activities. • The guideline (or attribute) is performed in a manner that its implementation is in such a way (according to the aspects of the level) that characterizes an institutionalized structure.

6.3 MODEL STRUCTURE AND COMPONENTS

The conceptual model structure, not considering aspects such as information components, work products examples and the detailing of the levels, is exposed in Figure 100. The figure summarizes the steps of conceptual extraction and grouping from the literature, composing knowledge up to the capability levels.

Figure 100: Illustrative model composition



Source: The author (2015).

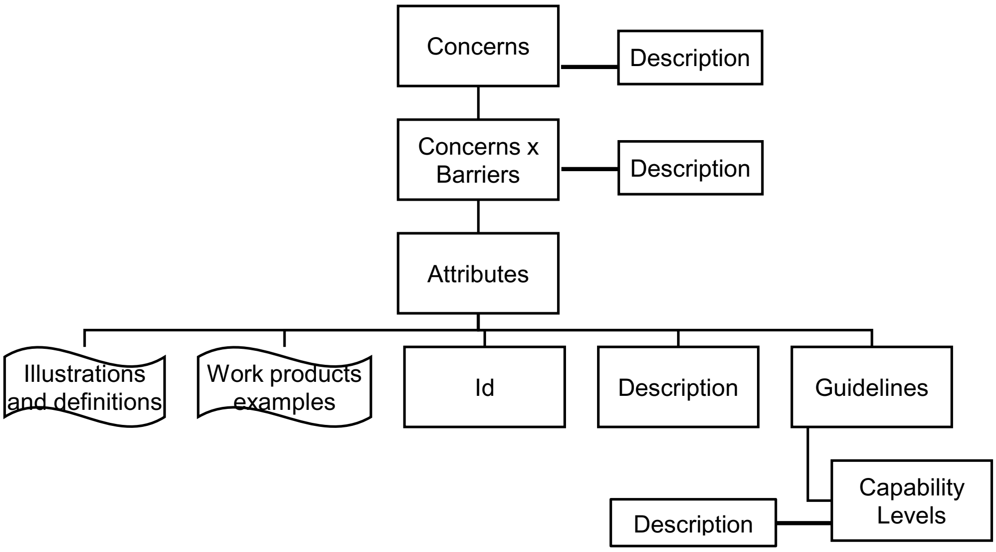
At the edge of the circle (in light blue), there is the representation of the 22 groups of concepts retrieved from the literature. The solid lines connecting the edge's groups to the small circles (e.g., A1 to A22) indicates the derivation of the grouped concepts into attributes. The dotted red lines indicate that some information from the concept's groups is used to compose the guidelines within each attribute. The green lines connecting indicates a connection between the attributes and guidelines to the proposed capability levels.

The model is composed of main types of components:

- Required components:
    - Essential and mandatory to understand the item. Critical to achieving the capability level and for the organization of the whole structure.
- Informative components:
    - Helps the understanding of the required components, providing some examples, notes, illustrations and other complementary information.

Figure 101 exposes the structure and the components of the model, considering the rectangular forms as the required components and the “banner style” form as the informative components.

Figure 101: General model structure



Source: The author (2015).

The first two rectangular blocks (“Concerns” and “Concerns x Barriers”) are related to the enterprise interoperability aspects and organization, a central aspect of this research domain.

The “Attributes” rectangle represents the proposed measurable qualifiers created based on the literature review and extraction techniques already exposed. The attributes possess two informative components (“Illustrations and definitions” and “Work products examples”) and they were exposed earlier in section 6.2.4. The “Id” rectangle is an acronym representing the attribute and, within each attribute, there are “Guidelines” that represents declarations, practices and suggestions that together maps and/or achieve the purpose of the attribute. The “Guidelines” are mapped directly to the “Capability Levels” and, as detailed in section 7, the diagnosis occurs as a bottom-up calculus composition. Both the “Attributes” and the “Guidelines” have “Description” explaining their meaning, interpretation and application.

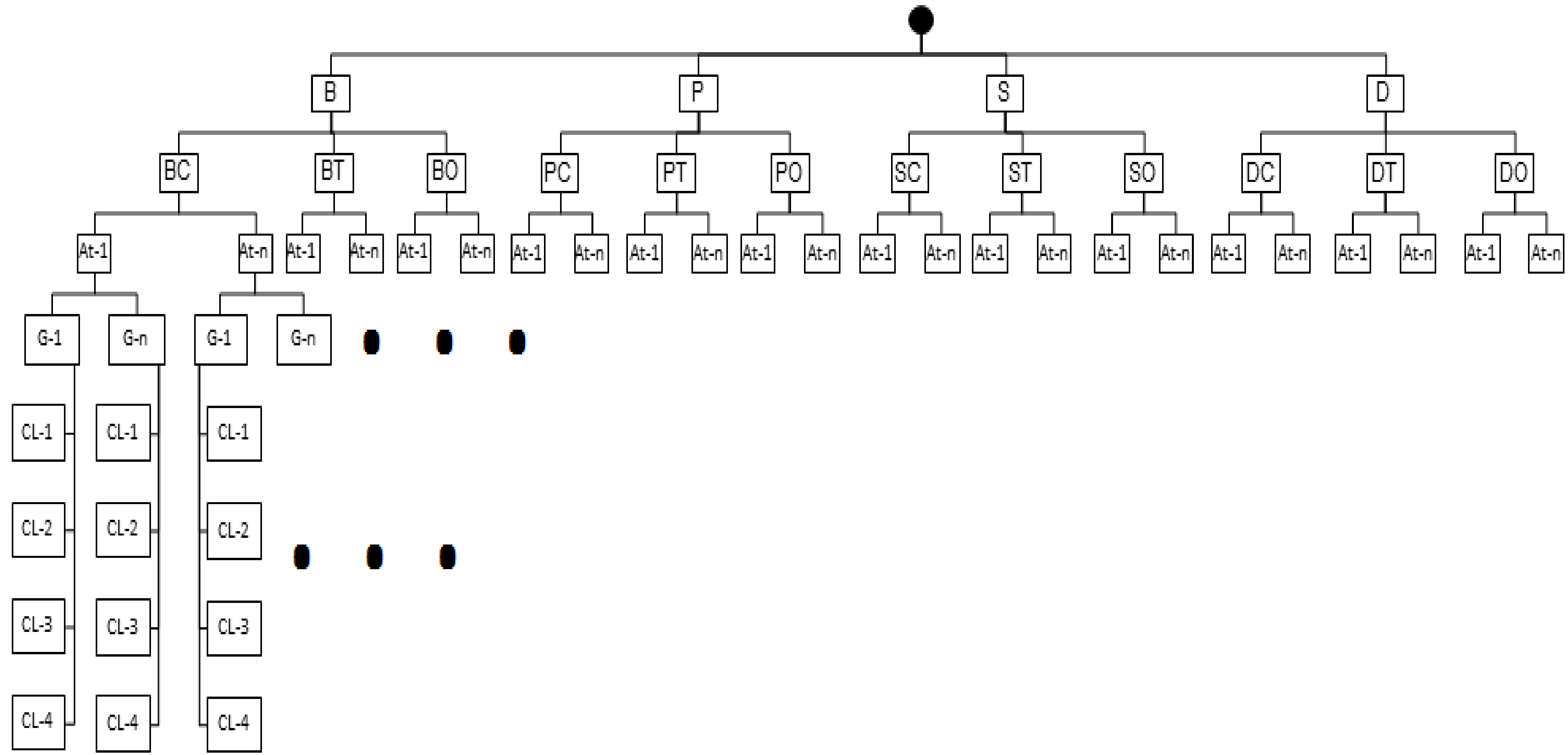
Two instantiated figures (Figure 102 and Figure 103) derived from Figure 101, illustrates the model with a more practical view. Figure 102 exposes a most general overview, while Figure 103 shows a detail considering some specific concerns, attributes, and only one attribute (“Conflicts”). Figure 102 exposes the layers of the structure exploring a general perspective. The first layer contains the four interoperability concerns (business, process, service and data) and they are the basis for the derivation of the other layers. That is, the rest of the structure is oriented according to the composition of each one of the concerns.

Still in Figure 102, the second layer shows the components (barriers) of each of the concerns. That is, each concern contains three barriers (conceptual, technological and organizational), and the three boxes under each concern represent this aspect (as in the matrix Concern x Barriers). The first letter of the barriers box indicates to which concern the barriers are related (e.g., BC – Business x Conceptual, PO – Process x Organizational).

Under the interoperability areas (Concerns x Barriers boxes) there are boxes representing the attributes related to those specific interoperability areas. The attributes, represented by “At-1” to “At-n” boxes are in the third layer of this model representation and, under each attribute, it is possible to find different guidelines (related to that attribute) and, therefore, related to the predecessor boxes (interoperability area and then concerns). The guidelines are represented by the boxes containing “G-1” to “G-n” and are in the fourth layer of the model. At last, the final layer (fifth) have the representation of the four capability levels (from CL-1 to CL-4). The capability levels are all at the same level (horizontally), but, for space reasons, Figure 102 represents them one under another. The bold bullets indicate that the same structure represented in the left side of the bullets is replicated the same way to the whole model.

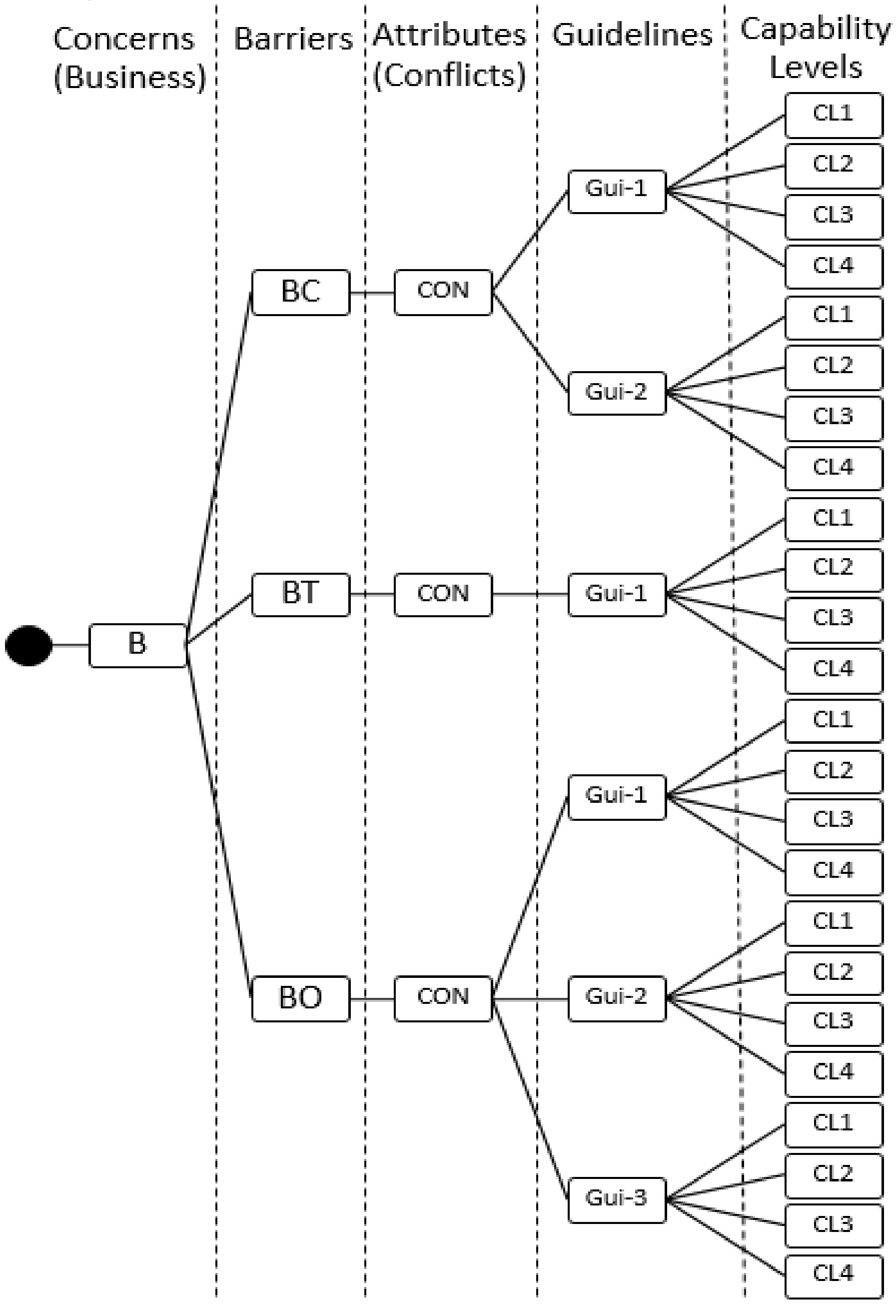
Figure 103 exposes an “instantiated” view of the model structure, considering the “Business” (“B”) as a representative example of the concerns aspects for the first layer. The figure is vertically oriented, rather than horizontally oriented as in Figure 102, and it is possible to see the lanes (with dotted lines) representing the layers (concerns, barriers, attributes, guidelines and capability levels). The chosen represented attribute is “Conflicts”, illustrated with the “CON” acronym. The other layers and components are the same as described in Figure 102, but considering the focus of only one concern view (“Business”).

Figure 102: Model structure with some instantiations



Source: The author (2015).

Figure 103: Model structure with the business concern as example



Source: The author (2015).

To organize and facilitate the understanding and composition of the whole model (PAICM), and as a basis for the diagnosis processes, the attributes are organized in cards (or tables) as illustrate the template model in Table 72.

Table 72: Card model for the attributes

Attribute	<name of the attribute>	**Id**	<an acronym identifying the attribute>
Description	<a general description of the attribute based on the details exposed in section XX. As complementary information, it is possible to see the illustrations and other comments relate to the informative components>. <text, text, text>		

Interoperability areas	The acronyms of the mapping regarding the Concerns x Barriers matrix (where the attributes “belong”). E.g., Concern x Barrier-01, Concern x Barrier-02, Concern x Barrier-NN.
Work products examples	<Documents, processes, information, text, text, text>
Guidelines	
Interoperability areas (Concern x Barrier Acronym-01)	
<Attribute_Id>-<Interoperability_Area>-Gui.01: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.02: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.NN: <text, text, text>	
Interoperability areas (Concern x Barrier Acronym-02)	
<Attribute_Id>-<Interoperability_Area>-Gui.01: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.02: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.NN: <text, text, text>	
Interoperability areas (Concern x Barrier Acronym-NN)	
<Attribute_Id>-<Interoperability_Area>-Gui.01: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.02: <text, text, text>	
<Attribute_Id>-<Interoperability_Area>-Gui.NN: <text, text, text>	

The structure of Table 72 represents some aspects illustrated in Figure 101, especially the organization and details regarding the attributes and its composition. The “Attribute” rectangle identify the name of the attribute being described, while the “Id” is its acronym and the “Description” field contain a general description and application of the attribute. The “Interoperability areas” exposes the acronym of the concern x barrier (e.g., BC, PO, and DT) cells to which that specific attribute is related. That is, the interpretation is “The attribute ‘X’ is related to the ‘CB_1, CB_N’ interoperability Concerns x Barriers cells”. The “Work products examples” exhibits, as an informational component, some examples of artifacts, documents and/or registers that can be used to exemplify the output artifact of that attribute and guidelines implementation. The “Guidelines” section contains the guidelines related to the specific attribute of the card. Under the “Guidelines” main section, there is the division by “Interoperability areas” and then the guidelines themselves, organized according to the nomenclature exposed in the lines of Table 72. “Gui” is from “guideline” and the sequential number after the “.” indicates the number of that guideline within a specific interoperability area. For example, consider the text “ACC-ST-Gui.02:” the “ACC” is for the attribute “Accessibility”, “ST” is for “Service x Technological” concern x barrier and “02” indicates that this is the second guideline of the ST area in the “Accessibility” attribute. All the attributes cards are described and exposed from Table 73 to Table 94.

Table 73: Accessibility card

Attribute	Accessibility	Id	ACC
Description	The access to all the information needed improves the interoperability. There can be degrees of access information, according to roles and job functions. Nevertheless, once the interoperability definitions relate to the exchange and use of information, the access to information is crucial. Information must be able to be used, obtained, reached or approached. *For more comments and illustrations, please see informative components exposed in section 6.1.3.1.*		
Interoperability areas	ST, DT.		
Work products examples	Access plan and rules, policy regarding the data access, open data available, data protection plan, configuration management for the data.		
Guidelines			
ST			
ACC-ST-Gui.01: Provide services (e.g., web services) to the users and other potential stakeholders so they can have transparent access to information.			
ACC-ST-Gui.02: There are policy and procedures (or equivalent documents) for accessing information within the entity (not only considering web services exchange of information but also related to the exchange of e-mail and other formal communication).			
ACC-ST-Gui.03: Provide accessible services to users using Internet technology (e.g., citizens and other users can perform activities using the internet).			
DT			
ACC-DT-Gui.01: There are defined protocols or formats to exchange information between databases, services or systems.			
ACC-DT-Gui.02: Identify all the data that can be shared, including criteria definitions criteria for access and change those data.			
ACC-DT-Gui.03: Implement open data principles (e.g., whenever it is possible, the data is public available and can use to build new services or tools to users).			

Table 74: Adaptability card

Attribute	Adaptability	**Id**	ADA
Description	An adaptable entity can adjust to new conditions to fit in some situation or purpose. Flexibility, versatility and a higher degree of adaptation facilitate the interoperability between entities. The relations are always changing and evolving through the year (e.g., political changes, human resources change, and technological evolution). *For more comments and illustrations, please see informative components exposed in section 6.1.3.2.*		
Interoperability areas	BT, BO.		
Work products examples	Tailoring rules, periodically review of processes and other documents, risk managing, contingency plan, non-dependency plan.		
Guidelines			
BT			
ADA-BT-Gui.01: Review and update (if it is necessary) the strategic plan (or equivalent document) on a periodic and defined basis.			
ADA-BT-Gui.02: Review the relationship with the suppliers and clients in a periodic and defined basis to verify if the needs are being met.			
ADA-BT-Gui.03: There are flexible processes and tools to support the daily operation.			
ADA-BT-Gui.04: There is an adaptive IT infrastructure that can evolve and adapt according to the needs.			
BO			
ADA-BO-Gui.01: Provide a tailoring rule and/or method for customizing the processes and other proceedings or documents according to the need of the demand.			
ADA-BO-Gui.02: Provide an adaptive business model according to the need and the demand.			
ADA-BO-Gui.03: The structure of the entity is flexible, considering needs and demands that can emerge from clients, partners or other stakeholders.			
ADA-BO-Gui.04: The team deals with changes in a proper attitude.			

Table 75: Collaboration card

Attribute	Collaboration	**Id**	COL
Description	Collaborative entities produce or conduct work together, sharing information and the work in a mutual engagement of participants in a coordinated effort. The idea is to achieve a common goal. When cooperating, people work together, in a sense of teamwork. *For more comments and illustrations, please see informative components exposed in section 6.1.3.3.*		
Interoperability areas	BT, BO.		
Work products examples	Declared goals, contracts, formed alliances, the perception of collaboration in the entity.		
Guidelines			
BT			
COL-BT-Gui.01: The entity provides collaborative tools to do the work (e.g., portals, source control mechanisms, project management tools).			
BO			
COL-BO-Gui.01: The entity values teamwork and knowledge exchange (e.g., internal training, pair programming, peer reviews, internal meetings, and wikis).			
COL-BO-Gui.02: There are sharing of values, goals, mission and vision.			
COL-BO-Gui.03: The entity values the dialogue, participation and discussions among the team, considering a horizontal and vertical relations.			

Table 76: Commitment card

Attribute	Commitment	**Id**	COM
Description	The state or quality of being dedicated to a cause or activity or the attitude of someone who works very hard to do or support something. The commitment aspect also deals with the term “support”, including, for example, a senior management support. In a complementary view, commitment is measured by what an entity (person, organization) are willing to give up for a certain cause, belief, project or activity. *For more comments and illustrations, please see informative components exposed in section 6.1.3.4.*		
Interoperability areas	BO.		
Work products examples	The strategic plan, perception, and daily actions, explicit agreed commitment (e.g., commitment to a plan or a project).		
Guidelines			
BO			
COM-BO-Gui.01: There is senior management support (top-down support and involvement in the tasks).			
COM-BO-Gui.02: There is a clear leadership (ownership, sponsorship, management are defined, and it is known for every involved).			
COM-BO-Gui.03: There is an implemented sense of trust, loyalty and honesty.			
COM-BO-Gui.04: There is an implemented sense of motivation, responsibility, and respect among the team.			
COM-BO-Gui.05: Commitments are formally established when needed (e.g., commitment to a project plan, commitment to the entity, commitment with the suppliers).			

Table 77: Communication card

Attribute	Communication	Id	COU
Description	Exchanging messages between a sender and a receiver through various methods (written words, nonverbal cues, spoken words). Communication is a mechanism that entities use to establish and modify relationships. The total number of potential communication channels is (n*(n-1))/2, where n represents the number of stakeholders (Project Management Institute, 2013). The communication process has a sender and a receiver, which exchanges information between then using multiples media. During the process, there is noise in the process and problems of the decoding and encoding of information (e.g., interpretations influenced by the context, semantical problems). One of the objectives is to minimize different semantics and syntax problems to perform a good sharing of ideas and feelings. Communication can be internal, formal, vertical, official, oral, written and so on. *For more comments and illustrations, please see informative components exposed in section 6.1.3.5.*		
Interoperability areas	BC, BT, BO, PC, PO, SC, ST, DC, DO		
Work products examples	Communication plan (e.g., who receives certain information, when, how, how often), reports.		
Guidelines			
BC			
COU-BC-Gui.01: There are efforts to minimize the syntactic and semantic differences regarding incompatibilities of information to be exchanged (e.g., business dictionaries, context interpretation, global contextualization of the subject).			
BT			
COU-BT-Gui.01: There are efforts to minimize the incompatibility of protocols and tools used to exchange information (e.g., adoption of common protocols, common tools, avoid different tools and repositories).			
COU-BT-Gui.02: There are common tools to share communication within the entity (e.g., newsletter, portals, and mailings).			
BO			
COU-BO-Gui.01: There is a communication process established (e.g., communication plan with names, tools, and information about who receives what, when and how).			
COU-BO-Gui.02: There are efforts to minimize multilingualism and culture barriers (e.g., socialization, exposition and discussion about diversity).			
COU-BO-Gui.03: There are promotion and dissemination of common definitions (i.e., the entity explains and disseminate what kind of information it wants to share and how to interpret such information).			
COU-BO-Gui.04: The entity values feedback and permits that people contribute to the processes (aiming to increase the overall performance).			
COU-BO-Gui.05: The results of meetings and other discussions are registered and maintained for future references (e.g., official memoranda, registers, lessons learned, and courses).			
PC			
COU-PC-Gui.01: The processes and activities are clear and communicate for all the involved (e.g., there are training, discussions, easy access to that information).			
PO			
COU-PO-Gui.01: People are trained in their pertinent processes so they can perform correctly.			

COU-PO-Gui.02: All the pertinent processes of the entity (e.g., support, business and management processes) work together as a system (e.g., system and process oriented entity).
SC
COU-SC-Gui.01: The services are described clearly, with comprehensive syntax (language/formalism used to describe the services) and semantics (meaning of services are clear).
COU-SC-Gui.02: There is a service portfolio available for all the pertinent people involved.
ST
COU-ST-Gui.01: The services work together using adequate technology and techniques to exchange information in a proper way (e.g., web services, connections to heterogeneous databases).
COU-ST-Gui.02: There are available services for the stakeholders, so it is possible to execute activities using them. *Obs: the services can exchange information among them (e.g., public channels that communicates with internal systems, remote tasks, tasks related to service desk services, help desk)*.
DC
COU-DC-Gui.01: There are data dictionaries and explanations regarding the meaning of the data (e.g., databases structures of the systems are documented, the development team can share and access those data dictionaries).
DO
COU-DO-Gui.01: Permission to access and share data are defined and implemented (e.g., database control).

Table 78: Conflicts card.

Attribute	Conflicts	Id	CON
Description	A conflictive environment difficult the implementation and maintaining of interoperability aspect, among other things. Crisis, political issues and conflict of interests produce noise and challenging barriers to transpose, once the multiples interests do not help the achievement of a common and shared goal. A conflict is an incompatibility between two or more opinions, principles, or interests, with a strong disagreement between people, groups or a competitive or opposing action. *For more comments and illustrations, please see informative components exposed in section 6.1.3.6.*		
Interoperability areas	BC, BT, BO.		
Work products examples	Perceptions of managers with different views, entities with opposite objectives, political aspects, people with different positions, different background and culture.		
Guidelines			
BC			
CON-BC-Gui.01: There is shared knowledge about terms, words and use of certain phrases to avoid semantical problems and misinterpretation (i.e., several conflicts emerge from communication problems, conflicting terminologies).			
BT			
CON-BT-Gui.01: The technical issues related to the business operation are managed strategically (according to the needs).			
CON-BT-Gui.02: There is an effort of minimizing the conflicts between systems (e.g., different operational systems, different databases, and different versions).			
CON-BT-Gui.03: The technical environment follows a certain standard, according to the possibility (e.g., same tools, machines, hardware, equipment, office).			
BO			
CON-BO-Gui.01: There are efforts to minimize the conflicts among the team within the entity (e.g., people conflicts, personalities).			
CON-BO-Gui.02: The relation between the entity and its partners (e.g., supplier, stakeholders, users) are transparent and with a common goal (usually formalized with agreements, contracts, non-disclosure agreements).			
CON-BO-Gui.03: There are efforts to solve conflicts with other involved entities (e.g., senior management gets involved, meetings, and negotiation).			
CON-BO-Gui.04: There are implemented formal ways and techniques to solve conflicts (e.g., there are guides, rules, and/or training relating the conflicts resolution).			
CON-BO-Gui.05: There is a focus on the problem and not on the person (process-oriented), avoiding the “blame game” and focusing on the future and not in the past.			
CON-BO-Gui.06: Identify and manage the conflicts until their resolution (e.g., register the problems, propose solutions, and follow up the activities).			

Table 79: Cooperation card

Attribute	Cooperation	Id	COO
Description	Cooperation is a little different from collaboration once it concerns to the division of labor among participants (e.g., between two or more different entities). Each person or entity handles a portion of the solution. When cooperating, entities perform together (co-operate) while working on selfish yet common goals. Usually is a more formal relationship and an understanding of compatible missions. Despite that, in both terms (collaboration and cooperation) there is an idea of engagement to work together to achieve a goal and to increase the interoperability. *For more comments and illustrations, please see informative components exposed in section 6.1.3.7.*		
Interoperability areas	BT, BO.		
Work products examples	Contracts, Partnerships, reports.		
Guidelines			
BT			
COO-BT-Gui.01: Tools, systems, and services work in a connected way (e.g., exchange information without the need of data replication).			
COO-BT-Gui.02: Tools, systems, and services share the same environment (e.g., same physical or logical environment, same servers, and established connections).			
COO-BT-Gui.03: There is a plan (e.g., documents, proceedings) formalizing how the systems cooperate (e.g., rules for data exchange, services parameters, and variables).			
COO-BT-Gui.04: There are criteria to select suppliers and/or partners.			
BO			
COO-BO-Gui.01: There is a plan (e.g., documents, proceedings) formalizing how people cooperate with the entity and vice-versa (e.g., expectations, duties and rights).			
COO-BO-Gui.02: There is an implemented perception of teamwork, honesty and mutual trust among the people, between people and the entity and between the entity and its suppliers, users or stakeholders.			
COO-BO-Gui.03: There is an explicit partnership with other entities or organizations (e.g., cooperation terms, agreements, public or private relationships).			
COO-BO-Gui.04: The relationship with the stakeholders (e.g., suppliers, users) is managed (e.g., verify and analyze the accomplishments and if the results are being achieved).			

Table 80: Culture card

Attribute	Culture	Id	CUL
Description	Culture is a set of shared attitudes, values, goals, and practices that characterize an institution or organization (corporate culture). A way of thinking, behaving, or working that exists in a place or agency. The characteristic features of everyday existence (as diversions or a way of life) shared by people in a place or time. Set of values, conventions, or social practices associated with a particular field, activity, or societal characteristic. The culture aspect influences the interoperability in a way that affects the people behavior and reflects sociological aspects of each one (not only people but also entity). The tradition and language of an entity, for example, can affect the relations between entities. *For more comments and illustrations, please see informative components exposed in section 6.1.3.8.*		
Interoperability areas	BO.		
Work products examples	Heritage, society context, religion, tradition, language.		
Guidelines			
BO			
CUL-BO-Gui.01: There is the appropriate degree of liberty to the employees, respecting the divergences of opinion, religion, race, gender and belief.			
CUL-BO-Gui.02: The tradition and historical aspects are properly managed (e.g., traditions are important but they cannot affect (negatively) the business partnerships and other relations).			
CUL-BO-Gui.03: The entity manages the changes and adaptation needs (e.g., the structure is formal but not 'solid' to the point of became impossible (or tough) to change or adapt).			
CUL-BO-Gui.04: The entity manages the society influences and other cultural context aspects to minimize negative impacts on partners, clients, and general stakeholders.			
CUL-BO-Gui.05: The entity manages human behaviors that can difficult the daily basis operation and affect the relations.			
CUL-BO-Gui.06: There are sense and willingness for cultural adaptation.			
CUL-BO-Gui.07: The entity manages the sociological aspects to provide a competitive advantage (e.g., increase the interoperability with people from different parts of the world, different languages).			

Table 81: Economy card

Attribute	Economy	Id	ECO
Description	The financial aspect helps to measure the wealth and resources of a country or region (or entity), especially in terms of the production and consumption of goods and services. The structure or conditions of economic life in a country, area, company or period affects an entity. Variations in the economic environment also influence the business development, partnerships, investments, mood and, of course, the willing to interoperate. Especially in a public administration scenario, when the economy directs affects new projects and services. *For more comments and illustrations, please see informative components exposed in section 6.1.3.9.*		
Interoperability areas	BO.		
Work products examples	Economic situation, renegotiation, postponement		
Guidelines			
BO			
ECO-BO-Gui.01: The strategic plan considers contingency items regarding the financial context of the environment (e.g., a risk management can also deal with this kind of risks).			
ECO-BO-Gui.02: The entity seeks for financial independence and plans its financial resources.			
ECO-BO-Gui.03: There is a financial manager responsible for the economic and fiscal aspects of the institution.			
ECO-BO-Gui.04: There is an external financial auditing and/or accountability (e.g., the financial aspects are publicized and can be approved for an external entity).			

Table 82: Efficiency card

Attribute	Efficiency	Id	EFF
Description	The ability to do something or produce something without wasting materials, time, or energy, seeking to optimize all the means used in pursuit of achieving excellence. Efficiency is related to productivity (relation between the results obtained and the resources used), and it is important for all the activities and processes performed by the entity. The management of the processes (see attribute "Monitoring") helps to control and measure the efficiency of the practices adopted. In general, the goal is always to maximize the effectiveness of the operations. *For more comments and illustrations, please see informative components exposed in section 6.1.3.10.*		
Interoperability areas	BT, BO, PT, PO.		
Work products examples	Measurement and control tables benchmark with partners and other entities.		
Guidelines			
BT			
EFF-BT-Gui.01: The degree of computerization is adequate for the needs (e.g., services, data and processes are automated in IT).			
EFF-BT-Gui.02: The IT can support the requirements of the business.			
EFF-BT-Gui.03: The usability of the tools is adequate and helps to achieve better performance rather than difficult the work.			
BO			
EFF-BO-Gui.01: There is waste management considering the outputs of the processes or material used on a daily basis.			
EFF-BO-Gui.02: The measures are evaluated with proper management and compared to the market (in complement, managers seek the improvement of indicators proposing and executing practical actions).			
PT			
EFF-PT-Gui.01: There are indicators that measure the processes of the entity (deviations are treated and managed until their conclusion).			
PO			
EFF-PO-Gui.01: There are guidelines, processes and practices regarding the measurement of the processes and outputs of the operation (e.g., guidelines and documentation describing the indicators, how to collect them, how to analyze).			
EFF-PO-Gui.02: The entity implements (or is certified in) standards or norms (e.g., ISO) and/or other maturity models (e.g., CMMI, MPS.BR (SOFTEX, 2012)).			

Table 83: Governance card

Attribute	Governance	Id	GOV
Description	The way an entity is controlled by the people who run it. Administration, authority, rule, government, jurisdiction, and regimen are related to governance. The organization, machinery, or agency through which an entity exercises authority and performs functions and which is usually classified according to the distribution of power within it. The way the rules, norms and actions are produced, sustained, and regulated. The degree of formality depends on the internal norms of a given organization. An entity willing to maintain interoperability practices must have governability of how the things are working. The IT governance plays a significant role in this context, increasing the interoperability aspects regarding IT involvement. *For more comments and illustrations, please see informative components exposed in section 6.1.3.11.*		
Interoperability areas	BT, BO, PT, PO.		
Work products examples	Governance plan, IT plan, rules, and proceedings.		
Guidelines			
BT			
GOV-BT-Gui.01: The IT supports and it is aligned with the business of the entity.			
BO			
GOV-BO-Gui.01: The investments are effectively managed throughout their life cycle.			
GOV-BO-Gui.02: The importance of governance is understood.			
GOV-BO-Gui.03: The IT is adding value to the business.			
PT			
GOV-PT-Gui.01: The IT risks are effectively mitigated.			
GOV-PT-Gui.02: There are clear ownership and responsibilities based on process orientation.			
PO			
GOV-PO-Gui.01: The management and business processes are transparent to the entity.			
GOV-PO-Gui.02: The management and business processes have a common language and goals for the executives, business and IT staff.			

Table 84: Human resources card

Attribute	Human resources	Id	HUM
Description	Related to personnel aspects (training, maturity, skills, and workforce). Concerned with the relations among the employees (and employer. Aligning with business strategy, re-engineering organization processes, listening and responding to employees, and managing transformation and change. With a connection to the culture issues, human aspects are important to implement a higher degree of interoperability in public administration entities, once several activities depend on the structured knowledge, historical aspects, and networking. *For more comments and illustrations, please see informative components exposed in section 6.1.3.12.*		
Interoperability areas	BO.		
Work products examples	Training plan, strategic plan, skills, and goals.		
Guidelines			
BO			
HUM-BO-Gui.01: The strategic needs of the entity are reviewed to identify resources, knowledge and skills (a plan of how to develop or hire people can be created as part of the whole human resources management).			
HUM-BO-Gui.02: The competencies and skills of the team are established and maintained.			
HUM-BO-Gui.03: The training needs are established and maintained, and a strategy to achieve them is defined.			
HUM-BO-Gui.04: The training is managed until its conclusion, and its effectivity is evaluated.			
HUM-BO-Gui.05: The people are evaluated according to objective criteria (e.g., personal performance evaluation, 360-degree evaluation, information about how to improve the performance and gaps are presented).			
HUM-BO-Gui.06: There are sharing of knowledge.			

Table 85: Infrastructure card

Attribute	Infrastructure	Id	INF
Description	Besides the resources required for an activity and the basic physical and organizational structure (or services) needed for the operation, infrastructure also relates to the management of incidents and problems (e.g., service desk support). *For more comments and illustrations, please see informative components exposed in section 6.1.3.13.*		
Interoperability areas	BT, BO, ST, SO.		
Work products examples	Defined infrastructure, services, building, and facilities.		
Guidelines			
BT			
INF-BT-Gui.01: The infrastructure to execute the daily operation is established and maintained.			
INF-BT-Gui.02: There is a system to manage the incidents and other requisitions.			
INF-BT-Gui.03: People have the adequate resource (regarding infrastructure) to perform their daily activities.			
BO			
INF-BO-Gui.01: There is a strategy to manage the incidents and other requisitions.			
ST			
INF-ST-Gui.01: Services and its dependencies are identified (e.g., systems interface and connections).			
SO			
INF-SO-Gui.01: The service's criteria and goals are defined in service level agreements (SLAs) or other pertinent documents.			

Table 86: Integration card

Attribute	Integration	Id	INT
Description	Working in an integrated way is a coordination of mental processes with the environment, combining and coordinating of separate parts or elements into a unified whole. The process by which the different parts of an organism are made a functional and structural whole. Existing applications that allow access to enterprise data and facilitate analysis and decision making using standard technology that permits the composition of the services. *For more comments and illustrations, please see informative components exposed in section 6.1.3.14.*		
Interoperability areas	ST, SO, DT, DO.		
Work products examples	Services documentation, process mapping (outputs of processes are inputs to others).		
Guidelines			
ST			
INT-ST-Gui.01: The entity provides integrated services, so the user does not need to use several services to perform an activity (e.g., the services are integrated, the platforms are integrated).			
INT-ST-Gui.02: The service's interface is planned and designed for compatibility with other services and/or tools.			
SO			
INT-SO-Gui.01: There is an integration strategy (not only for technical aspects but also related to the business perspective).			
DT			
INT-DT-Gui.01: The databases are integrated and/or work in a transparent way (e.g., multiples databases exchange data using transparent mechanisms, no data duplication or replication are needed, or the process of replication is transparent).			
DO			
INT-DO-Gui.01: The data access is managed (e.g., minimizing multiple logins and/or permissions configurations).			

Table 87: Legality card

Attribute	Legality	Id	LEG
Description	Each entity (and especially a public administration) works within its legal framework. The operation and interoperability aspects must follow the legal aspects of its context when dealing with exchange information (all information can be exposed or exchanged?). The adherence to the legislation and the attachment to or observance of the law is a required aspect of any entity. *For more comments and illustrations, please see informative components exposed in section 6.1.3.15.*		
Interoperability areas	BO, PO.		
Work products examples	Contracts, laws, legislations.		
Guidelines			
BO			
LEG-BO-Gui.01: The operation is managed in a way that the legal aspects are covered and managed.			
LEG-BO-Gui.02: There is an area (or a responsible) to review and monitor the legal dimensions of the entity and the environment.			
LEG-BO-Gui.03: All the pertinent information has its security level, and only those authorized may access (complementary to the accessibility, security and other aspects).			
PO			
LEG-PO-Gui.01: There are specific proceedings regarding the use and exchange of information (e.g., contracts, non-disclosure agreements).			
LEG-PO-Gui.02: There is a configuration management plan that defines the roles, permissions, location and other information regarding the contracts and other legal documents (including pertinent laws and bids).			
LEG-PO-Gui.03: External audits are defined and managed to evaluate the adherence to the multiples levels of the legislation aspects (e.g., municipality, state and federal).			

Table 88: Monitoring

Attribute	Monitoring	Id	MON
Description	Watch, observe, keep track of, listen to, or check (something) for a particular purpose over a period. Observe a situation for any changes that may occur over time. Observes a process or activity to check that it is carried out fairly or correctly. The management and monitoring provide an understanding of the progress of the entity and his processes so that appropriate corrective actions can be taken when the performance deviates significantly from the plan. *For more comments and illustrations, please see informative components exposed in section 6.1.3.16.*		
Interoperability areas	BO, PO.		
Work products examples	Measurement analysis, indicators, reports, plans.		
Guidelines			
BO			
MON-BO-Gui.01: The progress of the daily operation is reviewed and monitored against the schedule.			
MON-BO-Gui.02: The costs and effort of day-to-day operation are controlled according to the plan.			
MON-BO-Gui.03: Changes in the requirements of any service are updated in the whole set of documents and artifacts (e.g., contracts, service level agreements).			
MON-BO-Gui.04: The commitments, risks, and stakeholder involvement are managed.			
MON-BO-Gui.05: All found issues are analyzed, and corrective actions are taken.			
PO			
MON-PO-Gui.01: The processes (e.g., business, support or management) are monitored with the use of indicators.			
MON-PO-Gui.02: There are processes that describe the functioning regarding the monitoring aspect (e.g., how the monitoring works, what are the indicators, who are the responsible).			

Table 89: Policy and regulations

Attribute	Policy and regulations	**Id**	POR
Description	Define a course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions. General plan to embrace the general goals and acceptable procedures, especially of a governmental body. The system of principles to guide decisions and achieve rational outcomes. The rule, directive or order issued by an executive authority or regulatory agency of a government and having the force of law. *For more comments and illustrations, please see informative components exposed in section 6.1.3.17.*		
Interoperability areas	BC, BO, PC, PO.		
Work products examples	Policy, rules, senior management definitions.		
Guidelines			
BC			
POR-BC-Gui.01: There is an established and maintained organizational policy regarding technical aspects.			
POR-BC-Gui.02: There are rules about the use of gadgets and technology within the entity (e.g., cell phones, tablets, and internet).			
BO			
POR-BO-Gui.01: There is an established and maintained organizational policy related to strategic aspects (e.g., mission, vision, goals).			
POR-BO-Gui.02: There are rules about the behavior and conduct of employees and other pertinent involved (e.g., dressing code, safety aspects).			
PC			
POR-PC-Gui.01: The policy's content and coverage are adequate for the entity's purposes and processes.			
POR-PC-Gui.02: The syntax and semantics of the policy and regulations are appropriate and clear for all the involved.			
PO			
POR-PO-Gui.01: There is an established and maintained organizational policy for performing the processes (e.g., process performance goals, expectations).			

Table 90: Political card

Attribute	Political	Id	POL
Description	Political issues relate to the government or the public affairs of a country. Activities associated with the governance of a country or other area, especially the debate or conflict among individuals or parties having or hoping to achieve power. Politics deals with activities that relate to influencing the actions and policies of a government or getting and keeping power in a government. Also, in this context, politics are applied in the entity's environment and not necessarily regarding the whole country, once every entity and its employees do politics in a higher or lower degree (e.g., power games, influence games, personal will). Legal and economic changes may also occur because of politics. *For more comments and illustrations, please see informative components exposed in section 6.1.3.18.*		
Interoperability areas	BC, BO.		
Work products examples	Elections, change of political will, lack of endorsement.		
Guidelines			
BC			
POL-BC-Gui.01: The political aspects of the context are taken into account when it comes to managing the operations (e.g., continuity plan in case of political changes, risk management).			
BO			
POL-BO-Gui.01: The political influence is managed within the entity (e.g., proceedings and documents regarding the political lobby and relationships).			
POL-BO-Gui.02: The financial dependency of the political will or political environment is managed within the entity. *Obs: a public administration related entity may depend on some aspect of government investment, but not necessarily depending on a political will of some party or person*.			
POL-BO-Gui.03: There is a search for political endorsement or support to legitimize and empower the entity and its activities.			

Table 91: Responsibility card

Attribute	Responsibility	Id	RES
Description	The state or fact of having a duty to deal with something or of having control over someone. A thing that one is required to do as part of a job, role, or legal obligation. A duty or task that is required or expected to do. *For more comments and illustrations, please see informative components exposed in section 6.1.3.19.*		
Interoperability areas	BO, PO.		
Work products examples	Roles definitions, RACI matrix.		
Guidelines			
BO			
RES-BO-Gui.01: Responsibilities and authorities (within the entity) are defined and in place (e.g., responsibility matrix, RACI matrix).			
RES-BO-Gui.02: There are consensus and visibility of the ownership, management, and accountability regarding the authorities and roles.			
RES-BO-Gui.03: The expectations, roles, and responsibilities regarding the clients, partners, and other suppliers are established and maintained (e.g., contracts, agreements).			
PO			
RES-PO-Gui.01: The responsibilities and authorities to perform and execute the processes are established and maintained.			

Table 92: Security card

Attribute	Security	Id	SEC
Description	Includes physical and logical security. Procedures followed or measures taken to ensure the security of a state or organization. Information security: the practice of defending information from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction. It is a general term that can be used regardless of the form the data may take. The act of ensuring that data is not lost when critical issues arise. *For more comments and illustrations, please see informative components exposed in section 6.1.3.20.*		
Interoperability areas	BO, PO, DO.		
Work products examples	Security plan, data recovery plan, contingency plan, permissions, continuity.		
Guidelines			
BO			
SEC-BO-Gui.01: There are business security policies (e.g., strategic plans for security aspects, continuity plans, contingency plans).			
SEC-BO-Gui.02: There are audits regarding security aspects and actions are taken when needed.			
SEC-BO-Gui.03: Incidents related to security aspects are managed to their conclusion.			
SEC-BO-Gui.04: The security aspects are managed within the context of risk management principles.			
SEC-BO-Gui.05: There are established and maintained education and training actions regarding security aspects.			
PO			
SEC-PO-Gui.01: Security controls are implemented and maintained to address changing circumstances, such as changes in business and IT service requirements, IT architecture elements and threats.			
SEC-PO-Gui.02: There are established and maintained proceedings for physical access (e.g., access to the facilities, building, offices, and computers).			
SEC-PO-Gui.03: There are established and maintained proceedings for equipment maintenance (e.g., change of spare pieces, reviews, cleaning).			
SEC-PO-Gui.04: There are established and maintained proceedings for control against malicious code (e.g., viruses, hacker attack).			
SEC-PO-Gui.05: There are established and maintained proceedings for network security.			
SEC-PO-Gui.06: There are established and maintained proceedings for the management of removable media (e.g., flash drives, external HDs).			
SEC-PO-Gui.07: There are established and maintained proceedings for media discard.			
DO			
SEC-DO-Gui.01: There are practices regarding the control of propriety and inventory of data.			
SEC-DO-Gui.02: There is data access control.			
SEC-DO-Gui.03: There is protection against the leak of information and data.			

Table 93: Standardization card

Attribute	Standardization	Id	STA
Description	Something set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality. Regularly and widely used, seen, or accepted. Substantially uniform and well established by usage. The use of standards creates patterns, proceedings and common information for all stakeholders. Standards help interoperability, once it defines common layers and common guidelines and protocols to do the tasks and exchange information. *For more comments and illustrations, please see informative components exposed in section 6.1.3.21.*		
Interoperability areas	PT, PO.		
Work products examples	Standards, norms, models, processes.		
Guidelines			
PT			
STA-PT-Gui.01: There are processes and standards for the technical operation.			
STA-PT-Gui.02: There are support processes that support the technical activities.			
STA-PT-Gui.03: There are connectivity standards.			
PO			
STA-PO-Gui.01: The entity is process-oriented (e.g., there are support processes, business processes, and strategic processes).			
STA-PO-Gui.02: The entity adopts process-oriented norms, models or certifications (e.g., CMMI, MPS.BR (SOFTEX, 2012), and ISO).			

Table 94: Tools card

<table>
<tr><th>Attribute</th><td>Tools</td><th>Id</th><td>TOO</td></tr>
<tr><th>Description</th><td colspan="3">Something (an instrument or apparatus) used in performing an operation or necessary in the practice of an activity. Practical application of knowledge especially in a particular area. The manner of accomplishing a task especially using technical processes, methods, or knowledge. A collection of techniques, methods or processes utilized in the production of goods or services or the accomplishment of objectives. The use of technology is crucial to interoperability (especially, but not only, related to technical aspects). The existence of several tools from different suppliers demands a higher maturity skill to create abstraction layers to interpret and exchange data. Tools are components the makes the process work, along with human resources and proceedings.
For more comments and illustrations, please see informative components exposed in section 6.1.3.22.</td></tr>
<tr><th>Interoperability areas</th><td colspan="3">BT, PT, SC, ST, DC, DT.</td></tr>
<tr><th>Work products examples</th><td colspan="3">Supporting tools, portal, development tools, software, hardware, new processes, new design mechanisms.</td></tr>
<tr><th colspan="4">Guidelines</th></tr>
<tr><td colspan="4" align="center">BT</td></tr>
<tr><td colspan="4">TOO-BT-Gui.01: There are available tools that support the technical activities.</td></tr>
<tr><td colspan="4">TOO-BT-Gui.02: The degree of computerization is high.</td></tr>
<tr><td colspan="4" align="center">PT</td></tr>
<tr><td colspan="4">TOO-PT-Gui.01: The tools used in the daily operation have proceedings, guidelines and manuals for their correct use.</td></tr>
<tr><td colspan="4" align="center">SC</td></tr>
<tr><td colspan="4">TOO-SC-Gui.01: The tools that provide services (or are accessed using services' interfaces) have their interface and access protocols well defined and documented.</td></tr>
<tr><td colspan="4" align="center">ST</td></tr>
<tr><td colspan="4">TOO-ST-Gui.01: There are web-service interfaces, so it is possible to access remote services and execute cross-tools operations.</td></tr>
<tr><td colspan="4">TOO-ST-Gui.02: There are e-services offered to the end users (e.g., citizens, stakeholders).</td></tr>
<tr><td colspan="4" align="center">DC</td></tr>
<tr><td colspan="4">TOO-DC-Gui.01: The databases have dictionaries and formal explanation regarding the use of heterogeneous data format and structure.</td></tr>
<tr><td colspan="4" align="center">DT</td></tr>
<tr><td colspan="4">TOO-DT-Gui.01: There are established and maintained protocols or format available to share information (e.g., XML and others).</td></tr>
<tr><td colspan="4">TOO-DT-Gui.02: There are tools to deal specifically with data management (e.g., knowledge extraction, backups, security and access, export/import).</td></tr>
</table>

6.4 CONSIDERATIONS AND CHAPTER SYNTHESIS

This chapter presented a proposal of a capability maturity model called **Public Administration Interoperability Capability Model (PAICM)**, one of the goals of this research. The section not only described the model itself, but also exposed all the rational adopted to compose its elements: from the selection and extraction of the measurement aspects (attributes), to the categorization within the public administration domain. The PAICM is the reference model adopted to perform the diagnosis within public administration organizations, and, therefore, the diagnosis method (proposed in the next section 7) verifies the organization adherence to the PAICM.

The structure of the PAICM (cards, attributes, descriptions, capability levels organization) is represented in two set of work products: the first one is the collection of spreadsheets that organizes and "materializes" the model into usable artifacts. The spreadsheets contain explanations about the capability levels, contextualization, attributes, guidelines and general information about how to use them to perform a diagnosis. The spreadsheets and tabs are organized to collect and storage information during the diagnosis process, already according to the AHP/ANP structure and considerations regarding the pairwise comparisons. The second work product derived (but not necessarily built sequentially after the spreadsheets) is the Super Decisions model, which is the design representation (architecturally and graphically speaking) of the PAICM, according to the structural needs of the AHP/ANP method. The complete set of spreadsheets and the AHP/ANP design and structure within the Super Decisions software are presented in Cestari et al., (2015a).

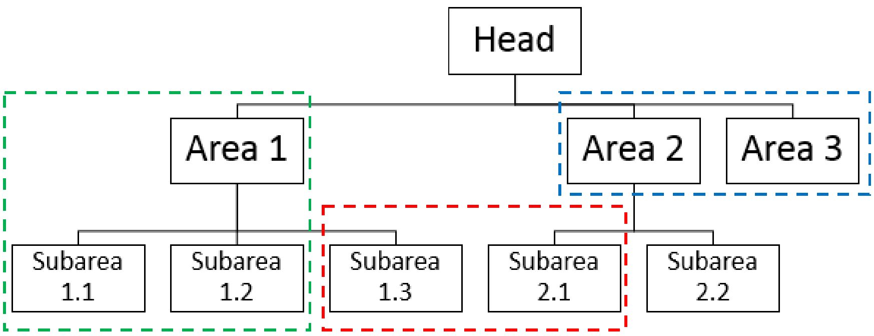
The rational exposed in this section is also a contribution of this research, once this kind of explanations and methods were not found in the literature. As exposed in section 1 (introduction), the documents usually present and exposes the ideas as "take this as a fact", not exposing a rational ("how to") and/or the construction behind it.

7 PUBLIC ADMINISTRATION INTEROPERABILITY DIAGNOSIS METHOD (PAIDM)

Based on a general definition from SCAMPI Upgrade Team (2011), a diagnosis is an examination of one or more processes by a trained team of professionals using one or more models as references as the basis for determining, at least, strengths, weaknesses and capability levels.

The diagnosis occurs in an entity, which is typically part of a larger organization, although, in a small structure, the entity can be the whole organization. An entity deploys one or more processes that have a coherent process context and operates within a coherent set of business objectives. An entity is a logical construction and does not need to be a specific area, but a set of related projects or areas with common aspects that can participate in an interoperability diagnosis process. The definition of which will be the evaluated entity is one of the first activities within the diagnosis process and it is important to remember that the entities should present interoperability requirements (e.g., collaboration, integration, cooperation). That is, the entity must be pertinent to the domain and with the objectives of the diagnosis. Figure 104 shows examples of possible entities (dashed lines – green, red and blue) within a fictional organization.

Figure 104: Examples of possible entities



Source: The author (2015).

It is important to remember that the PAIDM is a method to execute diagnosis according to an existent model and, in this case, the model used as a basis is the proposed PAICM (section 6). The PAIDM has four main goals related to the capability levels diagnosis, exposed in Table 95:

Table 95: PAIDM major goals

Goals	Descriptions	Aspect / View
Goal 1	Provide a Capability Level overview of the entire entity (as a summarization of all aspects treated in the "lower" structure). This view, as it englobes the entity, can be considered as a maturity level diagnosis of the entity, once the values are grouped from the bottom to the "highest" structure level.	Strategic view
Goal 2	Provide a Capability Level overview regarding the concerns aspects	Management view
Goal 3	Provide a Capability Level perspective of the concern x barrier area.	Tactical view
Goal 4	Provide a Capability Level overview of each attribute.	Operational view

Other characteristics and goals for PAIDM are, but not limited to, the following:

- Gain insight into an entity's capability by identifying the strengths and weaknesses of its current processes relative to diagnosis reference model (PAICM).
- Prioritize improvement plans and activities.
- Focus on improvements that are most beneficial to the entity, according to the current level of entity maturity and/or capability levels in interoperability.

Before the description of the activities within the processes related to PAIDM, it is important to explicit some general terms that can appear during a diagnosis process. Table 96 exposes a glossary that is based on shared terms also adopted in ISO/IEC (2015), SCAMPI Upgrade Team (2011) and SEI (2010).

Table 96: General diagnosis terms

Term	Brief description
Affirmation	An oral or written statement confirming or supporting the implementation of guidelines, attributes or practices provided by the implementers of the practice. Affirmations can be provided via an interactive forum (e.g., interviews) in which the diagnosis team leader has control over the interaction.
Consensus	A method of decision making that allows team members to develop a common basis for understanding and develop general agreement concerning a decision that all team members are willing to support.
Consolidation	The activity of collecting and summarizing the information provided into a manageable set of data to (i) determine the

Term	Brief description
	extent to which the data are corroborated and cover the areas being investigated, (ii) determine the data's sufficiency for making judgments, and (iii) revise the data gathering plan as necessary to achieve this sufficiency.
Diagnosis findings	The results of an appraisal that identify, as a minimum, any strengths and weaknesses within the diagnosis scope. Diagnosis findings are inferences drawn from the corroborated interviews and other evidence. The reports can contain the ratings generated as outputs of the appraisal, and the conditions and constraints under which the appraisal was performed and other useful information.
Diagnosis plan	Generated incrementally throughout the planning phase. A document (or set o documents) that contain information regarding the involved, schedules, limitations, dates, infrastructure and other relevant information.
Diagnosis reference model	The PAICM (Public Administration Interoperability Capability Model) or another model to which a diagnosis team correlates implemented process activities.
Diagnosis scope	Boundaries' definition of the diagnosis, considering entity's and model's limits regarding the processes to be investigated.
Diagnosis team	A group of people with proper skills, experience, and knowledge that helps and work together with the diagnosis team leader.
Interviews	A meeting for gathering information about work processes in place. This includes, for example, face-to-face interaction with those implementing or using the processes within the entity. Interviews can occur with various groups or individuals, such as project or work group leaders, managers, and practitioners. A combination of formal and informal interviews may be held, and interview scripts or exploratory questions can be developed to elicit the information needed.

Considering as reference the types of interoperability assessment exposed in Table 39 and some items in Table 44, the PAIDM is characterized by the following aspects:

- During a diagnosis of a sector or entity (as execute in the application cases, section 8), the PAIDM evaluates the potential interoperability of the entity within its application and action domain. In addition, this application/action domain is represented by the PAICM, considering attributes and qualifier guidelines of this domain (public administration). It is not a concern for the PAIDM or PAICM if an entity has a defined partner or if the partner is not known and will be defined in the future. The PAIDM evaluates the potential interoperability of the entity in the domain it operates (entire organization, a single unit, a group of areas, all of them within the public administration domain). For example, the temporal characteristics (*a priori*, *a posteriori*), presented in Table 44, is a consequence of the diagnosis/analysis, and not necessarily relevant or highly pertinent to this research. If the entity, in its application domain, is very adherent to attributes and guidelines, and presents a high maturity or capability level, the entity will probably have a good performance when interoperating with other entity (or organization) that also has a high capability/maturity level of potential interoperability.

- Relating the types of interactions, PAIDM is more adherent to:
    - G2B: government to business.
    - G2G: government to government.
    - G2Org: government-to-organizations.
- It is process-oriented.
- Oriented to capability levels (four levels).

In complement of the criteria adopted in Table 41, which exposes some basic characteristics of interoperability frameworks, Table 97 uses the same aspects to classify the PAICM plus PAIDM approach.

Table 97: PAIDM/PAICM positioning in comparison with other IMMs, based from Yahia (2011)

Framework/Models	Type of measurements	When?
LISI	Qualitative	A priori
OIMM	Qualitative	A priori
LCIM	Qualitative	A priori
EIMM	Qualitative	A priori
MMEI	Qualitative/quantitative	A priori
PAIDM/PAICM	Qualitative/quantitative	A priori

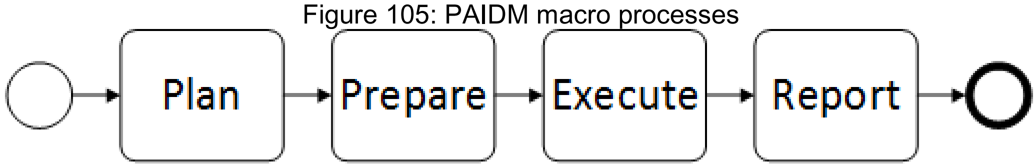
7.1 PROCESSES

The Public Administration Interoperability Diagnosis Method (PAIDM) is composed of a set of processes, including its activities and roles. Table 98 describes the main roles involved, and Figure 105 exposes its macro processes.

Table 98: PAIDM - Main roles involved

Roles	Description
Diagnosis sponsor	An individual (or a group of people), internal or external to the organization being evaluated, who requires the diagnosis to be performed. Can provides financial support or other resources to carry it out the process. In some cases, it can be performed by the senior manager role.
Diagnosis team leader	The person who leads the activities of the diagnosis processes. Must satisfy qualification criteria for experience, knowledge, and skills. In some cases, can be referred to as an "auditor", "appraiser" or another related name.
Project manager	The responsible for the diagnosing process within the entity (usually, the project manager is an entity's employee). Provides technical and administrative direction to those who will participate in the diagnosing process and helps to organize aspects such as access to the facilities, scheduling offices, infrastructure aspects (e.g., passwords, logins).
Senior manager (senior management)	Management role at a high enough level in the organization that the primary focus is the long-term vitality of the organization rather than short-term concerns and pressures. A senior manager can be, for example, the head of the organization. The senior manager is the sponsor of the diagnosis process.
Team of participants	A group of people with complementary skills and expertise who work together. A team can consist of a single individual, depending on the size and organization of the activities, or a group of people. In the diagnosing context, the team of participants is the respondents during the interview processes.

Figure 105: PAIDM macro processes

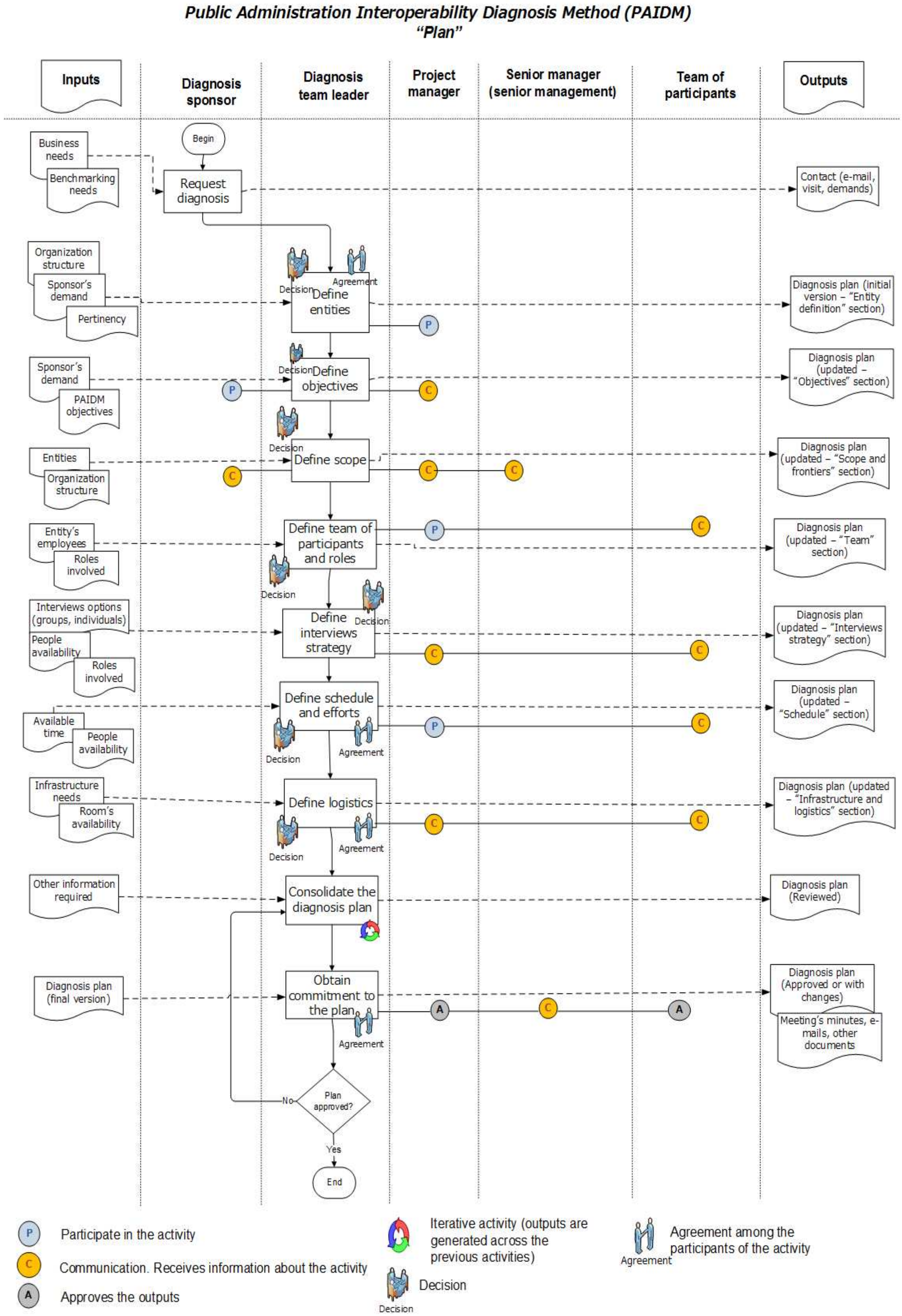


Source: The author (2015).

Figure 106, Figure 107, Figure 108 and Figure 109 details each of the phases exposed in the macro view. The detailed workflows contain lanes exposing the roles involved in the activities (rectangles) performed and an identification of the type involvement (colored circles connected to the activities and within the lane's area). The workflows have a glossary explaining the types of involvement (e.g., C: Communicate, A: Approve).

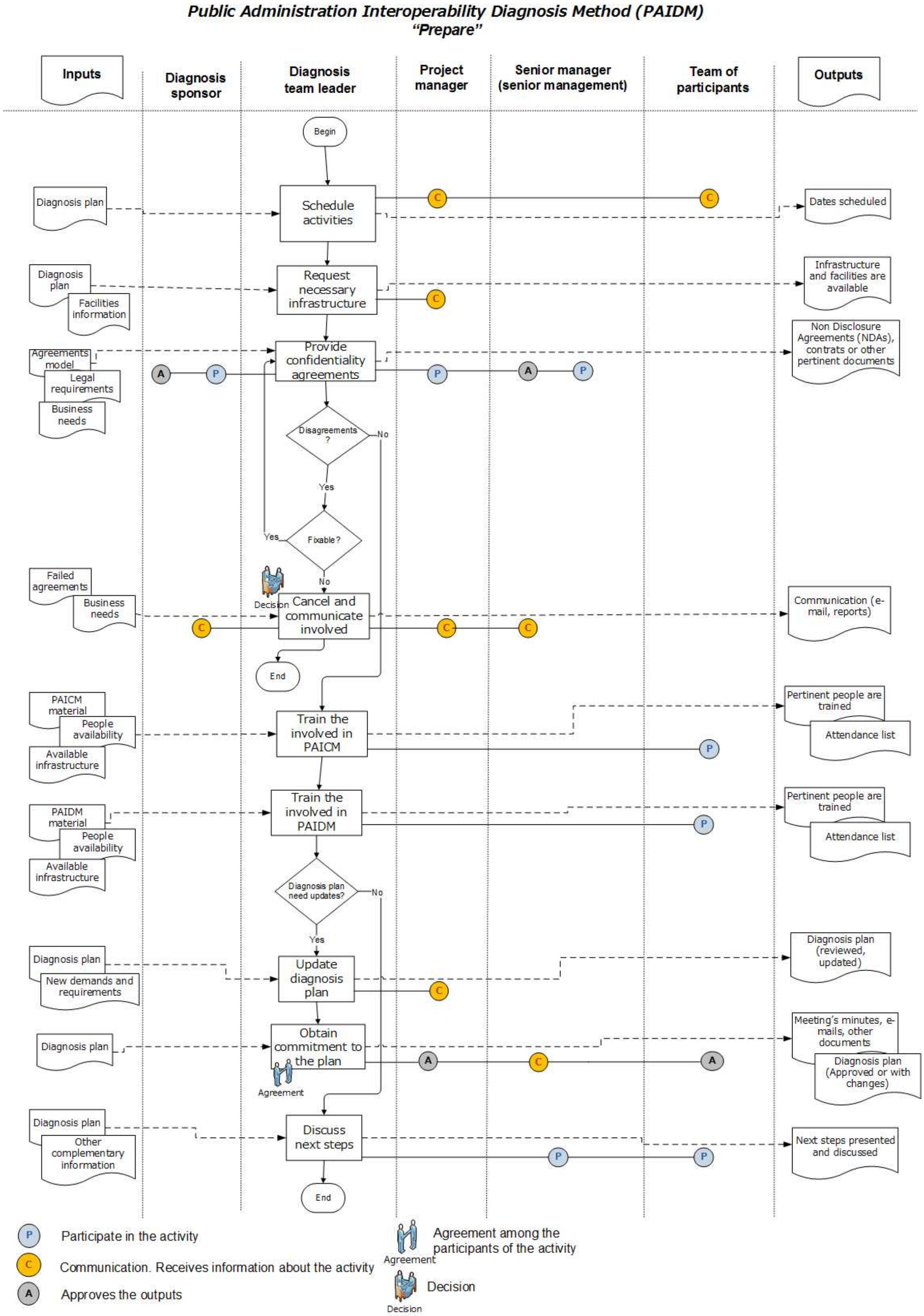
The first lane of the workflows (to the left of the figures) contains some inputs (banner style draw) for the activities and the last lane (to the right of he figures) exposes the outputs (banner style draw) generated by the activities. All these connections are made with dotted lines and arrows. Diamonds represent conditions and decisions and there is another graphical representation indicating some kind of action or extra information (e.g., the image of two people shaking hands indicating that in that activity there is a kind of “agreement”). Those graphical representations are exposed and defined at the bottom of the workflows as a glossary section.

Figure 106: PAIDM – Plan



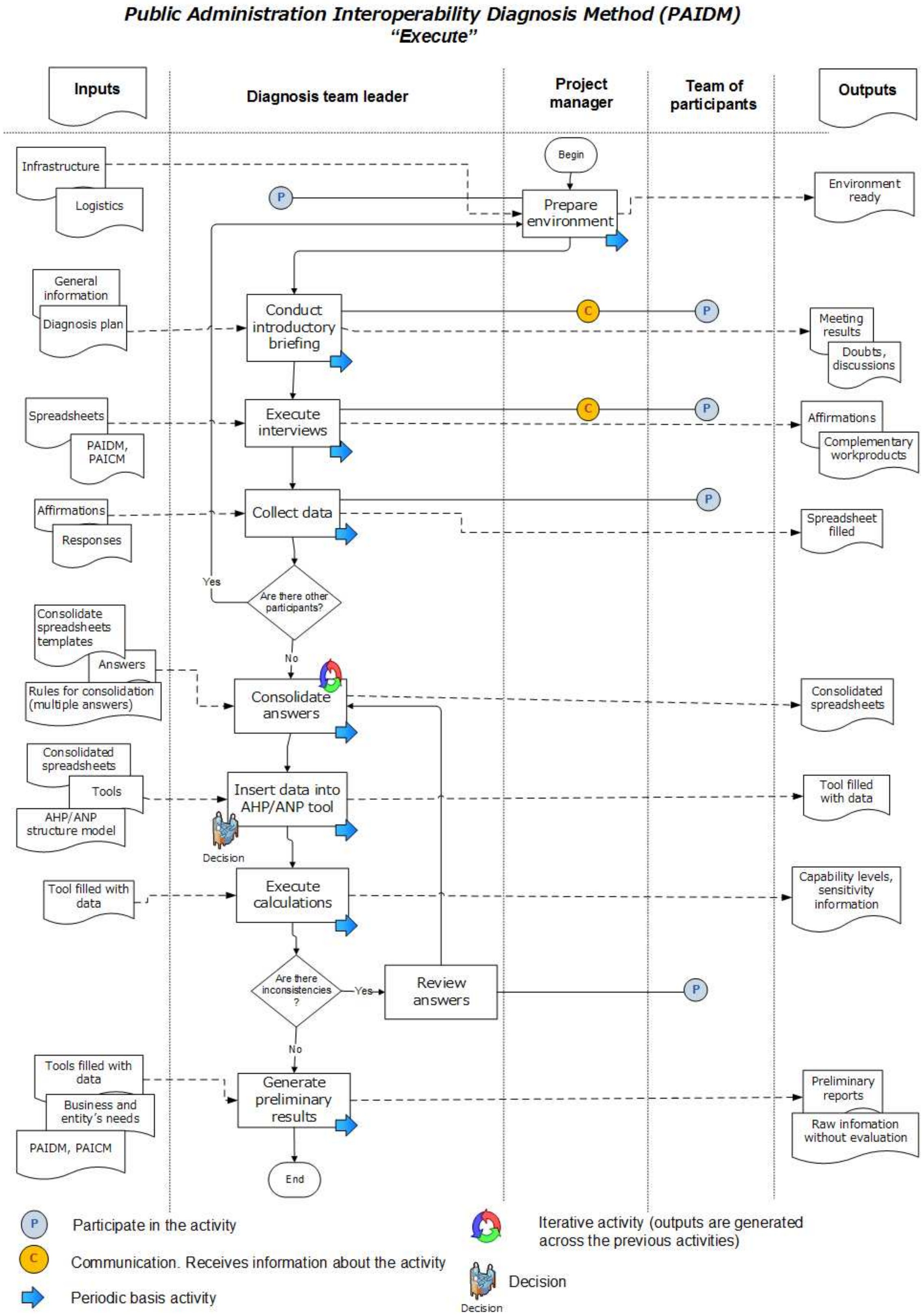
Source: The author (2015).

Figure 107: PAIDM – Prepare



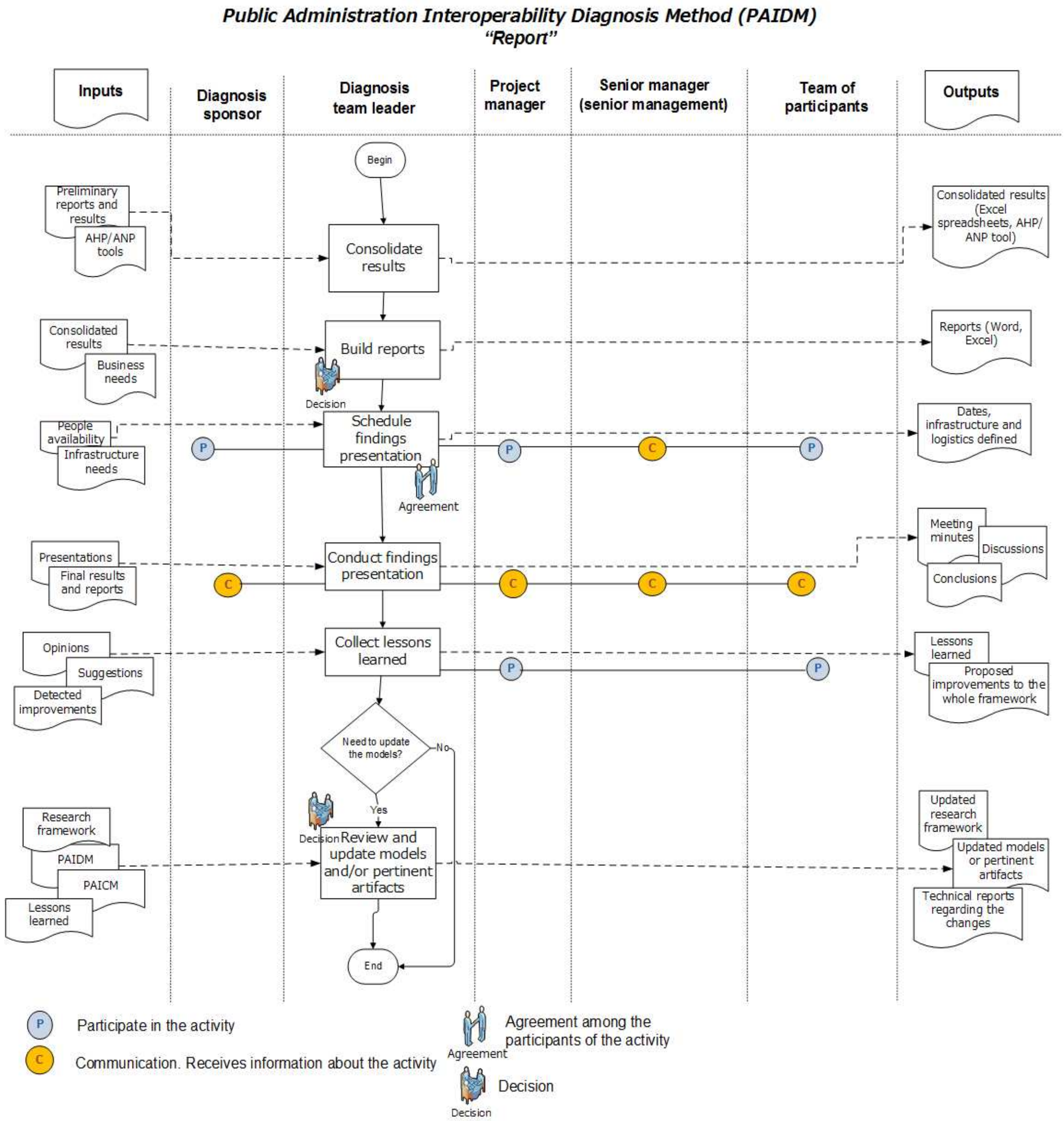
Source: The author (2015).

Figure 108: PAIDM – Execute



Source: The author (2015).

Figure 109: PAIDM – Report



Source: The author (2015).

As exposed in the workflows represented from Figure 106 to Figure 109, the activities within the processes are organized as presented in Table 99 and described from Table 100 to Table 103.

Table 99: PAIDM – Activities organization

Stages (macro-processes)	Activities
1. Plan	1.1 Request diagnosis 1.2 Define entities 1.3 Define objectives 1.4 Define scope 1.5 Define team of participants and roles 1.6 Define interviews strategy 1.7 Define schedule and efforts

Stages (macro-processes)	Activities
	1.8 Define logistics 1.9 Consolidate the diagnosis plan 1.10 Obtain commitment to the plan
2. Prepare	2.1 Schedule activities 2.2 Request necessary infrastructure 2.3 Provide confidentiality agreements 2.4 Cancel and communicate involved 2.5 Train the involved in PAICM 2.6 Train the involved in PAIDM 2.7 Update diagnosis plan 2.8 Obtain commitment to the plan 2.9 Discuss next steps
3. Execute	3.1 Prepare environment 3.2 Conduct introductory briefing 3.3 Execute interviews 3.4 Collect data 3.5 Consolidate answers 3.6 Insert data into AHP/ANP tool 3.7 Execute calculations 3.8 Review answers 3.9 Generate preliminary results
4. Report	4.1 Consolidate results 4.2 Build reports 4.3 Schedule findings presentation 4.4 Conduct findings presentation 4.5 Collect lessons learned 4.6 Review and update models and/or pertinent artifacts

Table 100: PAIDM – “Plan” activities

Stage: Plan	
Activities	**Brief description**
Request diagnosis	A diagnosis sponsor contacts the responsible for the execution of the diagnosing to explicit the desire to perform a diagnosis within the organization. The role of diagnosis sponsor may be internal or even external to the organization being evaluated. That is, in some cases, the demand can emerge from an external need (e.g., case studies, gap analysis). The diagnosis requisition can occur in at least two forms: (i) a representative of the organization contacts the representative of the diagnosis process; (ii) a team leader contacts a representative of the organization to offer the service. This is the initial process and usually is performed with some degree of informality (during a meeting or a business lunch). The subject is discussed, and it is internalized within the organization (e.g., are there other involved that needs to approve the requisition?).

Stage:	Plan

Activities	Brief description
	The activity can also be treated as an initial contact in a business selling process (the activity is interactive, and the parts involved discuss the subject until reaching a consensus).
Define entities	Definition of the most pertinent entities that can participate in the diagnosis is executed (considering the structure of the organization). The definition is based on criteria such as public administration relation context, type of relation, availability of people and information, pertinence. Together with other involved, there are discussions and analysis regarding this subject, trying to select the best representative's people and entity.
Define objectives	Definition of the goals of the diagnosis: purpose, expected results, rating options within the capability levels structure.
Define scope	Definition of the scope of the diagnosis, considering frontiers of the model to the diagnosed (e.g., PAICM). Types of services, areas or sub-unities that will be diagnosed within the entity (e.g., the whole entity's activities? A subpart?).
Define team of participants and roles	According to the needs of the diagnosis process and the availability of the people involved and the roles they perform, a team of participants is defined. Who will participate and which are the expected roles. The names and their responsibilities are discussed.
Define interviews strategy	The interviews can occur in at least two forms: individual interviews or group interviews. The decision can be mixed and depends on a series of other aspects such as (i) number of participants; (ii) time and schedule availability; (iii) coverage areas; (iv) methods to collect and consolidate the data; (v) degree on influence of one's answers over another's. For example, if there are several respondents, and they will be interviewed separately, it must occur a consolidation of the data (usually a geometric mean according to the AHP/ANP original literature). If there are several respondents and the interviews will occur in groups (one or more groups), it is necessary a consensus process that can be very time consuming considering the number of existent questions.
Define schedule and efforts	The decision regarding the suggestion of dates and dedication. This depends on the availability of the people involved and the organization schedule (e.g., holidays, workdays). Usually is an interactive activity once it depends on the consensus of almost every people involved. It is interesting to propose a schedule with a few days in advance (at least two or three weeks), so it is possible to prepare better for the process and mitigate some changes and issues. Be sure to allocate a proper time to each interview (usually 3 to 4 hours for individual interviews, for group

Stage:	Plan

Activities	Brief description
	interviews this aspect must be analyzed according to each case).
Define logistics	Define aspects regarding the infrastructure (access for the building, logins, passwords, meeting room reservations, presentation tools). Aspects regarding the parking lot, identification cards, authorization are also treated.
Consolidate the diagnosis plan	During the execution of the activities, some sections of the plan were already built. This activity formalizes and consolidates the plan so it can be communicated to the involved. The plan is reviewed and discussed among the people, and the information is organized in the proper way.
Obtain commitment to the plan	The diagnosis plan is reviewed with all involved with the objective of gathering the approval and subsequently commitment with the plan. That is, the people involved agree with the content, they support the plan and are committed to it. There are not doubts or misunderstandings regarding the plan, and every involved know their roles, schedules, and participation.

Table 101: PAIDM - "Prepare" activities

Stage:	Prepare

Activities	Brief description
Schedule activities	The activities are scheduled according to the needs and availability previously agreed. The diagnosis team leader contacts the project manager to schedule dates and discuss other aspects.
Request necessary infrastructure	The diagnosis team leader requests the minimum infrastructure to the project manager. Examples of infrastructure are computers, offices, telephones, presentation devices, coffee breaks, notebooks and others.
Provide confidentiality agreements	The team leader together with the project manager provides confidentiality agreements documents. Each entity and organization may have its own needs and particularities, and the discussion of the content of the documents take place. A usual document (e.g., non-disclosure agreement) contains information regarding the non-use of any information used or accessed by the diagnosis team leader. This is a very common aspect, especially regarding public administration related entities. The discussion relating the confidentiality agreements usually will involve legal aspects and other people (e.g., lawyers).
Cancel and communicate involved	If there is no agreement (by any of the involved parts) regarding the confidentiality aspects, the diagnosis process is canceled and all involved are communicated of the fact.
Train the involved in PAICM	To provide a better understanding, comprehension and contextualization of the model that will be diagnosed, training and/or course of the PAICM (Public

Stage:	Prepare
Activities	**Brief description**
	Administration Interoperability Capability Model) are executed. The objective of the training is to provide visibility about the model, its capability levels, structure, attributes, and guidelines.
Train the involved in PAIDM	Once the PAICM was already presented, and to provide a better understanding, comprehension and contextualization of the diagnosing method, training and/or course of the PAIDM (Public Administration Interoperability Diagnosis Method) is executed. The objective of the training is to provide visibility about the diagnosis method, pairwise comparisons, interviews, Excel sheets, software tools[1], examples and calculations.
Update diagnosis plan	If the plan needs changes (according to the previous discussions and activities), it is updated according to the needs (e.g., new dates, people involved).
Obtain commitment to the plan	The diagnosis plan is reviewed with all involved with the objective of gathering the approval and subsequently commitment with the plan. That is, the people involved agree with the content, they support the plan and are committed to it. There are not doubts or misunderstandings regarding the plan, and every involved know their roles, schedules, and participation.
Discuss next steps	The next activities and steps are discussed and exposed as a reminder to prepare the involved. “What are the next actions regarding the diagnosis process, roles involved and expectations?”

Table 102: PAIDM - "Execute" activities

Stage:	Execute
Activities	**Brief description**
Prepare environment	Project manager together with diagnosis team leader prepares and sets up the environment (offices, computers, facility access). Usually it is an internal activity (within the entity) and can interact with an external team if there is a need to prepare some extra requisitions (e.g., parking lot, coffee breaks, security).
Conduct introductory briefing	Previous to initiate the interviews, a brief introduction is executed to all the involved. The idea here is to provide some reminding about the capability model and the diagnosis method, comments about the logistic and dynamics of the whole process. Doubts and other explanations are discussed.
Execute interviews	The interviews are executed according to the adopted and defined strategy. Whenever possible, the interviews are a face-to-face interaction (but can also be done using on-line technologies if it is needed and

[1] There is an ongoing project related to a software development portal for interoperability diagnosis. See APPENDIX 3: PROTOTYPE SOFTWARE.

Stage:	Execute
Activities	**Brief description**
	possible[2]). A combination of formal and informal interviews may be held, and interview scripts or exploratory questions can be developed to elicit the information needed. The interviews always collect relative perceptions, using a pairwise comparison structure supported by the AHP/ANP.
Collect data	Date gathered from the interviews are input into Excel spreadsheets according to the available templates. In some cases, a tool (whenever is available) can be used to help the data collection[2]. The answers are registered according to the expectation of the diagnosis method, considering the whole aspects involved (e.g., attributes, influences, pairwise comparison, capability levels).
Consolidate answers	The answers are consolidated depending on its nature (e.g., multiple respondents, consensus need). The information is summarized and organized into a more manageable set of data. Any extra comments or information are all integrated into a unique set of expected templates.
Insert data into AHP/ANP tool	When the information is ready and organized, they are inserted into an AHP/ANP tool (e.g., Super Decisions, other software tool[2]).
Execute calculations	Once the information is all in the AHP/ANP tool, the calculations, comparisons, analysis and other preliminary studies can be executed. In this step, it is possible to detect aspects related to the inconsistency degree (Super Decisions tool helps to identify the inconsistencies according to the suggestions related to the AHP/ANP method[2]).
Review answers	This activity is executed after a conditional verification regarding the existence of inconsistency within the answers. The AHP/ANP technique proposes a rule to verify inconsistency in the pairwise comparison. The inconsistency degree is calculated automatically in the Super Decisions software or other tool[2]. An inconsistency degree of 10% is the reference adopted (Saaty, 1987). If it is the case, the answers can be reviewed to solve (or minimize) the inconsistency degree, changing the values of the comparison according to the reviewed position of the respondents. The Super Decisions (or another tool[2]) shows suggestions of how to review the comparisons, including propositions of adequate values.
Generate preliminary results	The preliminary results are automatically generated by the Super Decisions (or other tool[3]) and are adopted to generate more complex analysis and discussions.

———————————

[2] There is an ongoing project related to a software development portal for interoperability diagnosis. See APPENDIX 3: PROTOTYPE SOFTWARE.

Table 103: PAIDM - "Report" activities

Stage:	**Report**
Activities	**Brief description**
Consolidate results	Considering the preliminary results and the information generated, the results are consolidated in a managerial format, considering new pertinent analysis (e.g., depending on the needs of the entity). The several aspects of the results are organized (e.g., by levels, concerns) and presented.
Build reports	Documents and reports are generated to provide the results to the entity. Figures, analysis and comments regarding the application, limitations, suggestions, weakness and strengths can be registered.
Schedule findings presentation	Interact with the project manager to verify the best dates and involved to participate in the presentation of the results.
Conduct findings presentation	Present the results for the involved and other pertinent people suggested by the project manager, senior manager or sponsor. The presentation occurs in a meeting style, where the findings, ratings, suggestions and other information are discussed.
Collect lessons learned	Learning gained from the diagnosis process are collected and registered. The information can be gathered at the end of the final presentation or in another event to be scheduled. It is not necessary to gather the lessons learned only at the end of the process, they could be identified and documented at any point during the process. The purpose of documenting lessons learned is to update the model, the diagnosis method and use and share the information to improve the process.
Review and update models and/or pertinent artifacts	Considering the research framework, this activity is related to the process A12 (see Figure 17). Update and review the models and methods according to the comments, suggestions and needs (e.g., new attributes, new ways of diagnosis, new guidelines).

7.2 PAIRWISE COMPARISONS

The pairwise comparisons follow the AHP/ANP structure and for each of the three main goals of PAIDM (see Table 95, Goal 2, Goal 3 and Goal 4), there is a set of comparisons executed according to the interviews and consolidation strategies. Goal 1 does not have pairwise comparison once it is the result of the whole calculation and consolidation from the other goals. The comparisons generate the weight distribution from the bottom (alternatives) to top (goal), according to the illustrations in Figure 102 and Figure 103. The figures presented in this section 7.2 and related to the comparisons aspects (Figure 113, Figure

114, Figure 116 and Figure 119) are real examples and were retrieved from the Excel spreadsheets used for data collection during the application cases.

7.2.1 GENERAL INSTRUCTIONS

The evaluations are referential and pairwise (i.e., there is always a comparison between two items). Pairwise comparison generally is any process of comparing entities in pairs to judge which of each entity is “preferred” or whether or not the two entities are identical. It is important to remember that the adopted comparison attributes referential (e.g., “preference” used in the previous sentence) can be exchanged for any other more pertinent item (e.g., likelihood, adherence, pertinence).

Considering the structure of the comparisons and the scale based on Saaty (1987) and illustrated in Table 24, each line contains a vector representing the degree scale between the two items, and the colors are used only to facilitate and differentiate (see Figure 110):

Figure 110: General pairwise structure

Item 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Item 2

Source: The author (2015).

The interpretation and use are simple: if the respondent mark the blue cell 6, the meaning is interpreted according to the Table 24. That is, the respondent considers that the “Item 1” is "Between strong and very strong" more "important/pertinent/adequate" than “Item 2”. It is important to remember that the comparison implies an inverse value to the other compared (not chosen) item. That is, in the above example, “Item 1” is “6” and therefore “Item 2” has a relation of “1/6” to “Item 1”.

As an example, consider the cars’ models (BMW, Audi and Mercedes) and the degree of "preference" comparing all options (Figure 111).

Figure 111: Car’s model pairwise comparison

BMW	9	8	7	6	5	4	3	2	X	2	3	4	5	6	7	8	9	Audi
BMW	9	8	7	6	5	4	X	2	1	2	3	4	5	6	7	8	9	Mercedes
Audi	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Mercedes

Source: The author (2015).

In the above example, the comparisons were already executed and marked with an “X” or coloring the cell with a yellow background. The general raw interpretation of the answers is the following:

- Line 1: the respondent has “equally” (degree “1”) preference for BMW and Audi.
- Line 2: the respondent has a "moderate" (degree “3”) preference for BMW against Mercedes.
- Line 3: the respondent has a "strong" (degree “5”) preference for Mercedes against Audi.

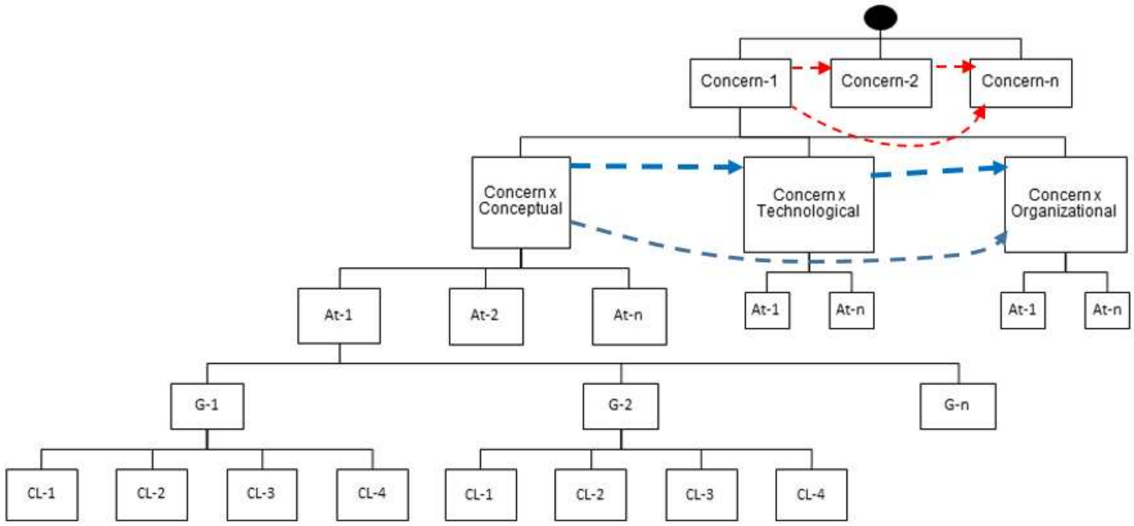
All the PAIDM comparisons follow the same structure and mechanism as exposed in Figure 110 and Figure 111.

7.2.2 CONCERNS COMPARISONS AND CONCERNS X BARRIERS COMPARISONS

These levels intend to evaluate the degree of “attention” and/or “focus” that the entity is giving to a particular item (criteria). The “concerns comparisons level” is related to the Goal 2 (see Table 95) and provides a management overview regarding the interoperability diagnosis, while the “concerns x barriers comparisons level” is related to the Goal 3 (see Table 95), providing a tactical perception.

At this point, there is no capability level comparison yet, once this aspect is related to the guidelines, as illustrated in the general PAICM structure exposed in Figure 101, Figure 102 and Figure 103. As an example, Figure 112 shows (with red dotted arrows) comparisons among three “concerns”. The arrows represent comparisons regarding the “Concern-1 with Concern-2”, “Concern-1 with Concern-n” and “Concern-2 with Concern-n”. The blue dotted arrows represent comparisons among the “concerns x barriers” views. In this case, the arrows represent comparisons regarding the “Concern x Conceptual with Concern x Technological”, “Concern x Conceptual with Concern x Organizational” and “Concern x Technological with Concern x Organizational”.

Figure 112: Concerns comparisons and concerns x barriers comparisons



Source: The author (2015).

Figure 113 and Figure 114 exemplifies some evaluations considering the concerns aspects and the barriers aspects (within each concern) using spreadsheets.

Figure 113: Pairwise related to the concerns' evaluation

	Regarding the interoperability concerns, which is the perspective (concern, area) that the entity is giving more attention? For the evaluation, consider the "as is" viewpoint, not a "to be". Compare the concerns according to the "Instructions" sheet and insert an "X", or mark with another form (e.g., coloring the cell), in the adequate cell containing the pertinent value.																		
1	**Business**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Process**
2	**Business**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Service**
3	**Business**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Data**
4	**Process**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Service**
5	**Process**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Data**
6	**Service**	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Data**

Source: The author (2015).

Figure 114: Two examples of pairwise related to the concerns x barriers

Regarding the interoperability barriers within each concern (see also the "Concerns x Barriers" matrix sheet), which is the perspective (barrier, area) that the entity is giving more attention? For the evaluation, consider the "as is" viewpoint, not a "to be".
Compare the barriers according to the "Instructions" sheet and insert an "X", or mark with another form (e.g., coloring the cell), in the adequate cell containing the pertinent value.

	1. Within the Business concern:																		
1	**BC**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**BT**
2	**BC**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**BO**
3	**BT**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**BO**

	2. Within the Process concern:																		
1	**PC**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**PT**
2	**PC**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**PO**
3	**PT**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**PO**

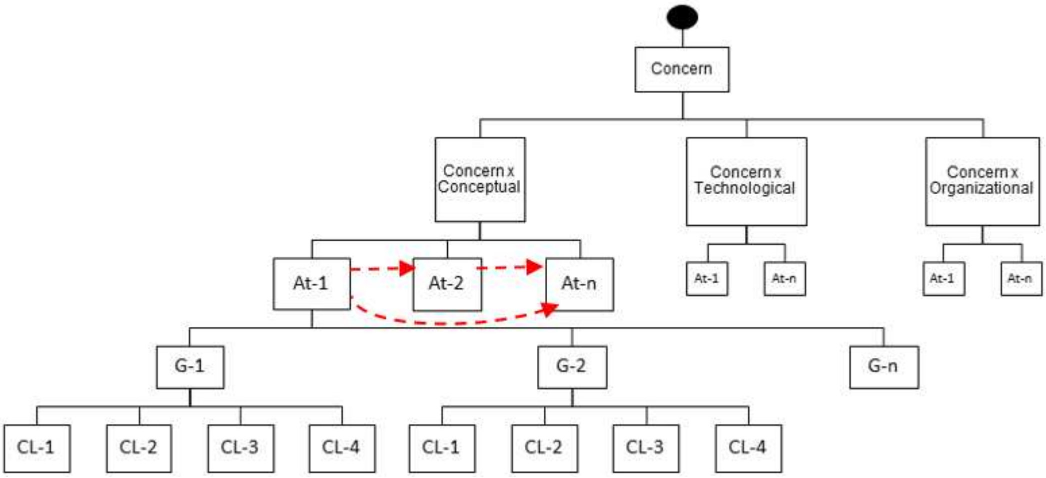
Source: The author (2015).

7.2.3 ATTRIBUTES COMPARISONS

This level of comparison also is related to the Goal 4 (see Table 95) and evaluates the degree of “attention” and/or “focus” that the entity is giving comparing pairs of attributes within the concern x barriers view (see PAICM, Figure 102 and Figure 103). As an example, Figure 115 shows (with red dotted arrows) comparisons among three attributes within a “concern x conceptual” view. The arrows represent comparisons regarding “At-1 with At-2”, “At-1 with At-n” and “At-2 with At-n”.

Figure 116 exposes the same kind of comparisons considering a “Business x Conceptual” view using a spreadsheet to implement the data collection.

Figure 115: Attributes comparison structural example



Source: The author (2015).

Figure 116: Attributes comparison within Business x Conceptual view

Regarding the attributes within each Concerns x Barriers cell (i.e., the attributes are distributed within interoperability structure), which is the attribute that the entity is giving more attention? For the evaluation, consider the "as is" viewpoint, not a "to be". Compare the attributes according to the "Instructions" sheet and insert an "X", or mark with another form (e.g., coloring the cell), in the adequate cell containing the pertinent value.

	Within BC (Business x Conceptual):																		
1	Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Conflicts
2	Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy and regulations
3	Communication	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
4	Conflicts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy and regulations
5	Conflicts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political
6	Policy and regulations	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political

Source: The author (2015).

7.2.4 CAPABILITY LEVELS (GUIDELINES COMPARISONS)

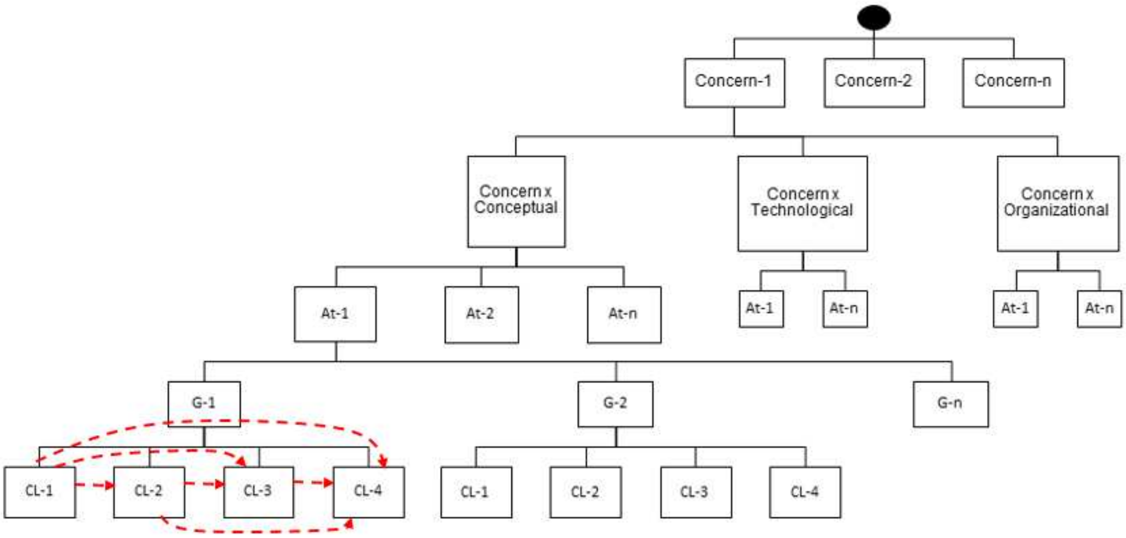
This level evaluates the degree of "adherence" or "pertinence" of each one of the guidelines regarding the capability levels alternatives, complementing the calculations for the Goal 4 (Table 95). That is, the guidelines are analyzed and ranked according to their pertinent capability level. There are 22 Excel spreadsheets (one for each attribute) and inside the spreadsheets, there are tabs (sheets) related to the concern x barrier area pertinent to that attribute, instantiating the example structure exposed in Figure 103. Each tab (sheet) contains an evaluation (pairwise comparison regarding the capability level) of only one guideline (see Figure 117 as an example).

Figure 117: Example of sheets' organization

Source: The author (2015).

As a structural example, Figure 118 shows (with red dotted arrows) comparisons among the four capability levels (alternatives) within a guideline. The arrows represent comparison regarding the “CL-1 with CL-2”, “CL-1 with CL-3”, “CL-1 with CL-4”, “CL-2 with CL-3”, “CL-2 with CL-4” and “CL-3 with CL-4”.

Figure 118: Capability levels comparison



Source: The author (2015).

Figure 119 shows an example of the capability levels comparisons regarding the first guideline of the “Communication” attribute, within the “Business x Organizational” area.

Figure 119: Communication attribute, guideline 01 within BO

COU-BO-Gui.01: There is a communication process established (e.g., communication plan with names, tools, and information about who receives what, when and how).

Regarding the above guideline, insert an "X", or mark with another form (e.g., coloring the cell), in the adequate cell containing the pertinent value considering the comparisons between the Capability Levels.

Capability Level 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 2
Capability Level 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 3
Capability Level 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 4
Capability Level 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 3
Capability Level 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 4
Capability Level 3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capability Level 4

Source: The author (2015).

The complete set of spreadsheets and the AHP/ANP design and structure within the Super Decisions software, both used during the diagnosis process, are presented in Cestari et al., (2015a). The technical report is a material to be used for the involved (e.g., diagnosis team leader) as a reference for future diagnosis.

It is important to mention that the comparison between guidelines (guideline x guideline) does not occur within the Excel spreadsheets context, once it is not relevant to the proposal of this research. The values of these comparisons are predefined as “1”, that is, “they have equal importance” for the goal. Although the spreadsheets do not contain these comparisons, the Super Decision tools execute them as part of the AHP/ANP process and the comparisons are explicitly set to “1” (see Figure 120 as an example). The structure of PAICM within the Super Decisions software is exposed in section 7.3.

Figure 120: Pairwise comparisons of guidelines within the Business x Organizational area

Source: The author (2015), using Super Decisions software.

7.3 SUPER DECISIONS MODEL

The Super Decisions software (Adams and Creative Decisions Foundation, 2013) implements the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP), setting priorities and doing the calculations. The tool allows the graphical modeling of the decision model, organizing the ideas according to the characteristics of AHP and/or ANP methods, maintaining the basic structure of the “Goal”, “Criteria” and “Alternatives”.

The structure of the Super Decisions model was created according to the structure of the PAICM and considering the needs of the PAIDM. The input of information come from the data collection inserted into the Excel spreadsheets after all the consolidation and data gathering.

In a few words, the Super Decision works in the following way:

(i) The user creates clusters regarding aspects such as “Goal”, “Criteria”, “Sub-criteria” and “Alternatives”.

(ii) Inside each cluster, it is necessary to create “nodes”, which are the basic element to be compared (in this research). The “nodes” contain text stating the “Goal” or the criteria (each “node” is a criterion) or the “Alternatives” (each “node” is an alternative).

(iii) Creation of the connections between the nodes.

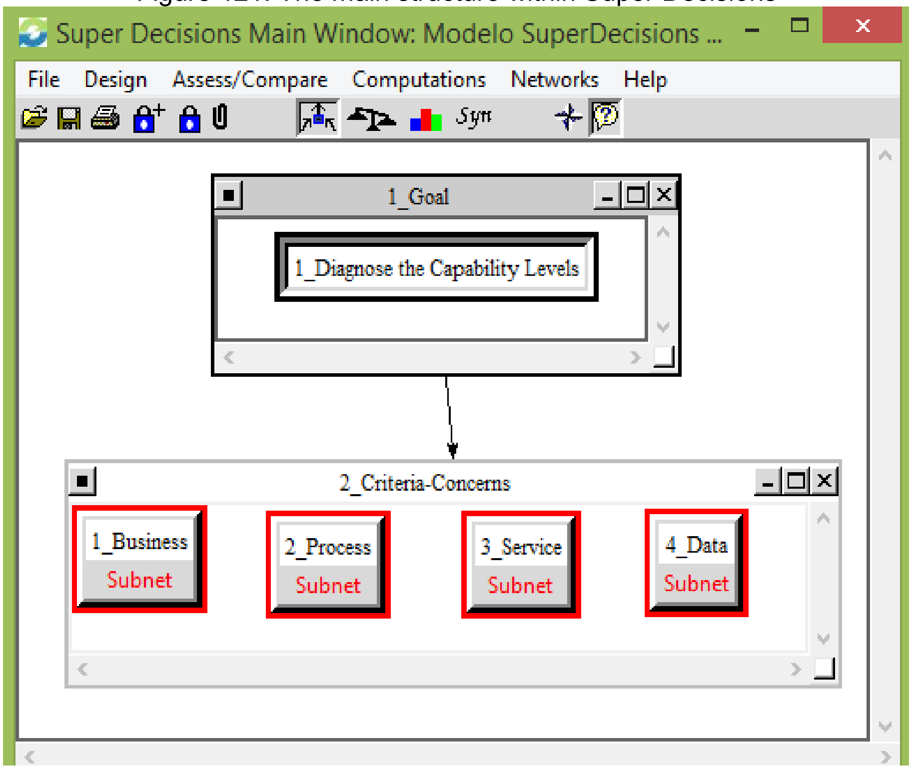
(iv) Insert the pairwise comparison considering the nodes connection and the nodes organization (all nodes within the same cluster can be pairwise compared and all nodes with explicit connections can be compared).

(v) Calculate the values considering all the weights, goals, criteria and alternatives.

Super Decisions allow the creation of subnets, within each node. It is a way to better organize complex models and obtain the results of partial calculations (for each subnet that has a “Goal”). This research uses the Super Decisions to organize the answers and get the calculations regarding the capability levels. The model is structured using “subnets” and is presented level by level, according to the extractions illustrated in Figure 121, Figure 122, Figure 123 and Figure 124.

Figure 121 presents the main structure of the model represented in Super Decisions. The main “Goal” cluster contain a node stating the main goal of the “decision-making problem”, which is to “Diagnose the Capability Level”. The statement is a text field that can be fulfilled with the most pertinent text description according to the needs. The second cluster is the “Criteria”, which contain four nodes representing each one of the enterprise interoperability concerns. The surroundings of the criteria nodes are in red, and this was set up at the Super Decisions tool only to indicate that are a connection between the “Goal” node and each one of the criteria node (they are all with red borders). Figure 121 also contains the main menu of the Super Decisions tool, as an illustration of the tool interface. The text “Subnet” within the nodes indicate that those nodes have a “subnet” modeled.

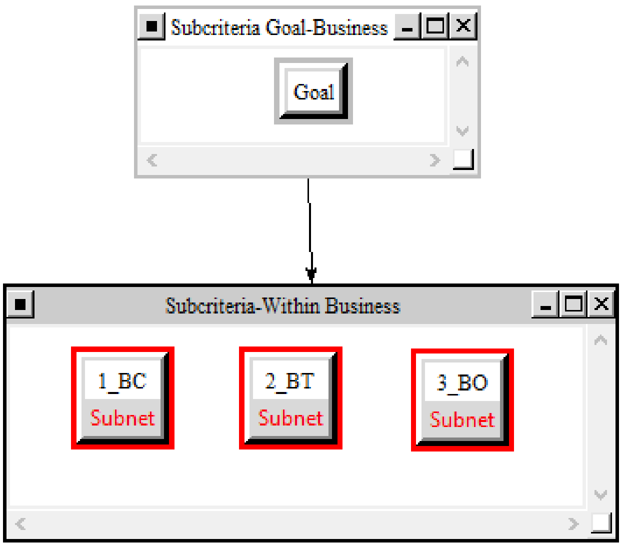
Figure 121: The main structure within Super Decisions



Source: The author (2015), using Super Decisions software.

After double-click the “1_Business” node, a subnet presented in Figure 122 appears. The subnet represents the sub-criteria “barriers” within the “Business” concept, creating the concerns x barriers mapping (BC, BT and BO).

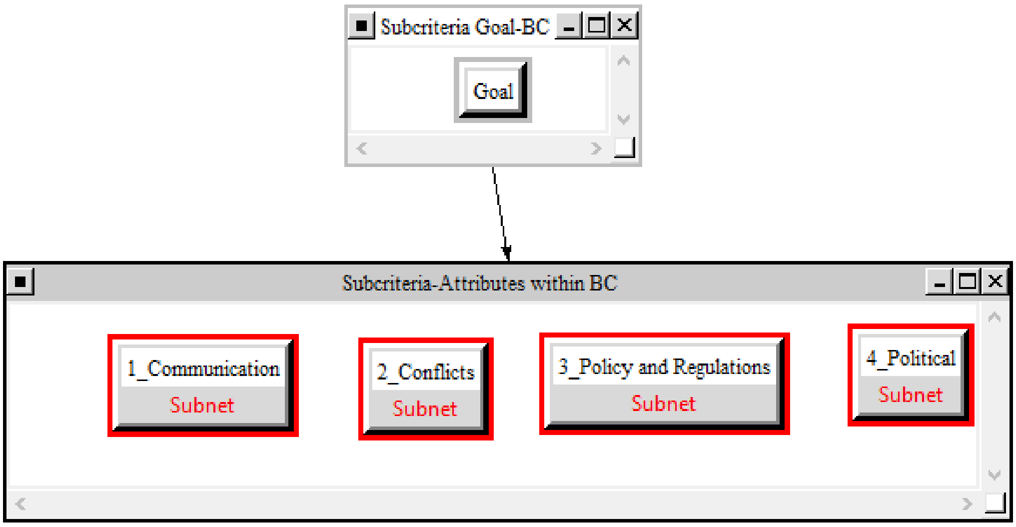
Figure 122: Subnet under Business. Sub-criteria (barriers) within Business



Source: The author (2015), using Super Decisions software.

Figure 123 presents the subnet under BC, exposing all the attributes within BC (organized as sub-criteria).

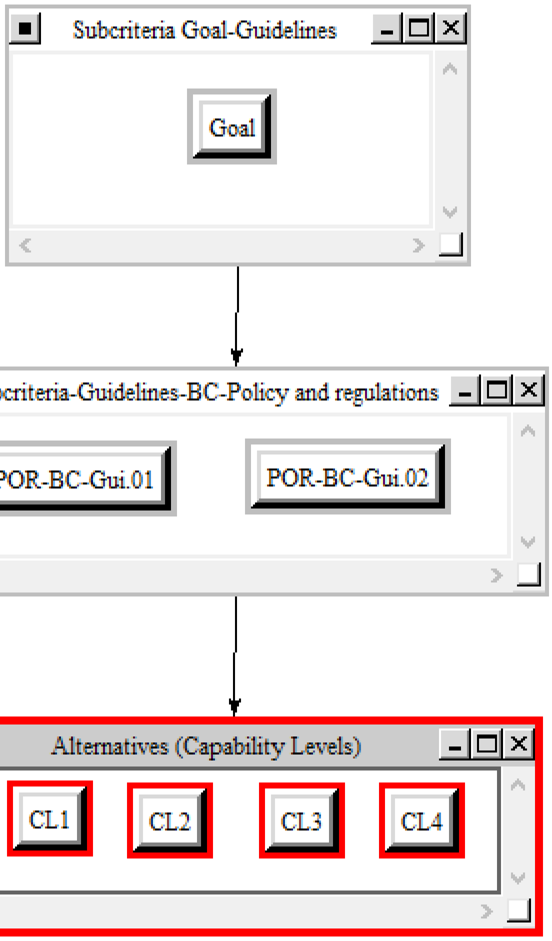
Figure 123: Subnet under BC. Sub-criteria (attributes) within BC



Source: The author (2015), using Super Decisions software.

The last level of the model tree (see Figure 102 and Figure 103) is represented in Figure 124. This is the level representing the capability levels choices ("Alternatives" cluster) and is a subnet under the node (attribute) "3_Policy and Regulations" containing all the guidelines (sub-criteria) associated with the attribute. There are two nodes representing the two guidelines (POR-BC-Gui.01 and POR-BC-Gui.02) and each of the nodes is connected to the entire group of alternatives (all four Capability Levels).

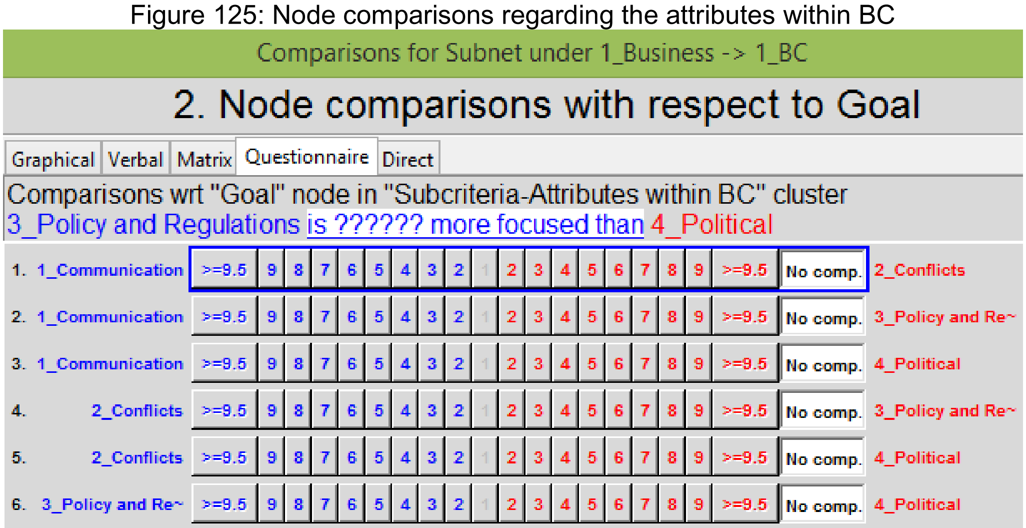
Figure 124: Subnet under 3_Policy and Regulations. Sub-criteria (guidelines) within Policy and Regulations and its alternatives (Capability Levels)



Source: The author (2015), using Super Decisions software.

The pairwise comparison occurs in each of the nets and subnets, as already exposed in Figure 120 and again exemplified in Figure 125, considering the comparison regarding the attributes within the Business x Conceptual area.

Figure 125: Node comparisons regarding the attributes within BC



Source: The author (2015), using Super Decisions software.

All the other subnets are represented and structured in the same way as the above examples. In addition, according to the navigation across the model (double clicking the nodes with subnets, for example), it is possible to “go down” to other levels and obtain a more granular view of the model. The whole structure, with all the illustrations, can be found in Cestari et al., (2015a).

7.4 RATINGS CALCULATION

The rating calculation is based on the collected and consolidated answers during the interview process (pairwise comparisons) and according to the calculations and proceedings of the AHP and ANP exposed in section 4.

The calculus of the evaluation is executed entirely by the Super Decisions software and is composed of a bottom-up mechanism, considering all the comparisons and weights of the connects components. Once each guideline is diagnosed according to the Capability Level, the summarization of the evaluation composes the Capability Level for the attributes, providing values for an operational view (Goal 4, Table 95). Then, the summarization of the evaluation of the attributes composes the Capability Level of the concern x barrier area, providing a tactical view related to the Goal 3 (e.g., BC, BT, BO).

The summarization of the evaluation of the concerns x barriers provides the Capability Level of the concerns aspects (management view, Goal 2). At last, the grouped calculation of the concerns’ view produces the Capability Level regarding the whole diagnosed entity (Goal 1), providing a strategic view. As stated in Table 95, this macro view can be interpreted as a Maturity Level categorization, grouping all the values from the bottom to the top.

7.5 CONSIDERATIONS AND CHAPTER SYNTHESIS

This section exposed the **Public Administration Interoperability Diagnosis Method (PAIDM)** in its structure, components, roles and related processes. The main goal of PAIDM is to structure and define a formal and organized method to execute a diagnosis in a public administration entity, providing overviews of the interoperability capability levels. It is important to mention that a diagnosis or assessment method uses a model as a reference to compare with, that is, a diagnosis is executed to verify adherence to an already defined and baselined referenced model. In this case, the reference model for PAIDM is PAICM.

PAIDM has four main goals (Table 95) related to the capability levels diagnosis and, the structure of PAIDM, the structure of PAICM and their organization regarding the use of AHP/ANP (including the model architecture within the Super Decisions software), are related to those four goals. Generally, the goals providing the following perspectives: (i) Strategic view, (ii) Management view, (iii) Tactical view and (iv) Operational view.

To obtain the diagnosis results, PAIDM uses pairwise comparisons as strategy, following the AHP/ANP structure (as exposed in section 4.4). The comparisons generate the weight distribution from the bottom (alternatives) to top (goal), according to the illustrations in Figure 102 and Figure 103. Although the AHP/ANP is a "decision-making method", the PAIDM uses their structure not to "classically" "make a choice". PAIDM uses AHP/ANP to minimize subjectivity related to the comparison of items, adopting always a referential comparison (pairwise) rather than an absolute selection or choice. At the bottom level (alternatives evaluation), PAIDM uses the AHP/ANP structure not to choose a "best alternative", but to "better rank which is the capability level that is more adherent to the context of that specific guideline". That is, it is not a pure matter of choice, but rather a matter of positioning a specific criterion within a defined interval of capability levels. This kind of application is one of the originalities of this research.

It is important to note that the diagnosis is executed in a defined entity and, according to the exposed in the introduction of section 7, an entity can be a composition of areas, subareas, projects or even the entire organization, and it is not necessarily a physical structure. This is important because the results are related to the entity evaluated, and not necessarily to the whole organization. The generalization of a capability/maturity level to all the organization is an inference, and it is not supported by the PAIDM. This extrapolation is very common with other types of certification and assessments, regarding norms or models. For example, ISO 9001:2015 (ISO, 2015), SCAMPI (SCAMPI Upgrade Team, 2011) and MPS.BR (SOFTEX, 2012) also demand that a "scope", "area" or "unit" be defined to clearly establish the object of assessment. In addition, the official documents regarding those assessments explicitly state which are the evaluated areas (or projects, units, entities). In the daily ("not formal") use, and sometimes by marketing issues, the communication is, for instance: the "company 'X' is certified ISO 9001". However, the fact is that the assessment is valid for a defined scope or area of the company (unless the whole organization was really assessed).

Two application cases (section 8) exposes the diagnosis results and use of PAIDM and the whole structure, with the complete illustrations, spreadsheets, Super Decisions architecture and other information, can be found in Cestari et al., (2015a) and Cestari et al., (2015b).

8 APPLICATION CASES

The application cases aim to apply the diagnosis method (PAIDM/PAICM) to evaluate public related organizations, obtaining the pertinent capability levels and, as a complementary goal, collecting suggestions related to the improvement of the whole process (with possible contributions to the research framework). The execution of the application cases and the consequent perception of possible improvements are related to the processes A10, A11 and A12 within the research framework (Figure 4). Considering the aspects and the goals of the research, it was possible to contact two public administration related organizations.

Both organizations asked for a non-disclosure agreement regarding the publication of its name and any other further details that could explicitly identify them, which is comprehensible because of the relationship with the public administration. Both organizations work with IT services for some cities in Brazil and within the Paraná State, and the consistency ratio (see section 4.4.1.3) was adopted as a measuring tool regarding the quality of the interviews.

8.1 APPLICATION CASE-01

8.1.1 ENTITY CHARACTERIZATION

The first application case application was within an organization that supplies IT services for cities (supplying municipality needs). The company has more than 200 employees and supplies different types of IT services (e.g., software development, incident management, logical and physical installation, support). Two areas within this organization were chosen to compose the “diagnosed entity” (see “define entities” activities, Table 100): both are directly related to the current (and future) IT operations within the cities and interact directly with the other side (public administration of the city).

8.1.2 PEOPLE SELECTION AND INTERVIEWS STRATEGY

Four people were selected, considering two of each area. One of each pair is the area manager (one for each area) and the other was a team member. Each one of the four persons has more than 10 years regarding the relation with public administration projects, and they are all considered senior employees.

As a first experience, it was decided to execute individual interviews, trying to avoid the interference of visions and minimize the influence of the manager over their team. The four answered the whole questionnaire, once they have the skills and engagement to do so. After the conclusion of the interviews, the consolidation of the data occurred using a geometric mean, as exposed in section 4, Figure 49. The whole data collection, including the geometric mean calculations, was executed using Excel spreadsheets built by the author. The final data were inserted into the Super Decisions software.

8.1.3 RESULTS AND ANALYSIS

The results are presented in the form of tables and radial graphs, considering the information regarding three basic columns of results: “raw”, “%” and “normalized”. The "raw" column contains the raw values of the pairwise comparisons considering all the calculations. The “%” column contain the values of the “raw” column transformed into a % of the total. That is, each of the cells are obtained dividing the value of the respective “raw” cell by the sum of the all “raw” cells (e.g., 0.095572 = (0.264886 / (0.264886 + 0.584098 + 0.962390 + 0.960215) as seen in Table 104). The "normalized" column presents the normalized values of the "%" columns or the "raw" column.

The results are organized according to the diagnosis goals as exposed in Table 95, but only the graphs related to Goal 1 (strategic overview of the entity), Goal 2 (management overview regarding the concerns aspects) and Goal 3 (tactical overview regarding the concerns x barriers aspects) are presented. Only a few samples regarding Goal 4 (operational overview regarding each attribute) are presented, once there are more than 60 graphs associated with the diagnosis. The full report (all tables and graphs) can be found in Cestari et al., (2015b).

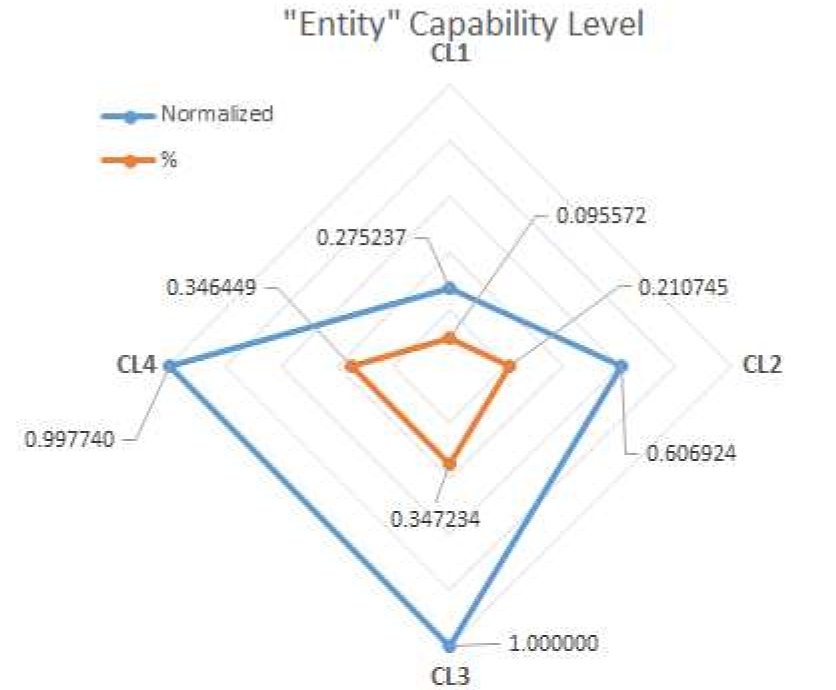
8.1.3.1 RESULTS REGARDING GOAL 1: STRATEGIC VIEW

At this level, the results represent the values regarding the Capability Levels of the entire entity, considered as a “maturity level” for the whole perspective.

Table 104: Application Case-01. Capability Levels for the whole entity.

Capability Levels	Normalized	%	Raw
CL1	0.275237	0.095572	0.264886
CL2	0.606924	0.210745	0.584098
CL3	1.000000	0.347234	0.962390
CL4	0.997740	0.346449	0.960215

Figure 126: Application Case-01. Capability Levels for the whole entity



Source: The author (2015).

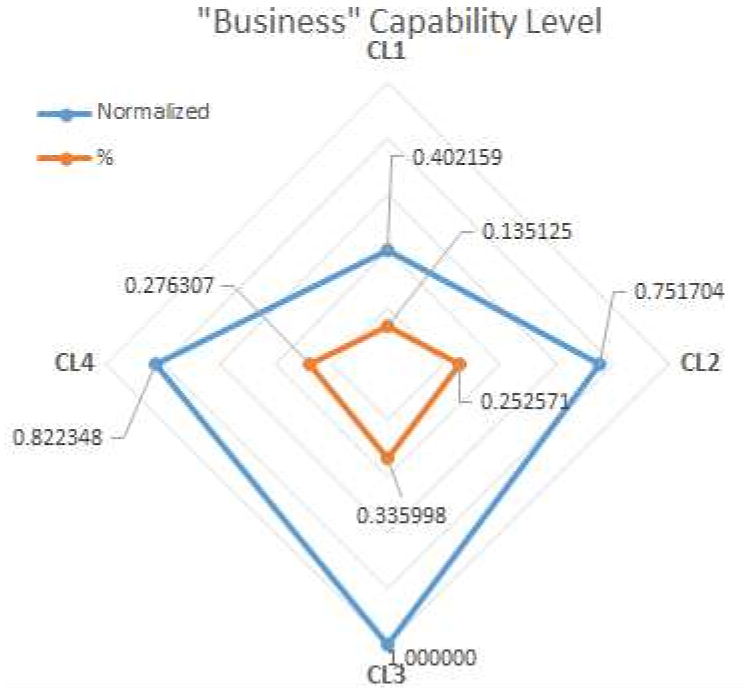
8.1.3.2 RESULTS REGARDING GOAL 2: MANAGEMENT VIEW

This level exposes the concerns view, with a management perspective relating the capability levels of the areas involved (Business, Process, Service and Data).

Table 105: Application Case-01. Capability Levels for the “Business” concern

Capability Levels	Normalized	%	Raw
CL1	0.402159	0.135125	0.402159
CL2	0.751704	0.252571	0.751704
CL3	1.000000	0.335998	1.000000
CL4	0.822348	0.276307	0.822348

Figure 127: Application Case-01. Capability Levels for the “Business” concern

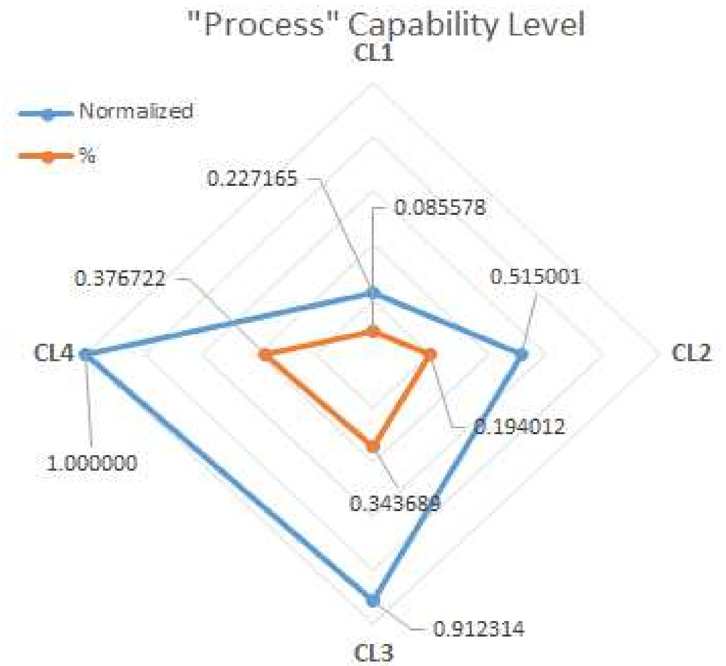


Source: The author (2015).

Table 106: Application Case-01. Capability Levels for the “Process” concern

Capability Levels	Normalized	%	Raw
CL1	0.227165	0.085578	0.222024
CL2	0.515001	0.194012	0.503346
CL3	0.912314	0.343689	0.891668
CL4	1.000000	0.376722	0.977369

Figure 128: Application Case-01. Capability Levels for the “Process” concern

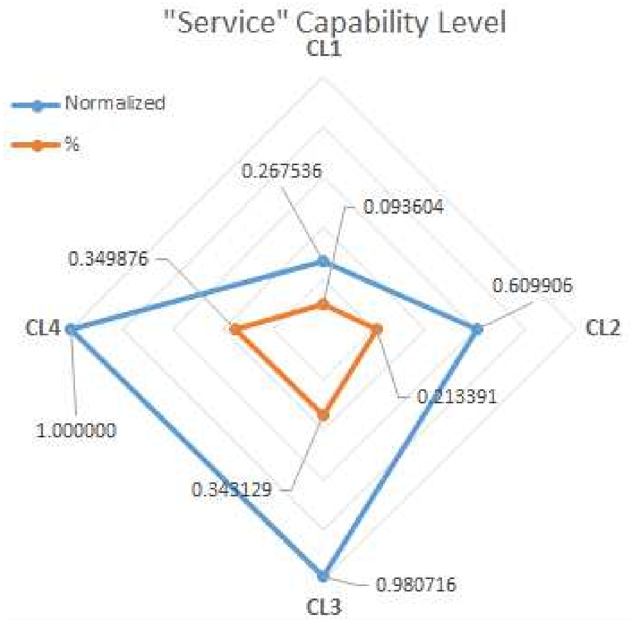


Source: The author (2015).

Table 107: Application Case-01. Capability Levels for the “Service” concern

Capability Levels	Normalized	%	Raw
CL1	0.267536	0.093604	0.260675
CL2	0.609906	0.213391	0.594264
CL3	0.980716	0.343129	0.955565
CL4	1.000000	0.349876	0.974355

Figure 129: Application Case-01. Capability Levels for the “Service” concern

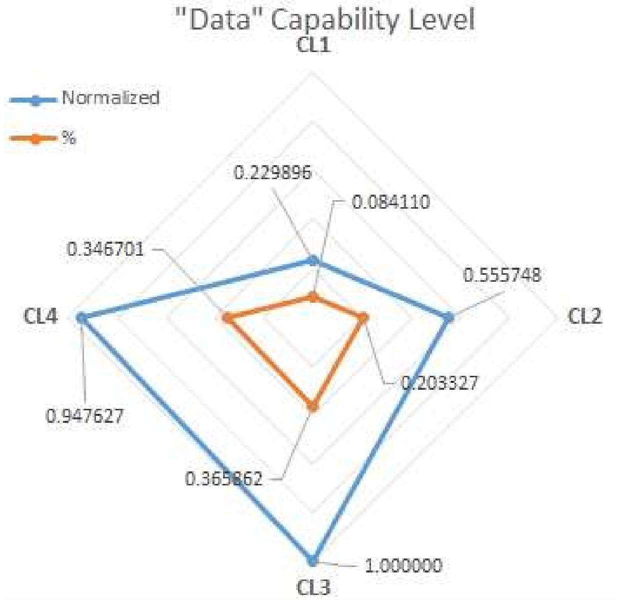


Source: The author (2015).

Table 108: Application Case-01. Capability Levels for the “Data” concern

Capability Levels	Normalized	%	Raw
CL1	0.229896	0.084110	0.228947
CL2	0.555748	0.203327	0.553454
CL3	1.000000	0.365862	0.995872
CL4	0.947627	0.346701	0.943715

Figure 130: Application Case-01. Capability Levels for the “Data” concern



Source: The author (2015).

8.1.3.3 RESULTS REGARDING GOAL 3: TACTICAL VIEW

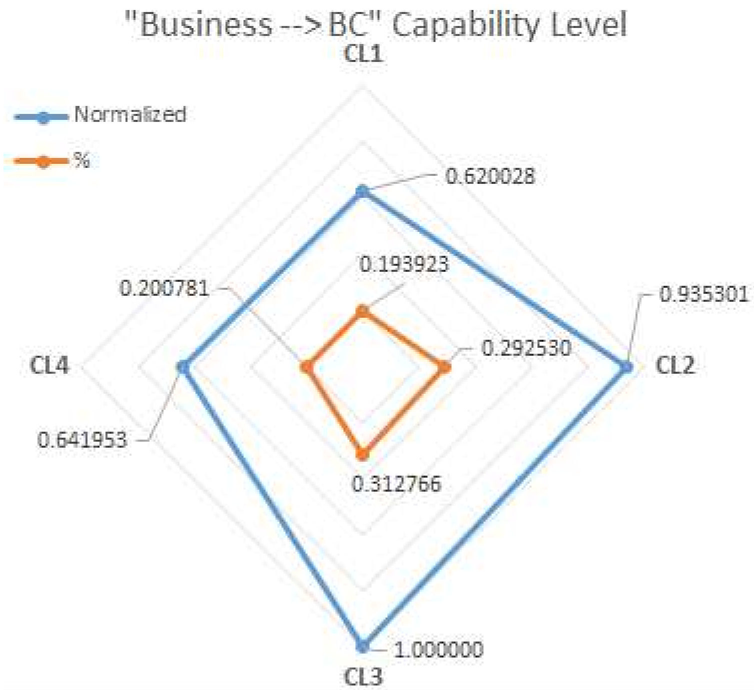
This level exposes a tactical view, considering the 12 combinations of Concerns x Barriers.

8.1.3.3.1 WITHIN BUSINESS

Table 109: Application Case-01. Capability Levels for BC

Capability Levels	Normalized	%	Raw
CL1	0.620028	0.193923	0.534531
CL2	0.935301	0.292530	0.806330
CL3	1.000000	0.312766	0.862107
CL4	0.641953	0.200781	0.553432

Figure 131: Application Case-01. Capability Levels for BC

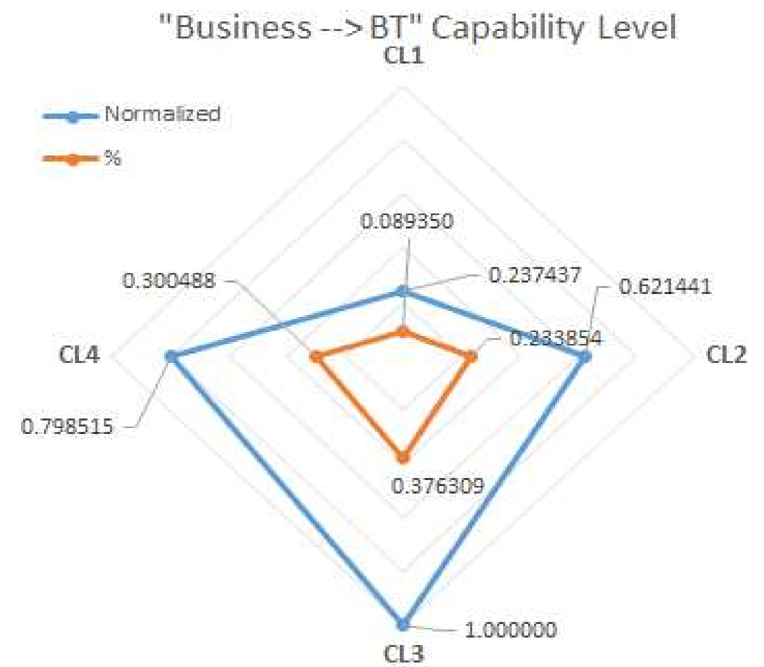


Source: The author (2015).

Table 110: Application Case-01. Capability Levels for BT

Capability Levels	Normalized	%	Raw
CL1	0.237437	0.089350	0.206981
CL2	0.621441	0.233854	0.541729
CL3	1.000000	0.376309	0.871730
CL4	0.798515	0.300488	0.696090

Figure 132: Application Case-01. Capability Levels for BT

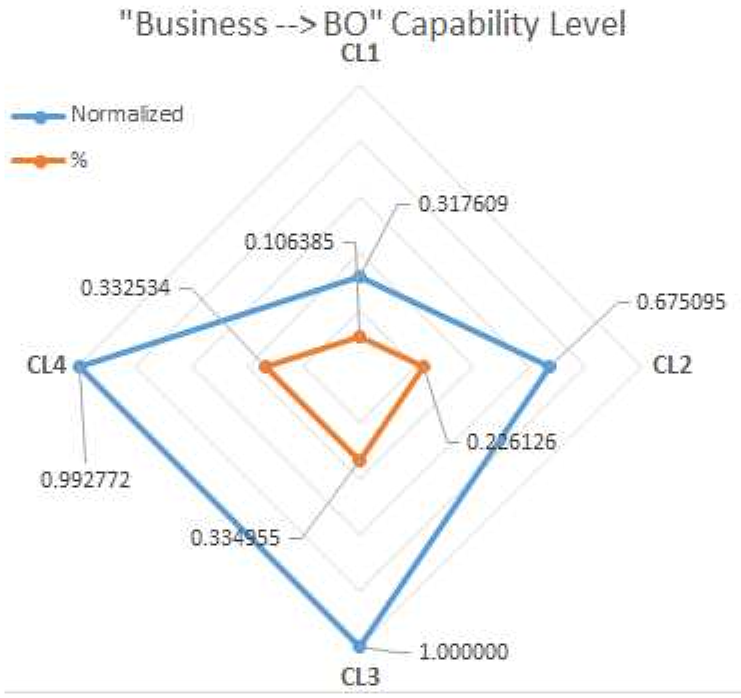


Source: The author (2015).

Table 111: Application Case-01. Capability Levels for BO

Capability Levels	Normalized	%	Raw
CL1	0.317609	0.106385	0.265419
CL2	0.675095	0.226126	0.564164
CL3	1.000000	0.334955	0.835681
CL4	0.992772	0.332534	0.829641

Figure 133: Application Case-01. Capability Levels for BO



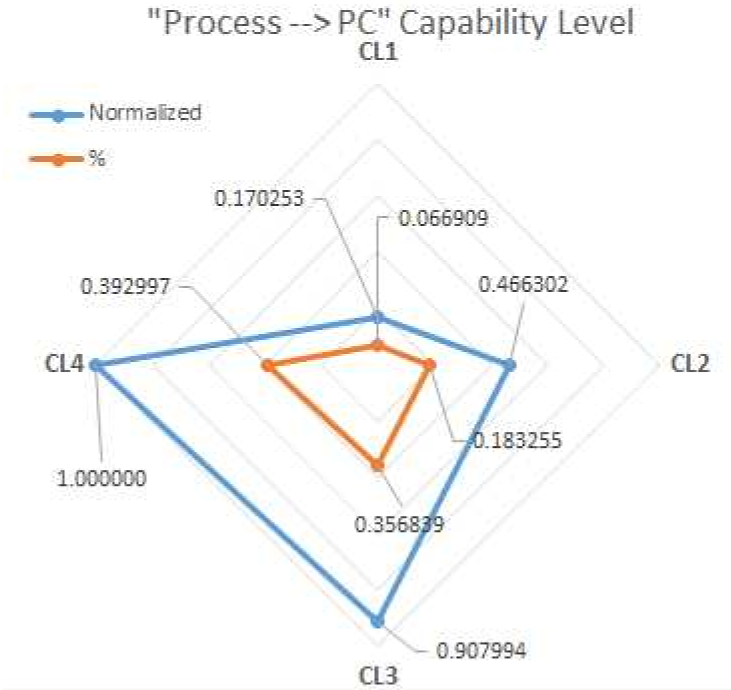
Source: The author (2015).

8.1.3.3.2 WITHIN PROCESS

Table 112: Application Case-01. Capability Levels for PC

Capability Levels	Normalized	%	Raw
CL1	0.170253	0.066909	0.170253
CL2	0.466302	0.183255	0.466302
CL3	0.907994	0.356839	0.907994
CL4	1.000000	0.392997	1.000000

Figure 134: Application Case-01. Capability Levels for PC

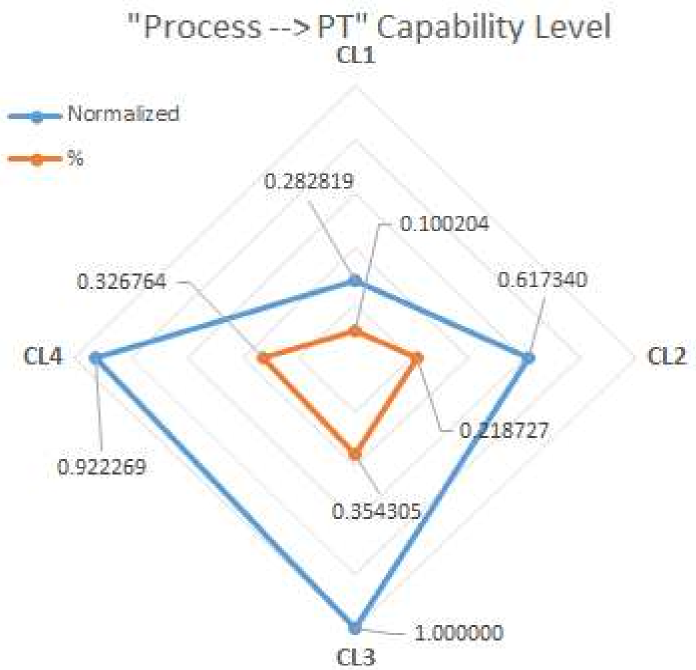


Source: The author (2015).

Table 113: Application Case-01. Capability Levels for PT

Capability Levels	Normalized	%	Raw
CL1	0.282819	0.100204	0.237877
CL2	0.617340	0.218727	0.519241
CL3	1.000000	0.354305	0.841095
CL4	0.922269	0.326764	0.775716

Figure 135: Application Case-01. Capability Levels for PT

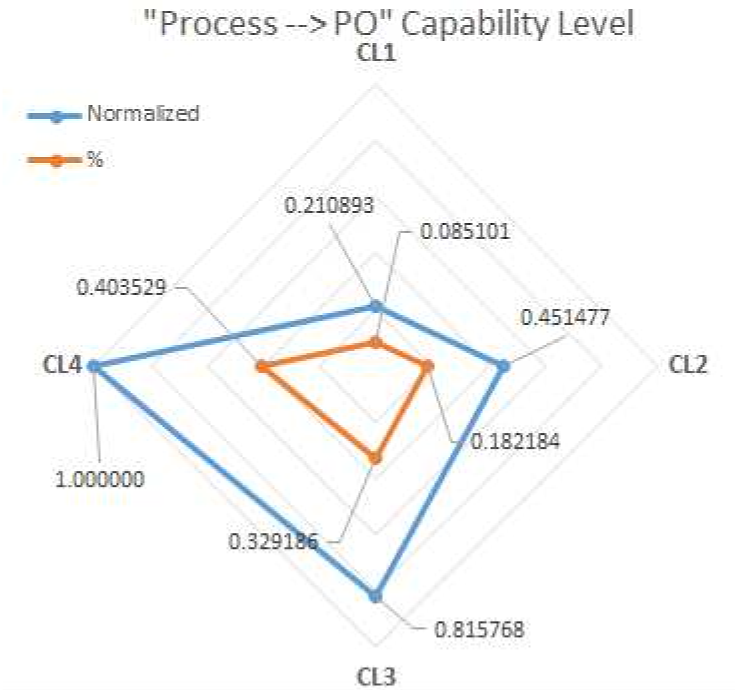


Source: The author (2015).

Table 114: Application Case-01. Capability Levels for PO

Capability Levels	Normalized	%	Raw
CL1	0.210893	0.085101	0.180907
CL2	0.451477	0.182184	0.387284
CL3	0.815768	0.329186	0.699779
CL4	1.000000	0.403529	0.857816

Figure 136: Application Case-01. Capability Levels for PO



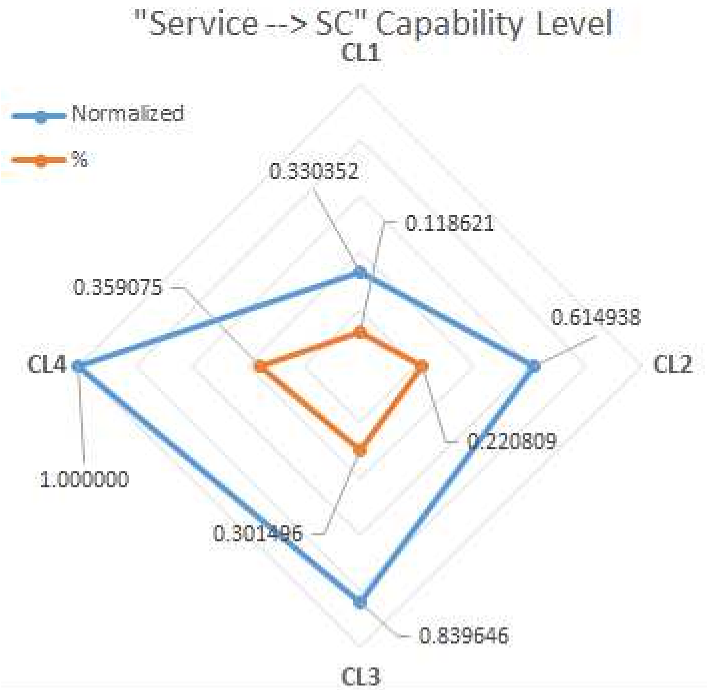
Source: The author (2015).

8.1.3.3.3 WITHIN SERVICE

Table 115: Application Case-01. Capability Levels for SC

Capability Levels	Normalized	%	Raw
CL1	0.330352	0.118621	0.330352
CL2	0.614938	0.220809	0.614938
CL3	0.839646	0.301496	0.839646
CL4	1.000000	0.359075	1.000000

Figure 137: Application Case-01. Capability Levels for SC

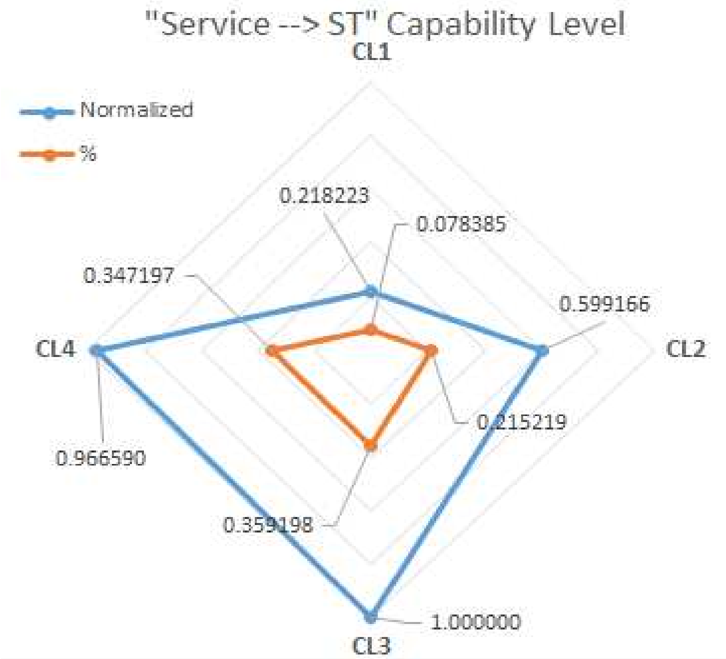


Source: The author (2015).

Table 116: Application Case-01. Capability Levels for ST

Capability Levels	Normalized	%	Raw
CL1	0.218223	0.078385	0.172126
CL2	0.599166	0.215219	0.472601
CL3	1.000000	0.359198	0.788764
CL4	0.966590	0.347197	0.762411

Figure 138: Application Case-01. Capability Levels for ST

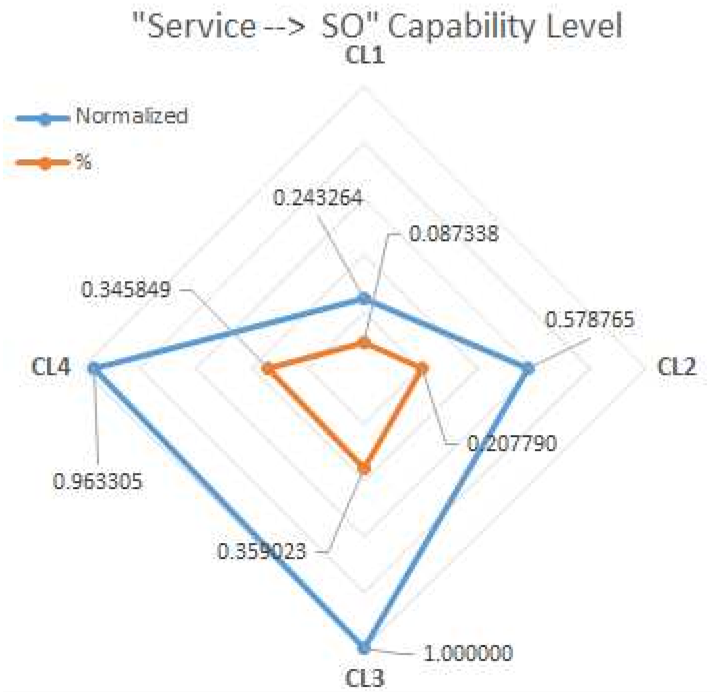


Source: The author (2015).

Table 117: Application Case-01. Capability Levels for SO

Capability Levels	Normalized	%	Raw
CL1	0.243264	0.087338	0.178324
CL2	0.578765	0.207790	0.424261
CL3	1.000000	0.359023	0.733045
CL4	0.963305	0.345849	0.706145

Figure 139: Application Case-01. Capability Levels for SO



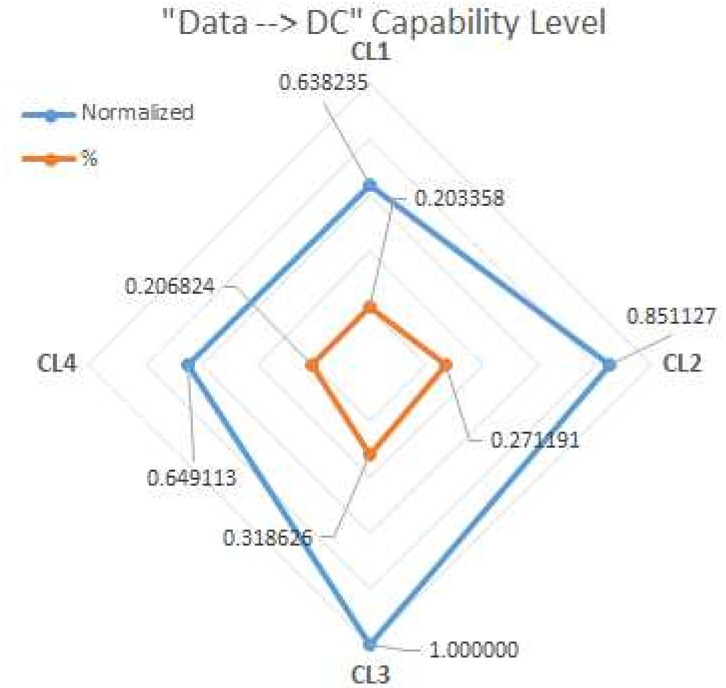
Source: The author (2015).

8.1.3.3.4 WITHIN DATA

Table 118: Application Case-01. Capability Levels for DC

Capability Levels	Normalized	%	Raw
CL1	0.638235	0.203358	0.530362
CL2	0.851127	0.271191	0.707272
CL3	1.000000	0.318626	0.830983
CL4	0.649113	0.206824	0.539402

Figure 140: Application Case-01. Capability Levels for DC

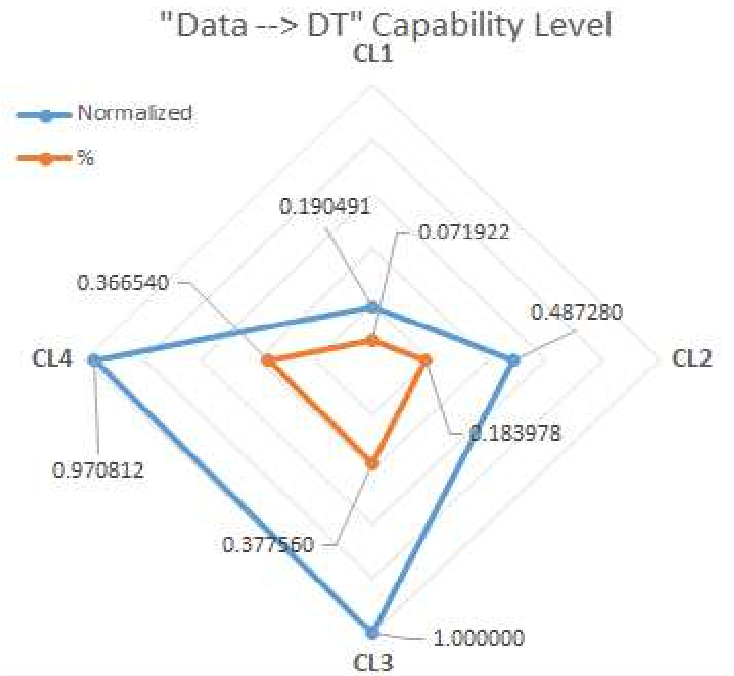


Source: The author (2015).

Table 119: Application Case-01. Capability Levels for DT

Capability Levels	Normalized	%	Raw
CL1	0.190491	0.071922	0.172372
CL2	0.487280	0.183978	0.440930
CL3	1.000000	0.377560	0.904879
CL4	0.970812	0.366540	0.878467

Figure 141: Application Case-01. Capability Levels for DT

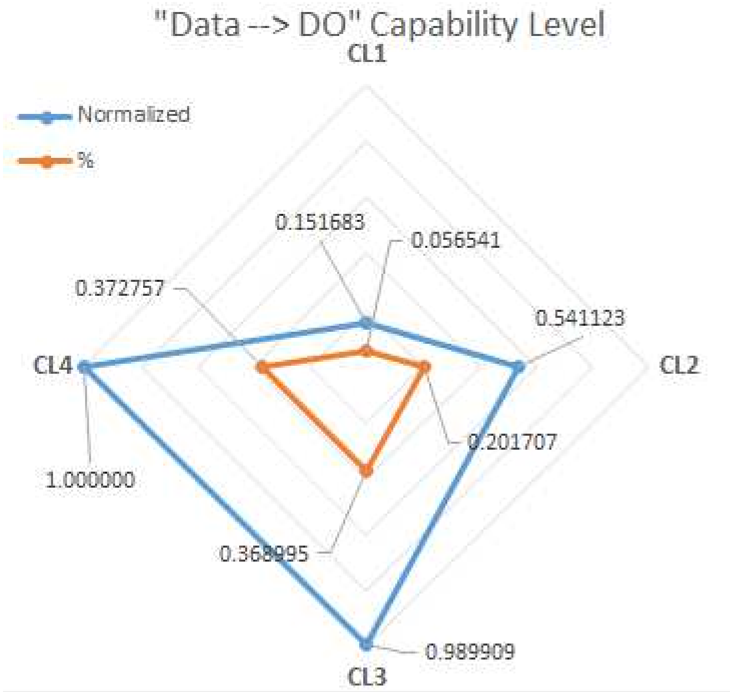


Source: The author (2015).

Table 120: Application Case-01. Capability Levels for DO

Capability Levels	Normalized	%	Raw
CL1	0.151683	0.056541	0.142374
CL2	0.541123	0.201707	0.507913
CL3	0.989909	0.368995	0.929157
CL4	1.000000	0.372757	0.938629

Figure 142: Application Case-01. Capability Levels for DO



Source: The author (2015).

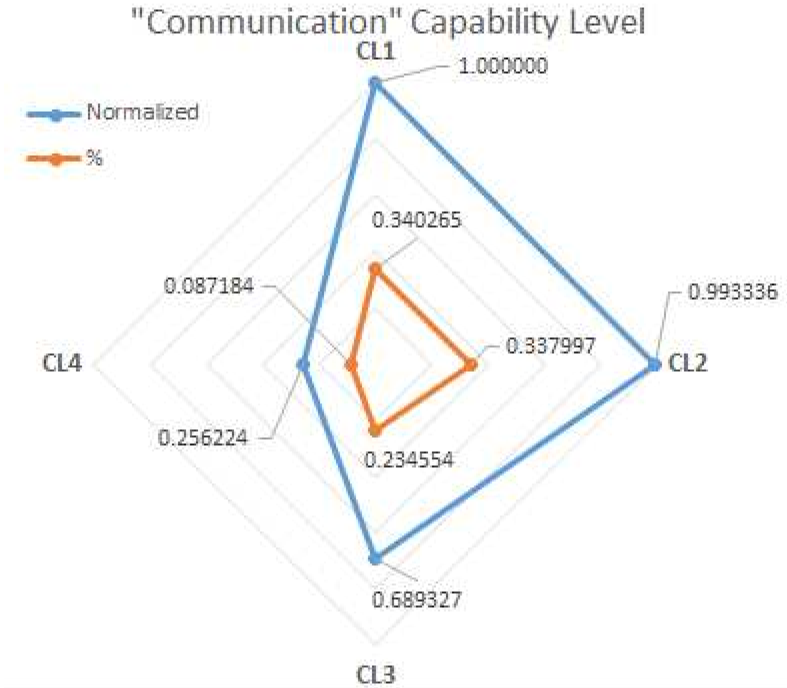
8.1.3.4 RESULTS REGARDING GOAL 4: OPERATIONAL VIEW

As previously exposed, the results regarding the operational view (Goal 4) generates more than 60 graphs, and it will not be presented here. Although, two examples are exposed: one considering lower degrees of Capability Levels (Table 121 and Figure 143) and other considering higher degrees of Capability Level (Table 122 and Figure 144).

Table 121: Application Case-01. Capability Levels for “Communication” attribute (within Business → BC)

Capability Levels	Normalized	%	Raw
CL1	1.000000	0.340265	0.170132
CL2	0.993336	0.337997	0.168999
CL3	0.689327	0.234554	0.117277
CL4	0.256224	0.087184	0.043592

Figure 143: Application Case-01. Capability Levels for “Communication” attribute (within Business → BC)

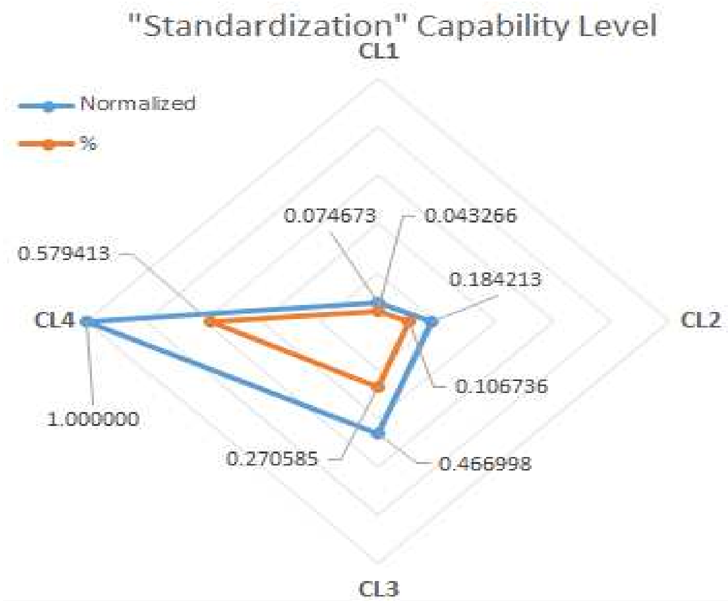


Source: The author (2015).

Table 122: Application Case-01. Capability Levels for “Standardization” attribute (within Process → PO)

Capability Levels	Normalized	%	Raw
CL1	0.074673	0.043266	0.021633
CL2	0.184213	0.106736	0.053368
CL3	0.466998	0.270585	0.135292
CL4	1.000000	0.579413	0.289707

Figure 144: Application Case-01. Capability Levels for “Standardization” attribute (within Process → PO)



Source: The author (2015).

8.1.3.5 GENERAL ANALYSIS

The results indicate that the capability levels related to Application Case-01 are around the levels 3 and 4, with a little less percentage within level 2, indicating a considerable mature entity with respect to the interoperability aspects. With the strategic overview indicating 34.72% adherent to level 3 and 34.64% adherent to level 4, the entity presents several aspects of a managed and institutionalized interoperability orientation. Considering the pertinent percentage, there are controls, formal management and institutionalization of processes, guidelines and attributes, as oriented in the Public Administration Interoperability Capability Model (PAICM). In addition, some specific aspects detected in Application Case-01 and based on the description of the capability levels (section 6.2, Table 71), are the following:

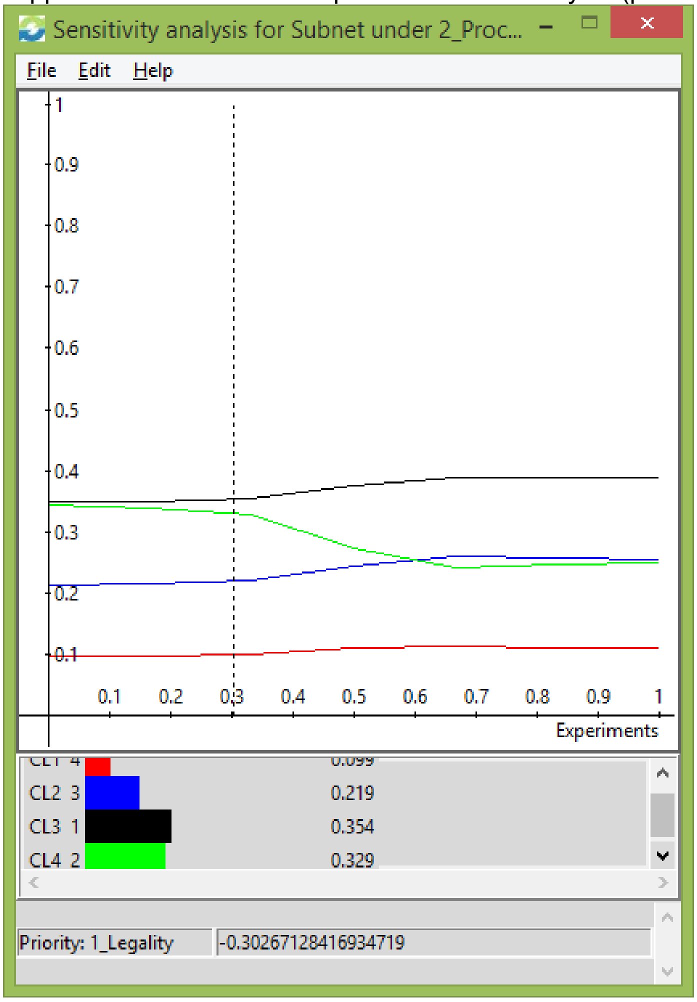
- Decision-makers are able to share information between systems.
- People are formally trained regarding the execution of the processes.
- There are adequate resources to produce controlled outputs.
- The processes discipline helps to ensure that existing practices are retained during times of stress.
- Interoperability is a strategic focus and is embedded within the entity's strategic plan.
- Several processes are institutionalized.
- Quantitative objectives for quality and process performance are established and used as criteria for managing the processes and/or guidelines.
- There are shared value systems and shared goals, a common understanding and readiness to interoperate.
- Systems allow data exchange.
- Entities are able to interoperate with multi-lingual and multicultural heterogeneous partners.
- Interoperability capability is extended to heterogeneous systems/partners.
- Data and applications are fully shared and can be distributed, with a common interpretation regardless of the form.

Once the collected diagnosis data are in the Super Decisions software, the tool allows performing almost an infinite number of analysis and comparisons, including a sensitivity analysis, which permits that the user creates independent variables that can be compared to the values of the alternatives according to the variation of the variables values. Considering a more organizational and operational application of these evaluation possibilities, it is possible to verify, for example, which is the weight of a certain concern or attribute (or other chosen variable), considering the different expectations (according to the goals presented in Table 95), in the influence on the interoperability capability of the entity. That is, how the change in the priorities of certain criteria can affect the capability levels?

The sensitive analysis can use the Interoperability Attributes Correlation Matrix (IACM) to choose the variables (attributes, concerns) according to the priorities or "importance degree" generated by the analysis of the IACM itself. For example, considering the complete IACM structure exposed in Figure 99, three attributes with a considerable relative importance weight are "Communication" (with 14.3%), "Policy and regulations" (with 6.3%) and "Tools" (with 9.5%). That is, "Communication" is an important item to improve, once it has the highest importance weight (according to the IACM qualitative analysis). Considering that, it is possible to simulate, using a sensitive analysis in Super Decisions, what happens when the "Communication" values variate. These aspects can be considered as an extend diagnosis perspective, and an organizational effort must be considered to execute the evaluation of which attribute/concern has a significant weight in the interoperability capacity, using IACM, QFD or other technique.

One example of a possible sensitive analysis within Application Case-01 is exposed in Figure 145 and Figure 146. The figures expose a sensitive analysis for the subnet under "Process" concern considering the attribute "Legality" (within "PO") as the variable (represented by the vertical dotted line). It is possible to move the dotted vertical line that represents the variable, and then, the values of the alternatives (horizontal lines) can change too (according to each scenario).

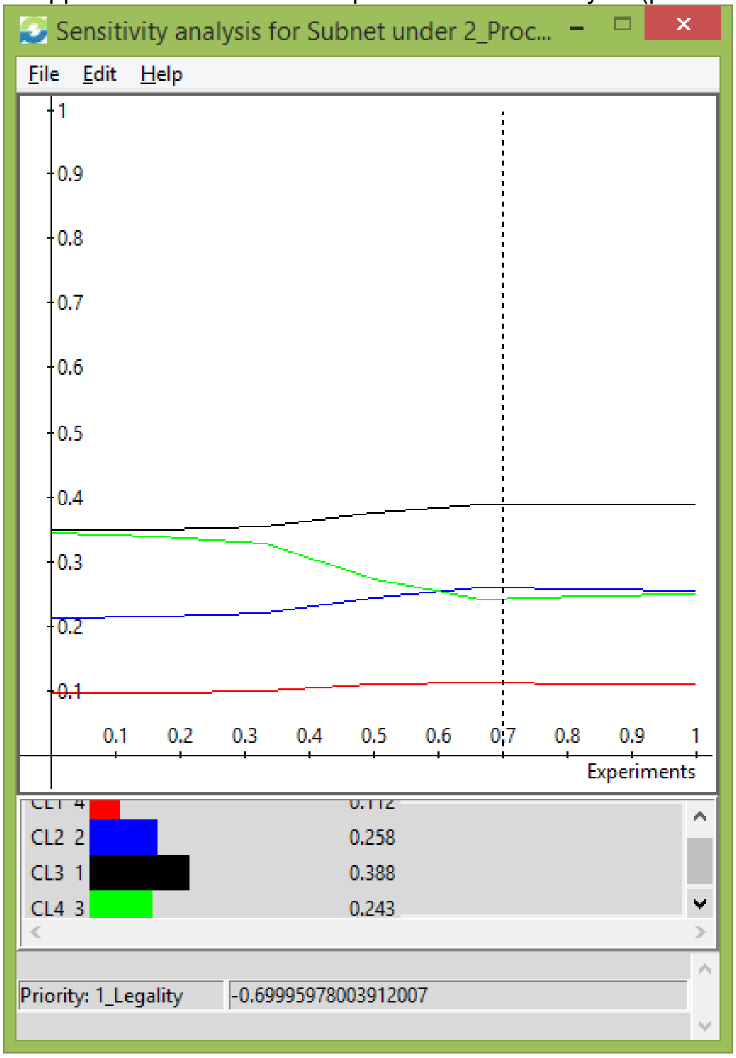
Figure 145: Application Case-01. Example of sensitive analysis (position 1)



Source: The author (2015), with Super Decisions software.

Figure 145 sets the value to “Legality” as 0.3 and then the distribution of Capability Levels has a Level 4 higher than the Level 2. If “Legality” have a value around 0.7 (Figure 146), then Capability Level 2 has a higher value than Capability Level 4. That is, if the importance of the attribute “Legality” increase, in comparison with the others, the Capability Levels 2 and 3 are more pertinent than the group of Levels 3 and 4. This occurs because other attributes have guidelines with higher capability levels than “Legality”.

Figure 146: Application Case-01. Example of sensitive analysis (position 2)



Source: The author (2015), with Super Decisions tool.

An interesting behavior occurs in this case: at no time (i.e., independently of the variable position), there are changes in the suggested capability level. That is, capability level 3 (CL3 1, black line) is always the most predominant. Considering this particular aspect, from the evaluation scenario obtained from the organization (characterizing the curves), the variable ("Legality") has no influence on the change of the highest capability level diagnosed. Thus, it does not improve the maturity. Instead, the more weight is given to the variable (up to 0.9), an increase in the level 2 (CL 2 2, blue line) occur, almost equating the values with capability level 4 (CL 4 3, green line) that started a decreasing behavior when the variable is at approximatively near 0.3.

8.1.4 FEEDBACK AND LESSONS LEARNED

At the end of the interviews, the team had the opportunity to provide suggestions and comments about the diagnosis process itself and about general pertinent issues. Besides that, some lessons learned and perceptions were collected by the author during the process, including, but not limited, to the following aspects:

- At the beginning of the process, it could have been allocated more time to the training related to the PAIDM and PAICM. The initial schedule considered one and a half hour for both training but, including all the discussions and explanations, two hours were spent. There was a perception that it would be better to have more time.
- The schedule for the interviews considered two and a half hours per person, but at the end, it took almost four hours with each one. An adequate schedule would be at least 4 hours.
- Individual interviews are interesting because it is possible to analyze the perceptions independently, but they are very effort demand (to gather and to consolidate all the data), with several repetitions of the same issues. In addition, the process can become very tiring and stressful if the diagnosis leader is working alone.
- The consolidation process (considering the gathering of all the separate answers, line by line of pairwise comparison) was done manually, as the insertion of the values into the spreadsheet for the geometric mean calculation and the input into the Super Decisions tool. The sum of this whole process took around 4 days, consuming approximatively 40 hours of effort. An automatization of these processes can be very useful and handy[3] (although it is important to remember that diagnosis, appraisals and certifications processes regarding other norms and models are made almost entirely manually).
- To get authorization or support to perform a diagnosis within a public related organization is not a trivial task. There several sensible documents,

---

[3] There is an ongoing project related to a software development portal for interoperability diagnosis. See APPENDIX 3: PROTOTYPE SOFTWARE.

access and politics involved. As the actor starting the process was the author of this research, it was necessary to sensitize some of the senior managers and other involved regarding the importance of the research. Luckily, they were all receptive to the idea and open to some new innovative processes and methods.

- Some of the suggestions (especially regarding the text and descriptions of some guidelines) were changed so the second application case application could be executed with an updated version of the PAICM and PAIDM. Although, no structural changes were made and the previous descriptions of the capability model and the diagnosis method exposed in sections 6 and 7 already expose the actual (most recent) version of the artifacts. That is, part of this thesis document was written already considering the updates detected in the Application Case-01.

All of the above perceptions (and other minor considerations) were used to updated and improve the framework in general and the next iteration with the models in specific, especially considering a next application case that was already planned to be executed. The improvement is planned in the research framework (Figure 4), specifically in process A12.

8.2 APPLICATION CASE-02

8.2.1 ENTITY CHARACTERIZATION

The second application case application was within a city hall office within Paraná state. The governmental office is within a formal municipality structure, and is the responsible to interact with service suppliers. Most of the interactions and developed services are IT oriented, but there is also some hardware, logical and physical network involved. The office is responsible for defining and detecting the municipality needs in terms of IT, building plans and bids to select suppliers that can deliver those services. The defined entity is the office itself, which has less than 10 employees.

8.2.2 PEOPLE SELECTION AND INTERVIEWS STRATEGY

Two people were select: one was an operational and technical manager of the area (not necessarily a political function); the other was a team member with a lot of interaction with governmental suppliers. Each one has more than 20 years regarding the relation with public administration projects, and they are all considered senior employees. The both answered the whole questionnaire, once they have the skills and engagement to do so.

As this is the second application, some changes were made regarding the first experience and then it was possible to detect differences and comparisons. The interviews were not individuals, they were executed with the both persons at the same time, and the answers were gathered considering a consensus from both. Therefore, it was not necessary to execute geometric mean consolidations of other types of data manipulations. The whole data collection was executed using Excel spreadsheets built by the author. The final data were inserted into the Super Decisions software.

8.2.3 RESULTS AND ANALYSIS

The results are presented in the same form as described in Application Case-01, with tables and radial graphs, considering the three basic columns of results: “raw”, “%” and “normalized”. Once again, only a few samples regarding Goal 4 are presented, and the full results can be found in Cestari et al., (2015b).

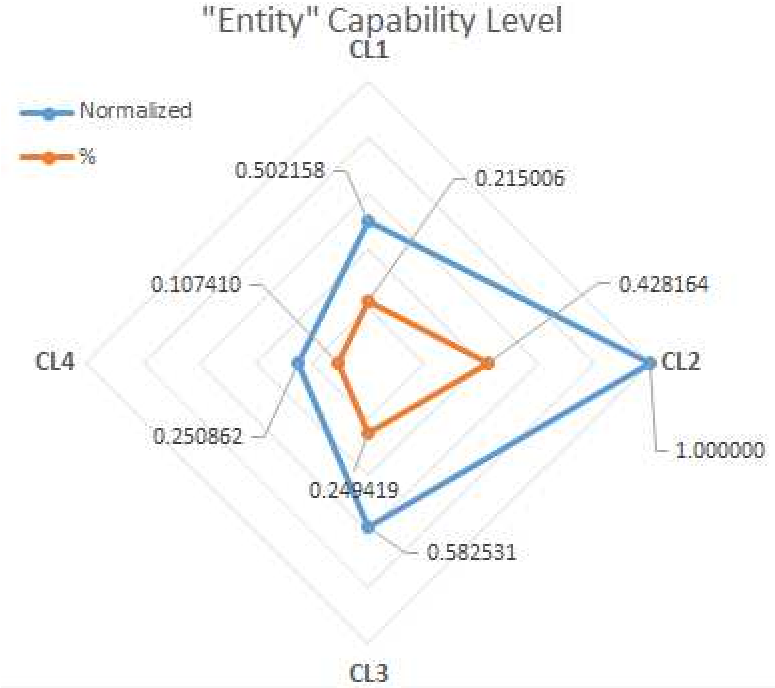
8.2.3.1 RESULTS REGARDING GOAL 1: STRATEGIC VIEW

At this level, the results represent the values regarding the Capability Levels of the entire entity, considered as a “maturity level” for the whole perspective.

Table 123: Application Case-02. Capability Levels for the whole entity

Capability Levels	Normalized	%	Raw
CL1	0.502158	0.215006	0.502158
CL2	1.000000	0.428164	1.000000
CL3	0.582531	0.249419	0.582531
CL4	0.250862	0.107410	0.250862

Table 124: Application Case-02. Capability Levels for the whole entity



Source: The author (2015).

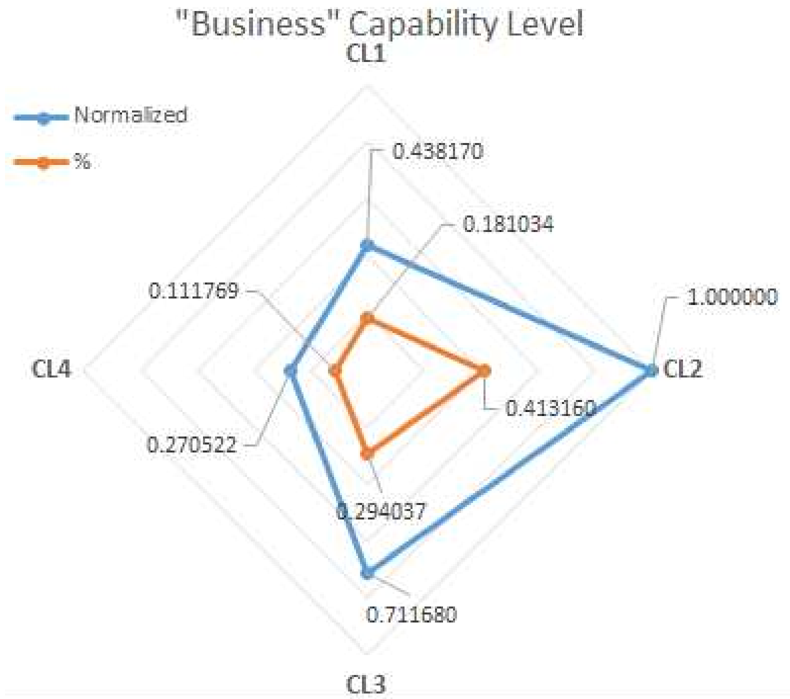
8.2.3.2 RESULTS REGARDING GOAL 2: MANAGEMENT VIEW

This level exposes the concerns view, with a management perspective relating the capability levels of the areas involved (Business, Process, Service and Data).

Table 125: Application Case-02. Capability Levels for the “Business” concern

Capability Levels	Normalized	%	Raw
CL1	0.438170	0.181034	0.430835
CL2	1.000000	0.413160	0.983258
CL3	0.711680	0.294037	0.699765
CL4	0.270522	0.111769	0.265993

Figure 147: Application Case-02. Capability Levels for the “Business” concern

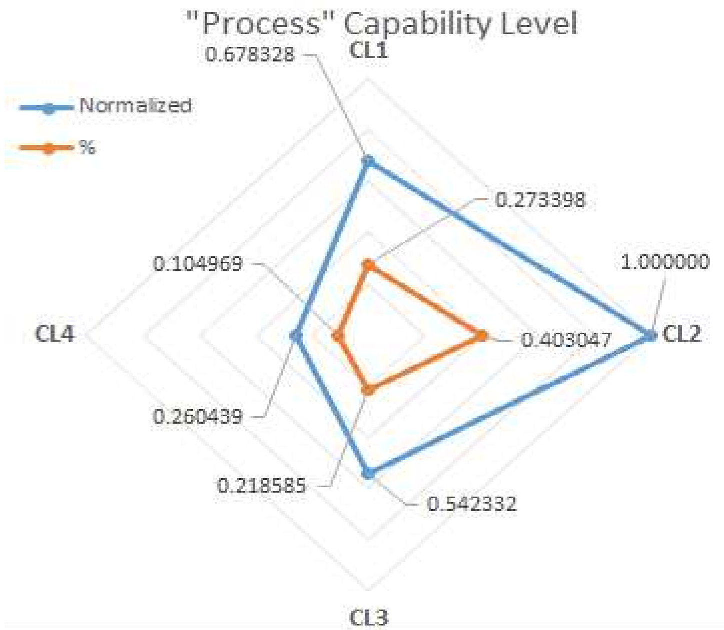


Source: The author (2015).

Table 126: Application Case-02. Capability Levels for the “Process” concern

Capability Levels	Normalized	%	Raw
CL1	0.678328	0.273398	0.673713
CL2	1.000000	0.403047	0.993197
CL3	0.542332	0.218585	0.538643
CL4	0.260439	0.104969	0.258667

Figure 148: Application Case-02. Capability Levels for the “Process” concern

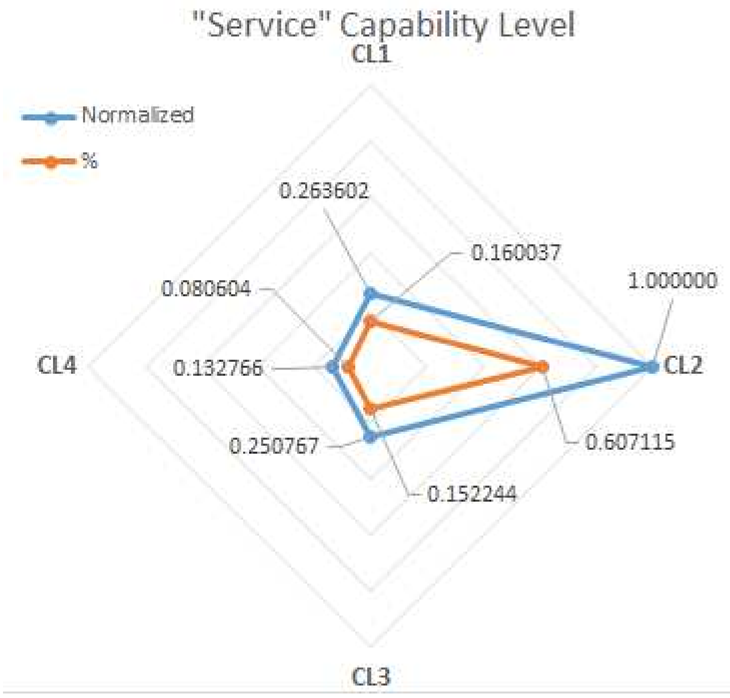


Source: The author (2015).

Table 127: Application Case-02. Capability Levels for the “Service” concern

Capability Levels	Normalized	%	Raw
CL1	0.263602	0.160037	0.263602
CL2	1.000000	0.607115	1.000000
CL3	0.250767	0.152244	0.250767
CL4	0.132766	0.080604	0.132766

Figure 149: Application Case-02. Capability Levels for the “Service” concern

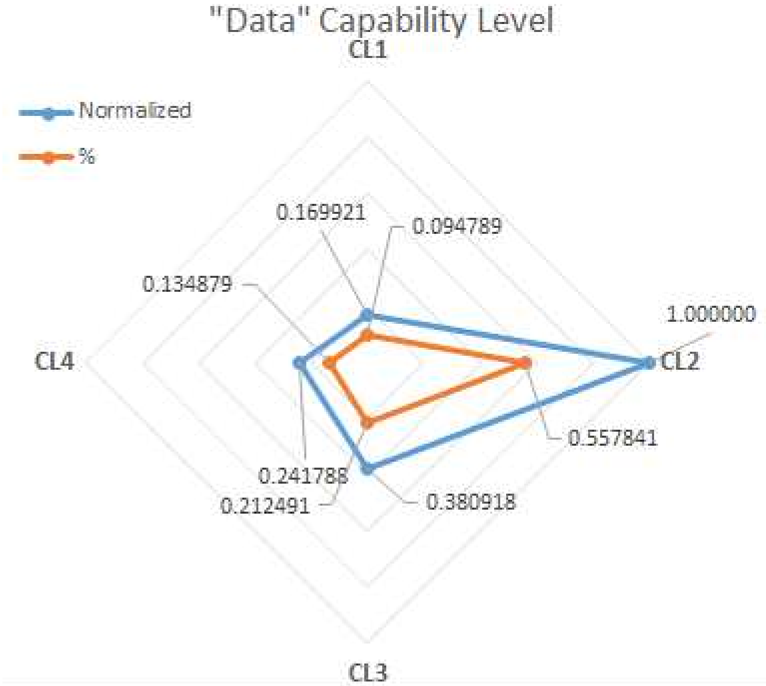


Source: The author (2015).

Table 128: Application Case-02. Capability Levels for the “Data” concern

Capability Levels	Normalized	%	Raw
CL1	0.169921	0.094789	0.169921
CL2	1.000000	0.557841	1.000000
CL3	0.380918	0.212491	0.380918
CL4	0.241788	0.134879	0.241788

Figure 150: Application Case-02. Capability Levels for the “Data” concern



Source: The author (2015).

8.2.3.3 RESULTS REGARDING GOAL 3: TACTICAL VIEW

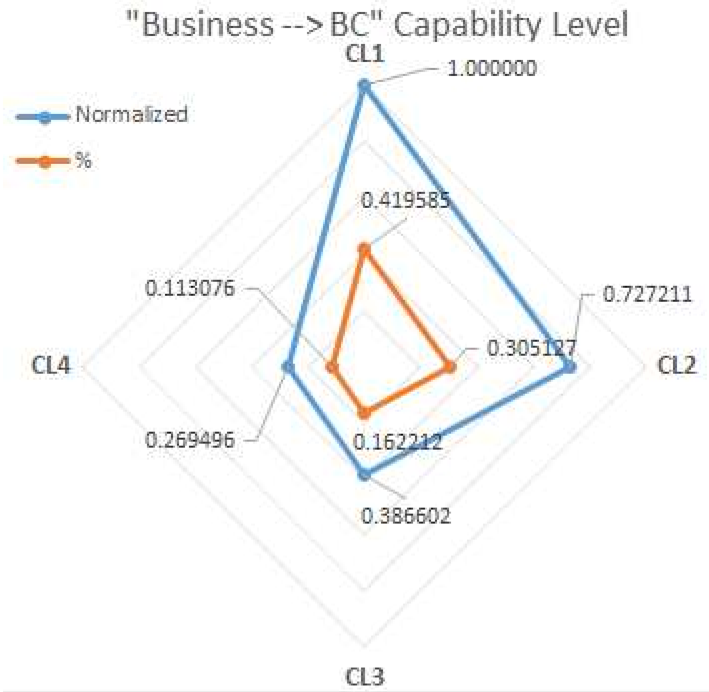
This level exposes a tactical view, considering the 12 combinations of Concerns x Barriers.

8.2.3.3.1 WITHIN BUSINESS

Table 129: Application Case-02. Capability Levels for BC

Capability Levels	Normalized	%	Raw
CL1	1.000000	0.419585	0.830278
CL2	0.727211	0.305127	0.603788
CL3	0.386602	0.162212	0.320987
CL4	0.269496	0.113076	0.223756

Figure 151: Application Case-02. Capability Levels for BC

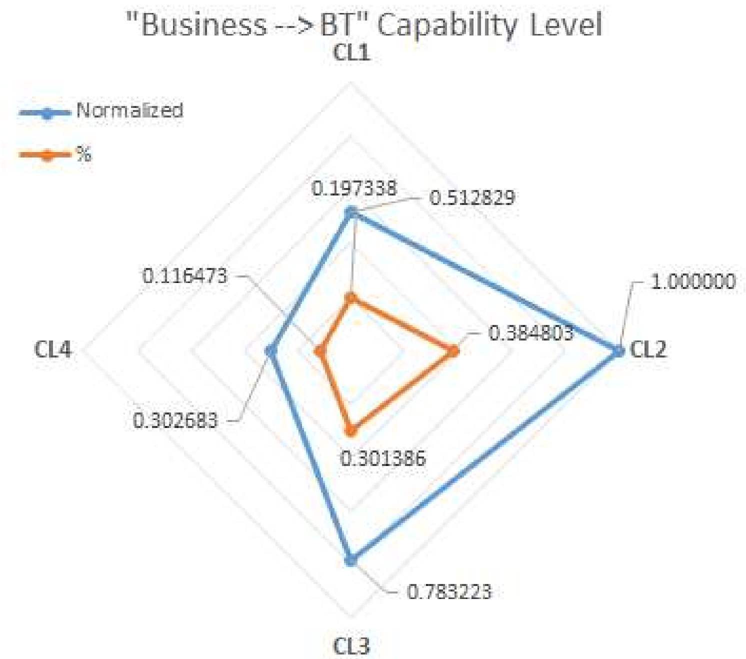


Source: The author (2015).

Table 130: Application Case-02. Capability Levels for BT

Capability Levels	Normalized	%	Raw
CL1	0.512829	0.197338	0.371447
CL2	1.000000	0.384803	0.724311
CL3	0.783223	0.301386	0.567297
CL4	0.302683	0.116473	0.219237

Figure 152: Application Case-02. Capability Levels for BT

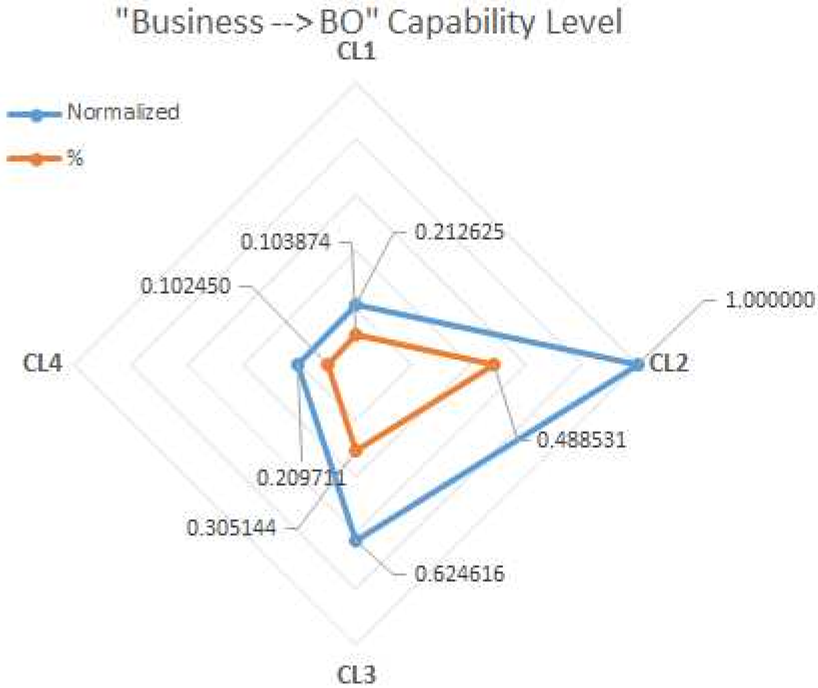


Source: The author (2015).

Table 131: Application Case-02. Capability Levels for BO

Capability Levels	Normalized	%	Raw
CL1	0.212625	0.103874	0.197782
CL2	1.000000	0.488531	0.930188
CL3	0.624616	0.305144	0.581010
CL4	0.209711	0.102450	0.195071

Figure 153: Application Case-02. Capability Levels for BO



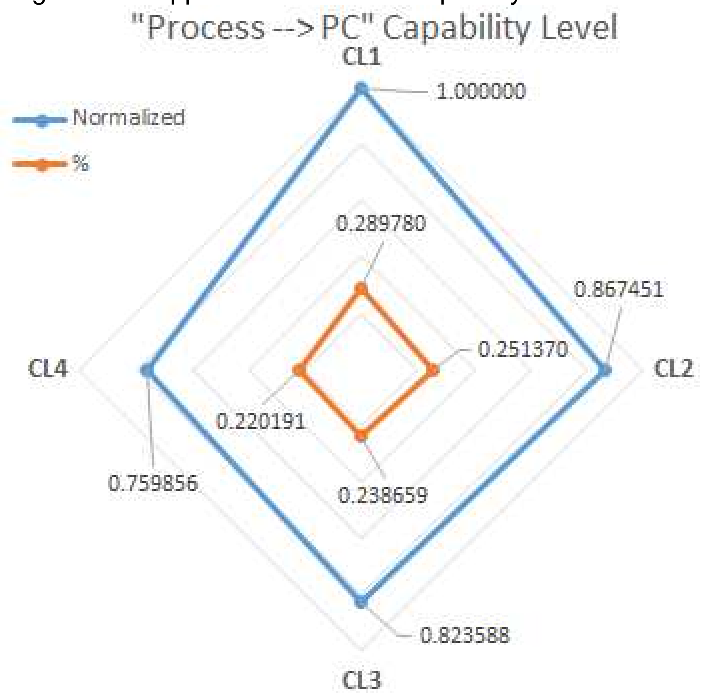
Source: The author (2015).

8.2.3.3.2 WITHIN PROCESS

Table 132: Application Case-02. Capability Levels for PC

Capability Levels	Normalized	%	Raw
CL1	1.000000	0.289780	0.944121
CL2	0.867451	0.251370	0.818979
CL3	0.823588	0.238659	0.777567
CL4	0.759856	0.220191	0.717397

Figure 154: Application Case-02. Capability Levels for PC

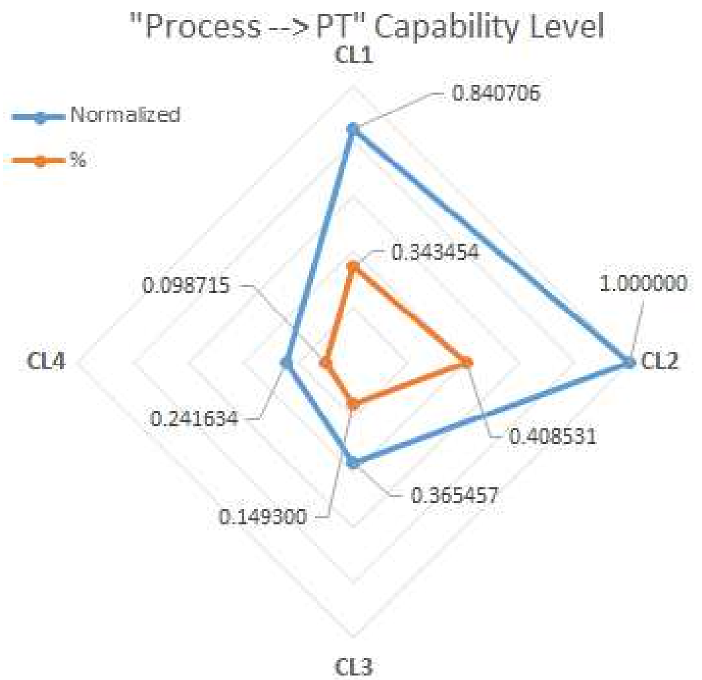


Source: The author (2015).

Table 133: Application Case-02. Capability Levels for PT

Capability Levels	Normalized	%	Raw
CL1	0.840706	0.343454	0.630503
CL2	1.000000	0.408531	0.749969
CL3	0.365457	0.149300	0.274081
CL4	0.241634	0.098715	0.181218

Figure 155: Application Case-02. Capability Levels for PT

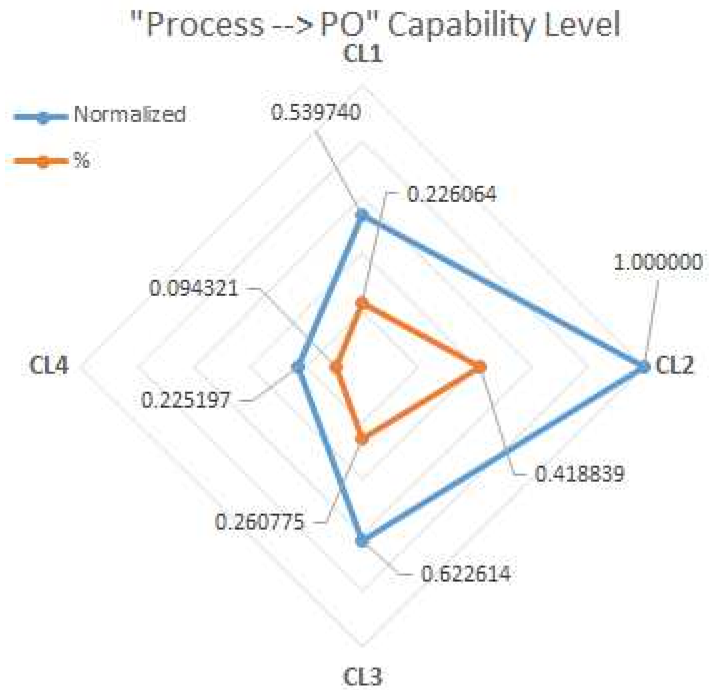


Source: The author (2015).

Table 134: Application Case-02. Capability Levels for PO

Capability Levels	Normalized	%	Raw
CL1	0.539740	0.226064	0.469189
CL2	1.000000	0.418839	0.869288
CL3	0.622614	0.260775	0.541231
CL4	0.225197	0.094321	0.195761

Figure 156: Application Case-02. Capability Levels for PO



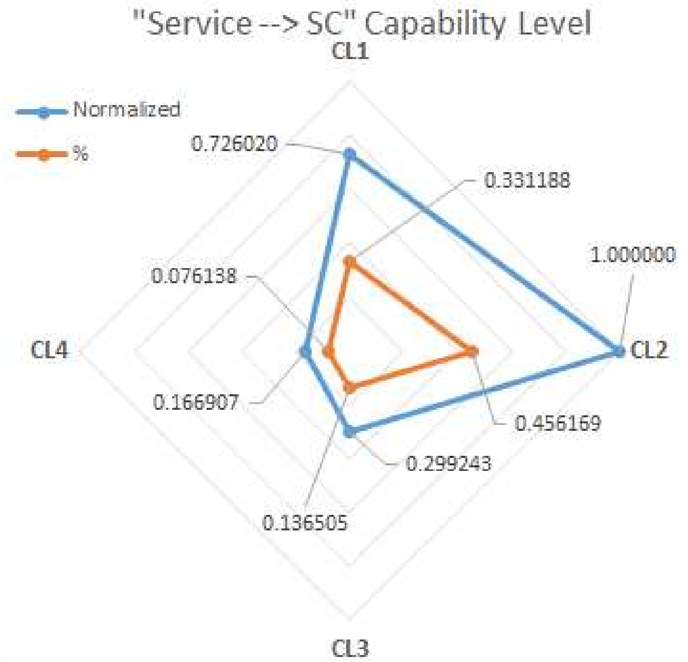
Source: The author (2015).

8.2.3.3.3 WITHIN SERVICE

Table 135: Application Case-02. Capability Levels for SC

Capability Levels	Normalized	%	Raw
CL1	0.726020	0.331188	0.726020
CL2	1.000000	0.456169	1.000000
CL3	0.299243	0.136505	0.299243
CL4	0.166907	0.076138	0.166907

Figure 157: Application Case-02. Capability Levels for SC

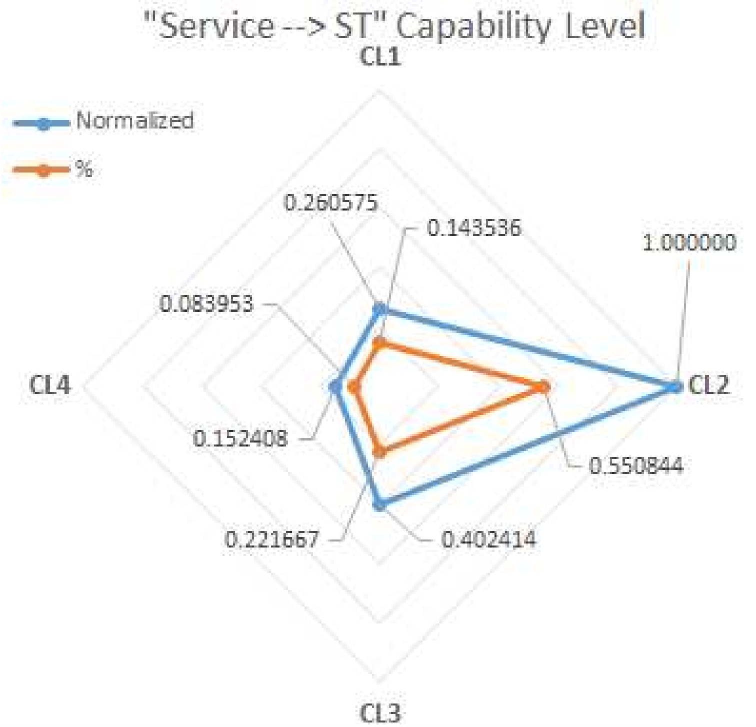


Source: The author (2015).

Table 136: Application Case-02. Capability Levels for ST

Capability Levels	Normalized	%	Raw
CL1	0.260575	0.143536	0.258454
CL2	1.000000	0.550844	0.991860
CL3	0.402414	0.221667	0.399138
CL4	0.152408	0.083953	0.151168

Figure 158: Application Case-02. Capability Levels for ST

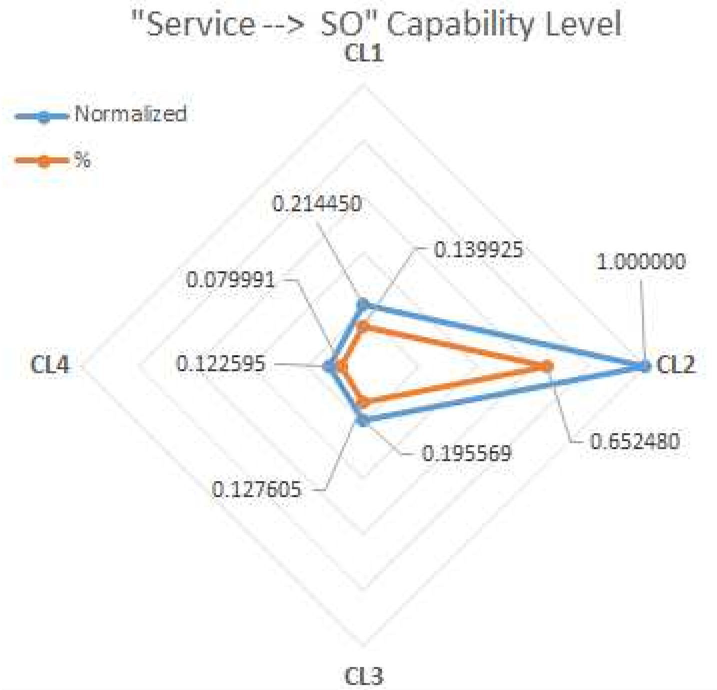


Source: The author (2015).

Table 137: Application Case-02. Capability Levels for SO

Capability Levels	Normalized	%	Raw
CL1	0.214450	0.139925	0.194647
CL2	1.000000	0.652480	0.907657
CL3	0.195569	0.127605	0.177510
CL4	0.122595	0.079991	0.111274

Figure 159: Application Case-02. Capability Levels for SO



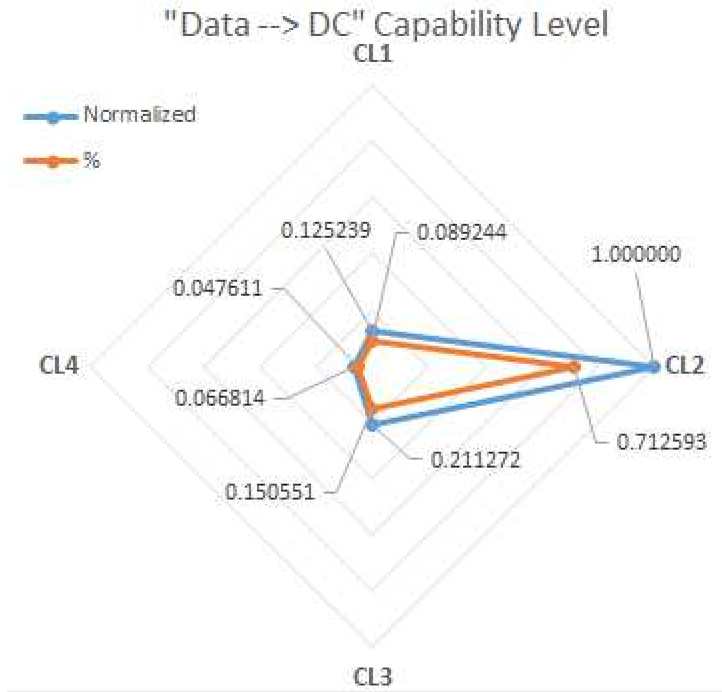
Source: The author (2015).

8.2.3.3.4 WITHIN DATA

Table 138: Application Case-02. Capability Levels for DC

Capability Levels	Normalized	%	Raw
CL1	0.125239	0.089244	0.125239
CL2	1.000000	0.712593	1.000000
CL3	0.211272	0.150551	0.211272
CL4	0.066814	0.047611	0.066814

Figure 160: Application Case-02. Capability Levels for DC

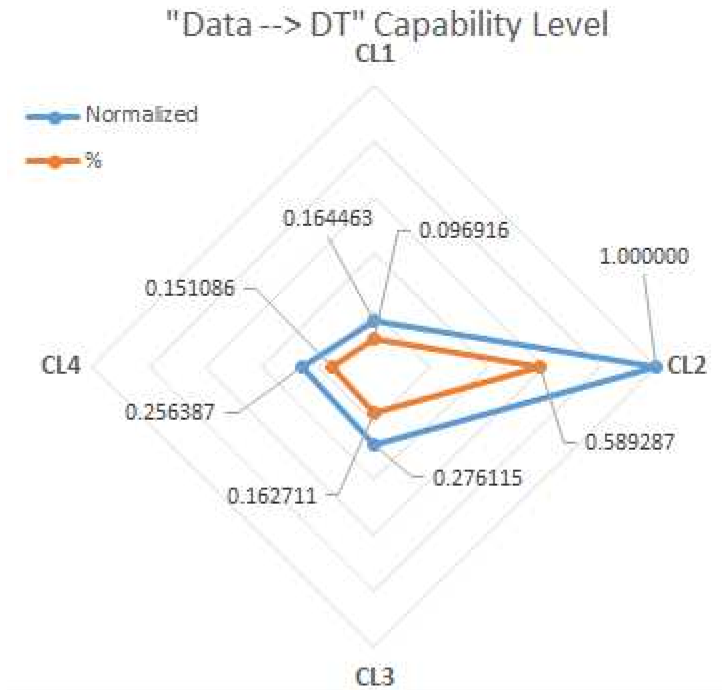


Source: The author (2015).

Table 139: Application Case-02. Capability Levels for DT

Capability Levels	Normalized	%	Raw
CL1	0.164463	0.096916	0.163206
CL2	1.000000	0.589287	0.992353
CL3	0.276115	0.162711	0.274004
CL4	0.256387	0.151086	0.254427

Figure 161: Application Case-02. Capability Levels for DT

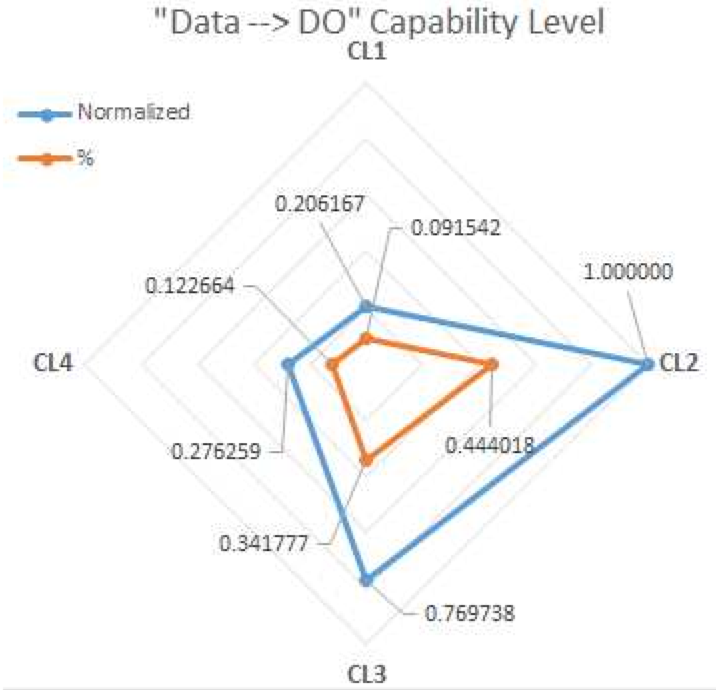


Source: The author (2015).

Table 140: Application Case-02. Capability Levels for DO

Capability Levels	Normalized	%	Raw
CL1	0.206167	0.091542	0.195159
CL2	1.000000	0.444018	0.946606
CL3	0.769738	0.341777	0.728638
CL4	0.276259	0.122664	0.261508

Figure 162: Application Case-02. Capability Levels for DO



Source: The author (2015).

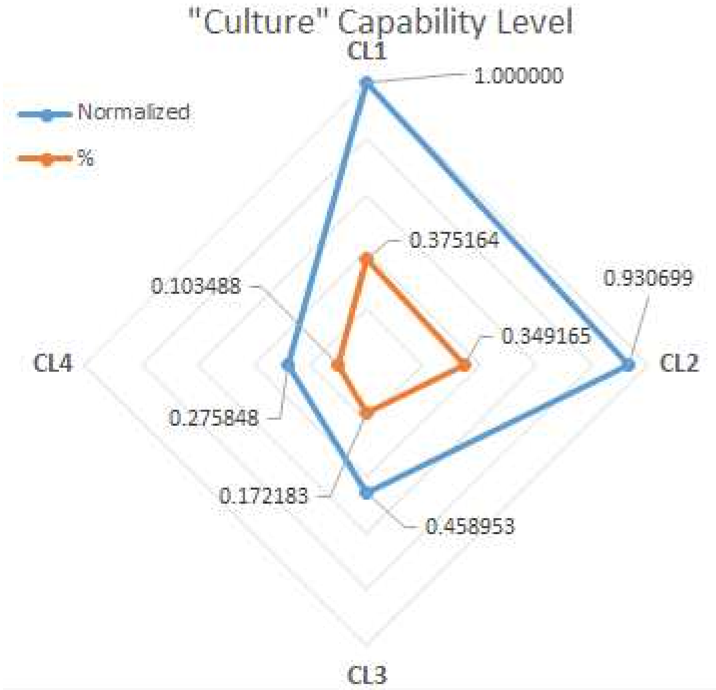
8.2.3.4 RESULTS REGARDING GOAL 4: OPERATIONAL VIEW

As previously exposed in Application Case-01, the results regarding the operational view (see Goal 4) generates more than 60 graphs, and it will not be presented here. Although, two examples are exposed: one considering lower degrees of Capability Levels (Table 141 and Figure 163) and other considering higher degrees of Capability Level (Table 142 and Figure 164).

Table 141: Application Case-02. Capability Levels for “Culture” attribute (within Business → BO)

Capability Levels	Normalized	%	Raw
CL1	1.000000	0.375164	0.187582
CL2	0.930699	0.349165	0.174582
CL3	0.458953	0.172183	0.086091
CL4	0.275848	0.103488	0.051744

Figure 163: Application Case-02. Capability Levels for “Culture” attribute (within Business → BO)

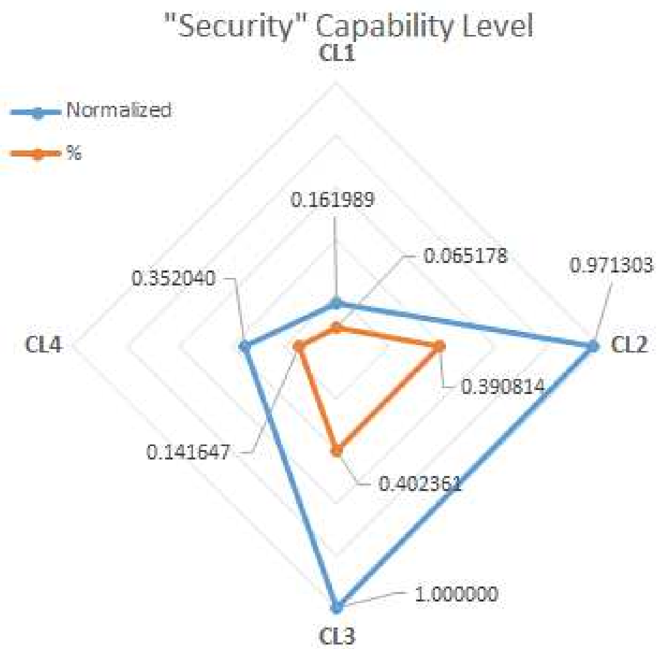


Source: The author (2015).

Table 142: Application Case-02. Capability Levels for “Security” attribute (within Data → DO)

Capability Levels	Normalized	%	Raw
CL1	0.161989	0.065178	0.032589
CL2	0.971303	0.390814	0.195407
CL3	1.000000	0.402361	0.201180
CL4	0.352040	0.141647	0.070824

Figure 164: Application Case-02. Capability Levels for “Security” attribute (within Data → DO)



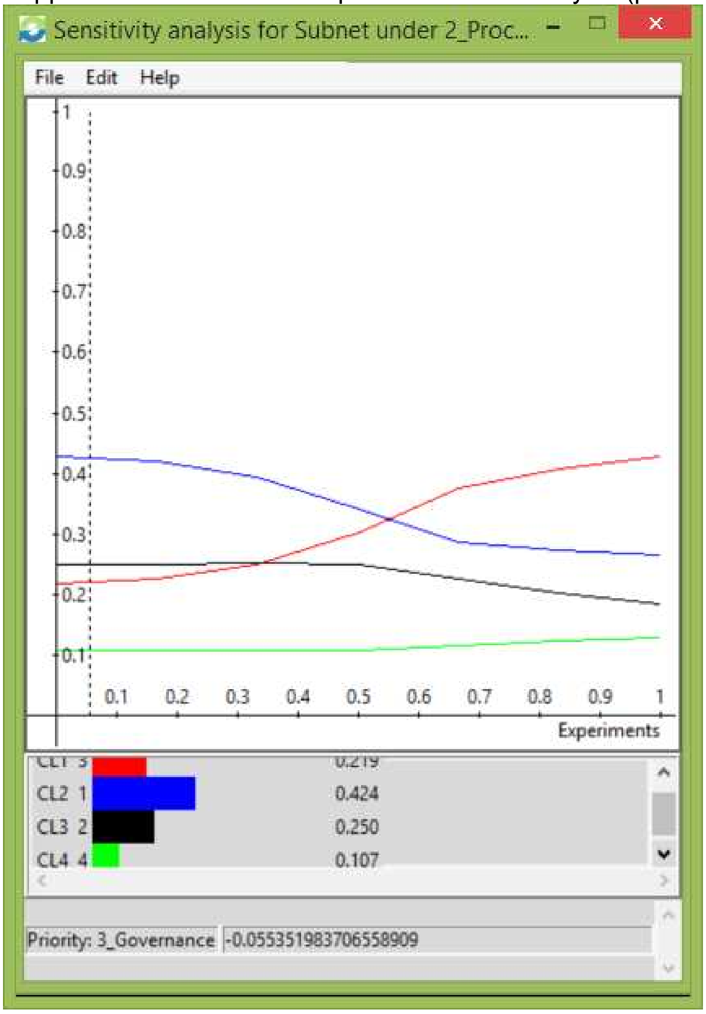
Source: The author (2015).

8.2.3.5 GENERAL ANALYSIS

The results indicate that the capability levels related to Application Case-02 are majorly around the level 2 (42.81%), with 24.94% within level 3 and 21.50% within level 1. That is, in general, the entity related to Application Case-02 are less interoperability mature than the entity relates do Application Case-01.

As exposed in the general analysis of Application Case-01, one example of a possible sensitive analysis is exposed in Figure 165 and Figure 166. The figures expose a sensitive analysis for the subnet under “Process → PO” considering the attribute “Governance” as the variable. It is possible to move the dotted vertical line that represents the variable, and then the values of the alternatives also change. The “Governance” priority considering its pairwise comparison with the other attributes within “Process → PO” is low (around 5.7%) and with this value, as exposed in Figure 165 (vertical dotted line at the very left of the graph), the capability levels regarding the “Process → PO” aspect are as exposed in Table 134. Figure 165 exposes those capability levels also using colorful lines (around 42% to level 2 – blue line, around 26% to level 3 – black line and around 22% to level 1 – red line).

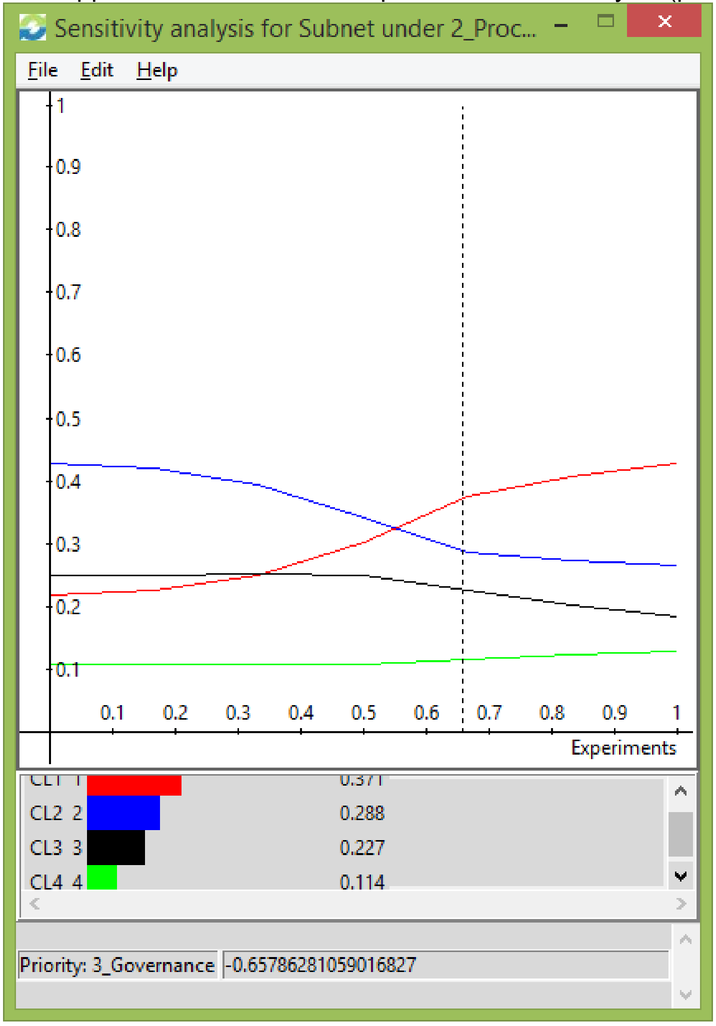
Figure 165: Application Case-02. Example of sensitive analysis (position 1)



Source: The author (2015), with Super Decisions software.

In an event of changing the priorities regarding the pairwise comparison, if the “Governance” attribute had a value around 0.65, the capability levels for the “Process → PO” view would be as exemplified in Figure 166. That is, the level 1 would be predominant (around 37% - red line), then followed by level 2 (around 28% - blue line) and then level 3 (around 22% - black line).

Figure 166: Application Case-02. Example of sensitive analysis (position 2)



Source: The author (2015), with Super Decisions tool.

An interesting behavior occurs in this case but unlike the Application Case-01, where no changes occur in the suggested highest capability levels, in this scenario (Figure 166) there is a major change between capability level 2 (CL2 2, blue line) and capability level 1 (CL1 1, red line).

So, considering this particular aspect, from the evaluation scenario obtained from the organization (characterizing the curves), the variable ("Governance") has a high influence regarding the main capability level diagnosed. Thus, the variable decreases (according to its value) the general diagnosed maturity. That is, the more weight is given to the variable (up to 0.55), a major decrease occurs in capability level 2 (CL2 2, blue line) and a minor decrease occur in capability level 3 (CL3 3, black line). A massive increase of capability level 1 is detected (CL1 1, red line), exemplifying a general decrease of the predominant capability level diagnosed.

8.2.4 FEEDBACK AND LESSONS LEARNED

As in Application Case-01, at the end of the interviews, the team also had the opportunity to provide suggestions and comments about the diagnosis process itself and about general pertinent issues. Again, some lessons learned and perceptions were collected by the author, including, but not limited, to the following aspects:

- As a need detected in Application Case-01, more time was dedicated to the interviews (four hours) and initial training (2 hours).
- The group interviews have a different dynamic from the individual interviews. There are natural discussions regarding almost each one of the comparisons, and this can take a lot of time and become very stressful. As the intention is to get the consensus regarding each comparison, the meeting is very time-consuming and it was necessary to act very firmly as a "mediator", once some of the discussions could last "forever". The participants of a group interview can be influenced by others answers or by the environment, especially if a superior is present. The reach for a consensus, the use of a pairwise comparison and the role of the diagnosis team leader as a mediator tries to minimize these eventual influences.
- There is no consolidation process as described in Application Case-01 (using geometric mean), once all the answers are achieved by consensus, the input of the values to the Super Decisions software "one to one" according to the values collected with the spreadsheets.
- As detected in Application Case-01, to get an "authorization" or support to perform a diagnosis was also a little difficult. It demanded previous meetings and network to organize the process. Again, Application Case-02 was also receptive to the idea and open to some new innovative processes and methods.
- No suggestions were made regarding the text description or a particular issue, but it was clearly detected that the subject is not obvious and more knowledge and experience with maturity models, appraisal, diagnosis and such could help the participants to achieve a better comprehension and "performance".

Similar to the exposed in Application Case-01, all of the above perceptions and other considerations) were used to updated and improve the framework. The improvement is planned in the research framework (Figure 4), specifically in process A12.

8.3 CONSIDERATIONS AND CHAPTER SYNTHESIS

This section presented the results of two application cases regarding the use of PAIDM/PAICM. The application cases were executed to evaluate public related organizations, obtaining the pertinent capability levels and collecting suggestions related to the improvement of the research framework and PAIDM/PAICM themselves. Both organizations work with IT services for municipalities, the first application case is related to a service provider (a private company) to the municipality while the second application case is related directly to a governmental entity. The results are presented in the form of tables and radial graphs and are organized according to the diagnosis goals exposed in Table 95. Both cases have a consistency ratio (see section 4.4.1.3) lower than 10%.

The “percent” and “normalized” values presented indicates the degree of adherence within the four capability levels proposed in PAICM, with the adoption of AHP/ANP techniques to perform the pairwise calculations and comparisons. Within the PAIDM approach, these results represent a quantitative support for the diagnosis positioning of an entity in the several interoperability perspectives, considering different organizational levels based on the diagnosis goals (Table 95). That is, the decision makers of the organization (or the entity) can have a perception of the interoperability capability level considering four main views, as following:

- **Strategic** view of the entire entity. A certain kind of “maturity level”, once it is in the “top” of a “bottom-up” diagnosis structure.
- **Management** view. In this scenario, the decision makers have access to the capability levels positioning regarding each one of the interoperability concerns (“Business”, “Process”, “Service” and “Data”)
- **Tactical** view. With this more granular view, it is possible to analyze the entity performance (regarding the interoperability aspects) with a

not so operational perspective, considering each one of the three interoperability barriers (“Conceptual”, “Technological” and “Organizational”) within each one of the four concerns (“Business”, “Process”, “Service” and “Data”). This gives the possibility to analyze a combination of 12 (concerns x barriers) complementary aspects.

- **Operational** view. At this point, the decision makers have a very granular positioning regarding the capability levels of each attribute. As this is the level directly associated with the diagnosis all guidelines (within the attributes), the decision makers have the possibility to do a very detailed analysis regarding the practices being executed within the entity, and then take actions to improve or adequate their performance. That is, the set of guidelines, as proposed by the PAICM, helps the decision makers to take and/or demand improvement actions focusing on the increase of the interoperability capability levels.

The diagnosis positioning proposed by PAIDM, using PAICM and illustrated with application cases, transcends current methods such as SCAMPI (SCAMPI Upgrade Team, 2011) or similar assessment processes (e.g., ISO 9001, MPS.BR), once PAIDM gives more granularity and perspectives based on the goals definition (Table 95) and made possible because of the PAICM structure. Besides that, PAIDM provides a quantitative approach (using AHP/ANP) that is not used in other “commercial oriented” methods.

It is important to notice that a diagnosis process is not a consultancy process, although is related to future actions that a consultancy can execute to improve the results of the gaps detected by the diagnosis. This is one of the reasons that the diagnosis results do not have direct suggestions or comments regarding the improvement of certain concern or guideline in a format of “to do” list, once this is an activity associated with a consultancy practice that will adopt the diagnosis results as base and input for a decision making and process improvement actions.

The diagnosis helps the decision makers to better focus on the most pertinent gaps, evaluating (with sensitive analysis simulation, for example) if the weight variation of a component (attribute, concern) changes diagnosis results.

The sensitive analysis is a very interesting aspect of the diagnosis potential, once it can simulate the behavior of the results according to the variation of a certain variable. The **Interoperability Attributes Correlation Matrix (IACM)** can provide previous analysis that can be a powerful tool to help the choice of variables with high importance and, therefore, the decision maker (along with other stakeholders) can perform its sensitivity evaluation with most pertinent variables for the entity. However, having an identified variable with high sensitivity in the influence of the capability level has no use if such variable demands a high effort (e.g., cost, legal mobilization, political tension) to be implemented or improved.

For example, even though the "Communication" attribute has a high relative weight within the interoperability performance (see Figure 99) and its sensitive analyses show that if "Communication" is improved, the whole entity gets a higher capability level, no action can be done (decision maker perception) once the effort and difficulty associated to improve this attribute is very high. Related to the cost aspect, an economic engineering analysis can be done to corroborate the indication/guide given by PAIDM and oriented by the sensitivity analysis. Regarding this whole impact and feasibility analysis, both application cases presented initial data for their effort perception regarding the attributes, providing preliminary information for a feasibility analysis considering the sensitive aspect of a variable versus the implementation/improvement difficulty of that variable. The information was gathered during the interviews (with every respondent), using a Likert scale (Likert, 1932) to get the answers regarding all attributes (see Figure 167). The results for Application Case-01 and Application Case-02 are respectively presented in Table 143 and Table 144.

Figure 167: Question structure to collect difficulty perception for each attribute

Difficulty to implement. Ratings.		
From 1 to 5, what is the difficulty degree (considering costs, effort, feasibility) to improve/implement actions and issues regarding this attribute. Insert an "X" in column "Answer" or mark with another form (e.g., coloring the cell).		
Answer	**Degree**	**Definition/Description**
	1	Easy to accomplish.
	2	Moderately easy to accomplish.
	3	Neither easy nor difficult to accomplish (medium effort, cost).
	4	Moderately difficult to accomplish.
	5	Difficult to accomplish.

Source: The author (2015).

Table 143: Application Case-01 – Attributes difficulty perception

#	Attributes	Respondents				Arithmetic mean
		A	B	C	D	
1	Accessibility	4	4	3	4	3.75
2	Adaptability	3	3	4	5	3.75
3	Collaboration	3	2	1	5	2.75
4	Commitment	4	2	2	2	2.50
5	Communication	4	3	2	3	3.00
6	Conflicts	2	4	4	2	3.00
7	Cooperation	4	2	3	4	3.25
8	Culture	4	2	4	5	3.75
9	Economy	4	4	4	5	4.25
10	Efficiency	3	3	3	4	3.25
11	Governance	5	3	4	5	4.25
12	Human resources	3	3	5	4	3.75
13	Infrastructure	4	2	2	4	3.00
14	Integration	4	3	3	5	3.75
15	Legality	4	2	2	5	3.25
16	Monitoring	4	3	2	3	3.00
17	Policy and regulations	3	4	2	4	3.25
18	Political	5	4	4	5	4.50
19	Responsibility	3	3	2	4	3.00
20	Security	4	2	4	4	3.50
21	Standardization	4	2	2	5	3.25
22	Tools	4	2	3	5	3.50

Table 144: Application Case-02 – Attributes difficulty perception

#	Attributes	Respondents (consolidated)
1	Accessibility	3
2	Adaptability	2
3	Collaboration	2
4	Commitment	4
5	Communication	2
6	Conflicts	5
7	Cooperation	5
8	Culture	5
9	Economy	4
10	Efficiency	4
11	Governance	3
12	Human resources	2
13	Infrastructure	5
14	Integration	2
15	Legality	2
16	Monitoring	2
17	Policy and regulations	3
18	Political	5
19	Responsibility	3
20	Security	2
21	Standardization	4
22	Tools	3

Another important aspect that can be taken into consideration to perform an analysis of the diagnosis results is the existent influences among the attributes. These influences are represented using the IACM “roof” structure (Figure 98) after a quantitative and qualitative analysis (see Figure 10 and Figure 95) related to the process A5 of the research framework (Figure 4). Section 6.1.5 exposed the steps and results of the attributes influence evaluation. The existence of influences may suggest a spread analysis of the weights received across the hierarchical structure of AHP, deriving to an ANP structure.

It is pertinent to remember that ANP is a generalization of AHP, allowing feedback connections and loops and considering that the criteria, sub-criteria, and alternatives are treated equally as nodes in a network. Each of these nodes might be compared to any other node, as long as there is a relation between them (Figure 50 illustrates this aspect using two-way arrows), and this relation can be the existence of influence among the attributes (each node is an attribute in the PAICM representation).

Using the analysis represented in the IACM “roof” (Figure 98), a spreadsheet was developed to gather the pairwise comparisons among the “correlated” attributes, considering only the “strong correlations”, represented by the symbol “↑”. The influence weight among those attributes was gathered during the interviews, within the execution of PAIDM in the application cases. The header of the presented question is exposed in Figure 168. The comparison follows the same pairwise and scale method (based on Saaty (1987)), that is, the respondent analyzes the attributes in comparison to a "father attribute".

Figure 168: Comparison header for influence among attributes

Influences inter attributes

Some attributes are influenced by (or influences) other attributes. The influence can be in a higher or lower degree, according to initial analysis using IACM ("roof of quality") correlations as a supporting tool. The comparison method follows the same principle of the previous comparisons already executed. That is, the respondent analyses the attributes in comparison to a "father attribute". For the evaluation, consider the "as is" viewpoint, not a "to be". Compare the attributes according to the "Instructions" sheet and insert an "X", or mark with another form (e.g., coloring the cell), in the adequate cell containing the pertinent value.

Degree of "influence" - Definitions/descriptions	
1 - Equal	6 - Between strong and very strong
2 - Between equal and moderate	7 - Very strong
3 - Moderate	8 - Between very strong and extreme
4 - Between moderate and strong	9 - Extreme
5 - Strong	

Source: The author (2015).

Figure 169 and Figure 170 expose examples (based on real correlated attributes) of the influence evaluation regarding two attributes, respectively "Culture" and "Political".

Figure 169: "Culture" influence comparison

	Culture																		
	Which attribute provides higher degree of influence to "culture".																		
1	Human resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political

Source: The author (2015).

Figure 170: "Political" influence comparison

	Political																		
	Which attribute provides higher degree of influence to "Political".																		
1	Conflicts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Culture
2	Conflicts	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economy
3	Culture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economy

Source: The author (2015).

Even though there may be strong connections among attributes (symbol "↑" in the IACM "roof"), the correlations do not need to be necessarily bi-directional (i.e., an attribute "A" that influences an attribute "B" do not need to be influenced by the attribute "B"). As an example of this property, the "Culture" attribute exposed in Figure 169 also has strong connections (to the left of the IACM "roof", see Figure 98) with "Cooperation", "Conflicts", "Communication" and "Commitment". However, those attributes do not influence "Culture" (only vice-versa), and that is why the "Culture" comparison matrix (Figure 169) do not have other influencing attributes rather than "Human resources" and "Political".

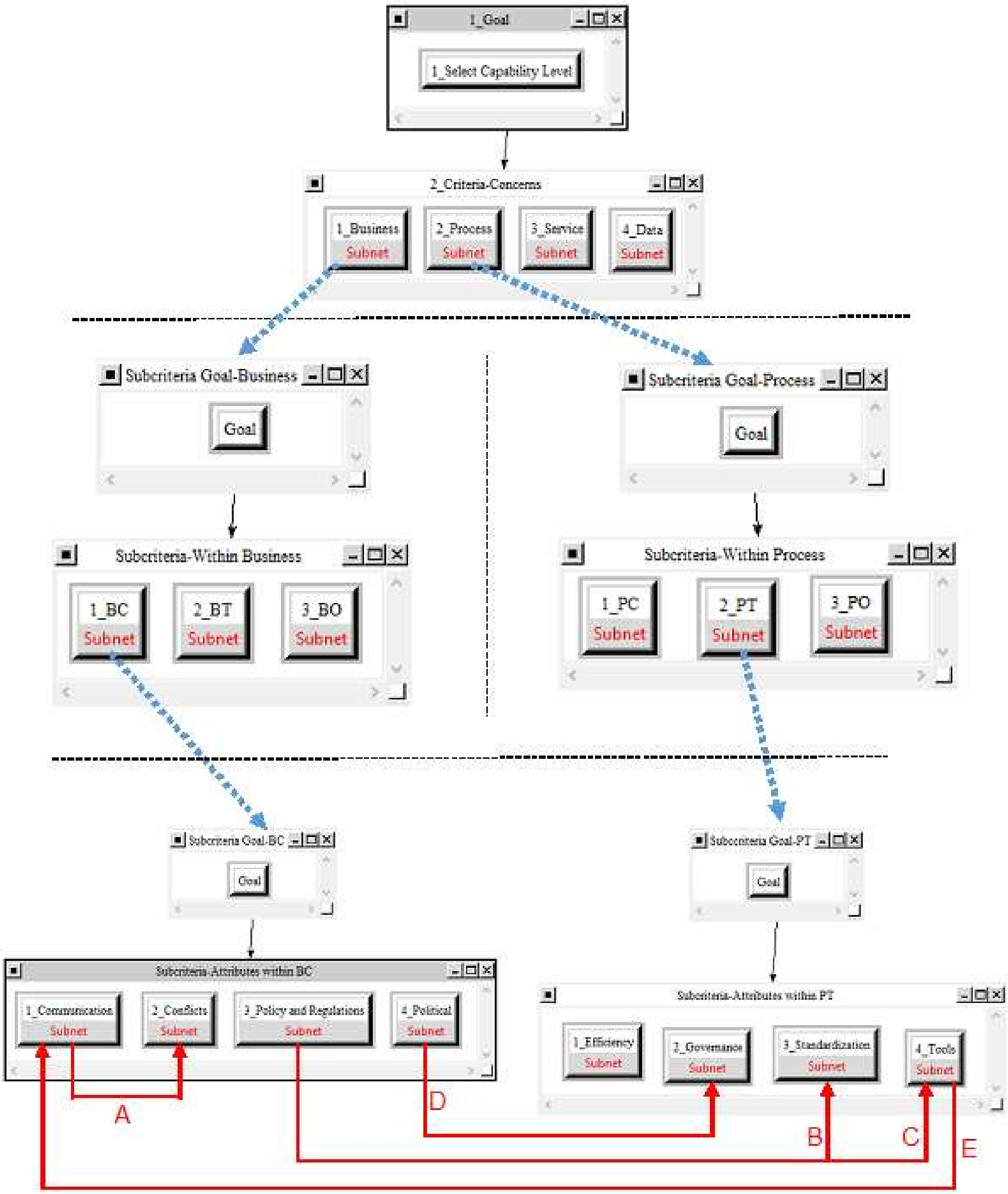
As described in section 7, the gathered data must be inserted into the Super Decisions software, according to the PAICM model designed within the tool, so the calculations regarding the capability levels can be executed. The existence of influences may change the results of a diagnosed entity regarding its capability levels (once the AHP structure turns into an ANP structure, and new calculations and comparisons are added between nodes).

Considering the influence connection as a representation of "A → B" ("A" influences "B"), Figure 171 represents the Super Decisions structure regarding the following connections:

A. "Communication → Conflicts"
B. "Policy and Regulations" → Standardization"
C. "Policy and Regulations" → Tools"

D. “Political → Governance”
E. “Tools → Communication”

Figure 171: Super Decisions structure with influence connections (ANP)



Source: The author (2015).

Figure 171 is a composition of subnets for the purpose of illustrating part of a “new” PAICM structure that considers influence connections among attributes with an ANP related organization. The first block of Figure 171 contain the concerns’ subnets (“Business”, “Process”, “Service” and “Data”) and the blue dotted arrows are representations that the “destination” (bellow) subnets derive from a previous “node” within a “higher level” subnet. The second block contains the concerns x barriers nodes within “Business” concern (left figure) and

“Process” concern (right figure). Finally, the last block of the figure contains the subnets and the attributes within “BC” (left figure) and within “PT” (right figure). The red arrows represent the influence connections among the attributes, as exposed a few paragraphs earlier. With those new red arrows implemented within Super Decisions, the calculations regarding the capability levels could be different, including for the application cases exposed in this section.

It is very important to mention that this thesis did not implement the influence connections in an operational way, mainly due to two complementary issues:

- The structure of PAICM and PAIDM regarding the diagnosis goals. To obtain the capability levels according to the goals and in different perspectives (as exposed in Table 95), the PAICM and PAIDM had to be transported into the Super Decisions in such an architecture that the components have to be organized by subnets.
- Restrictions regarding the Super Decisions software. The Super Decisions software does not allow connections between nodes in different subnets and, as illustrated in Figure 171, all the blocks are organized in subnets.

Therefore, further analysis regarding the use of ANP and the influence connections is suggested as future works, basically considering an adaptation of the Super Decisions architecture regarding the design of PAICM. That is, the PAICM must be represented in only one big diagram (without subnets) and, by doing that, it will be possible to create the influence connections. However, this “new model” will not present the capability levels according to the different aspects and goals exposed in Table 95, and, whenever possible, there will be “two designed” models to make the analysis: the original one, considering the different aspects and goals, and a complementary one considering the influence factors.

The complete set of spreadsheets, also considering the influence comparisons are presented in Cestari et al., (2015a). The values of the influence comparisons within the spreadsheets (as gathered with the application cases) are presented in Cestari et al., (2015b).

9 CONCLUSIONS

This section presents the conclusions for this research, firstly with introductory major aspects related to the research and goals, and then with highlights regarding the contributions and originality aspects, frameworks' applicability and usefulness. Finally, some comments related to future works and final observations are presented.

The main goal of this research was to present a proposed framework methodology to diagnose the interoperability in a public administration scenario, in order to answer the research question regarding "how a capability model and diagnosis method of interoperability, in the public administration domain, allows measuring an entity's level of potential interoperability?"

In this sense, this research adopts the premise (supported by the literature review) that the development of frameworks (including models and methods) contributes to the processes of diagnosis interoperability capability/maturity levels in public administration and is relevant, both for the development of the research field and for public administrations.

Although there are basically three primary goals associated with achieving interoperability in any system (data exchange, meaning exchange and process and business agreement), when it comes to public administration, the context can be more complex because of the necessity of dealing with some influencing factors such as legal, political and sociocultural issues. Within public administration related interoperability, the context is crucial, once some major differences must also be addressed (e.g., poor infrastructures, dictatorial countries).

9.1 CONTRIBUTIONS AND ORIGINALITY

The major contributions of this research can be highlighted as the following aspects:

- Creation and definition of a **research framework** (Figure 4) that, among other things, allows the characterization of a life cycle that supports the elaboration and evaluation of the other contributions outputs;

- Creation and definition of a capability model related to public administration interoperability, called **Public Administration Interoperability Capability Model (PAICM)**.
- Creation and definition of a diagnosis method, called **Public Administration Interoperability Diagnosis Method (PAIDM).**

Other contributions are:

- Exposition of a QFD adaptation, called **Interoperability Attributes Correlation Matrix (IACM)**.
- Rationale, rules and procedures regarding the knowledge discovering steps of interoperability aspects in public administration interoperability.
- Adoption of a mathematical and quantitative approach (AHP, ANP) for the definition of PAICM and PAIDM, as for the diagnosis execution itself.
- A combination of quantitative and qualitative methods and tools (e.g., semantical similarity, Natural Language Processing, context analysis, IACM).

It is important to mention that the proposed diagnosis method (PAIDM) minimizes some issues related to other assessment related models and methods (ISO 9001:2015 (ISO, 2015), SCAMPI (SCAMPI Upgrade Team, 2011) and MPS.BR (SOFTEX, 2012). Concerning specifically the SCAMPI, which is a main reference for the PAIDM, some limitations exposed in Valle (2015) are the following:

A. Appraisals are inherently dependent on the appraisers and the competencies of appraisers.
B. Appraisals are long, complex, expensive and resource demanding.
C. Subjectivity to analyze and to judge about the levels adherence.
D. A degree of lack of confidence regarding sample selection and its representativeness.

The models and methods proposed in this thesis minimize some of the issues regarding SCAMPI, especially the items “A”, “C” and “D”. The diagnosis is still dependent on the appraisers and his competencies, but the data collection and interviews strategy, combined with the use of AHP/ANP method can minimize this aspect, together with the problem related to subjectivity (item “C”). The lack of confidence related to the sample selection (item “D”) is not an inherent issue of PAICM and PAIDM, once PAIDM aims to provide capability levels visibility regarding four goals (Table 95) entirely related to an entity definition (there are no internal projects or sub-processes selection). A possible sample selection problem can be related to the number of interviewed people, but this can be solved statistically (with sample solution techniques) and with a software support. Regarding this software aspect, considering that the diagnosis, appraisals and certifications processes are almost entirely manually, that fact that this research is associated with a software development project regarding the diagnosis, is another contribution (APPENDIX 3: PROTOTYPE SOFTWARE).

A diagnosis within a public administration entity can be also characterized by the complexity regarding the relative perception and uncertainty, aspects that are supported by the proposed model and method. The proposal, in a friendly way, quantifies the uncertainty within the perception of tacit knowledge.

9.1.1 Applicability and usefulness

The framework and its related concepts and outputs were evaluated in different stages of the research (see APPENDIX 1: GENERAL CONTRIBUTIONS DURING THE PHD PROGRAM for some publications references). Both application cases and applied survey generated comments from the participants, indicating a pertinence, usefulness and applicability of the diagnosis. Besides that, the research framework, PAICM, PAIDM and other aspects demonstrated to be viable in an operational perspective (once the execution of the application cases, for example, occurred with no major surprises or impossibilities).

9.1.2 Cultural context

The research and the application cases were based in Brazilian public administration related organizations, consequently subject to Brazilian regulations, cultural aspects, political influences and such. This can be considered a limitation point for the research, but it is important to note that some aspects of the originality and relevance of this research are related to, among others, the following aspects:

- The Brazilian initiative in the area is almost entirely focused on the e-Ping framework (Ministério do Planejamento, 2012);
- The complexity presented in the public administration interoperability context is particularly prominent in some emergent countries, like Brazil.

This provides a broad field for research in the public administration/eGovernment interoperability domain, once eGovernment interoperability frameworks focus almost 90% in the technical aspects (CSTRANSFORM, 2010).

9.2 LIMITATIONS

Some of the drawbacks of the research are related to the following points:

- Execution of PAICM and PAIDM in only two application cases, bringing possible issues related to the generalized applicability and depth vs breadth.
- No use of artifacts or document evidences in the diagnosis. PAICM and PAIDM can be adapted to consider, within the pairwise comparison, aspects related to documents verification, but this was not the object of the research. The research is oriented to a diagnosis (and/or kind of gap analysis) and not to provide (at this point) some "official certification".
- The research framework was adopted and used only once (for this own research).
- The three main contributions (PAICM, PAIDM and research framework) were used and applied only by the own author.

9.3 FUTURE WORKS

Future application cases are recommended and necessary, especially to increase the power of generalization.

A combination of PAIDM method with a process mining approach (as exposed in Valle (2015) can be interesting, once it combines, for example, the process mining to complement the data gathering and uses qualitative methods for the interviews.

Further analysis regarding the use of ANP and the influence connections is suggested, considering an adaptation of the Super Decisions architecture regarding the design of PAICM and PAIDM, as exposed in 8.3.

9.4 FINAL COMMENTS

According to the presented results, interpreted and discussed throughout this document, it is possible to conclude that this thesis provides answers and information regarding the research question ("how a capability model and diagnosis method of interoperability, in the public administration domain, allows measuring an entity's level of potential interoperability?") and research goals (Table 1).

REFERENCES

ABPMP. (n.a.). (2015). [Web portal]. Association of Business Process Management Professionals (Brazil). Retrieved from http://www.abpmp-br.org/

Adams, B. & Creative Decisions Foundation. (2013). Super Decisions (Version 2.2.6) [Software]. Available from http://www.superdecisions.com

Akao, Y. (1990). Quality Function Deployment: Integrating Customer Requirements into Product Design, Cambridge, MA, Productivity Press, ISBN 0-915299-41-0.

Alias, M. A., Hashim, S. Z. M., & Samsudin, S. (2008). Multi Criteria Decision Making and Its Applications: A Literature Review. In Asia-Pacific Journal of Information Technology and Multimedia, Jurnal Teknologi Maklumat, Vol. 20, N° 2, pp.129–152.

Almeida, D., dos Santos, M. A. R., & Costa, A. F. B. (2010). Aplicação do coeficiente alfa de Cronbach nos resultados de um questionário para avaliação de desempenho da saúde pública. In Proceedings of XXX Encontro Nacional de Engenharia de Produção. Retrieved from http://goo.gl/7UNM5g

Archmann, S., & Nielsen, M. M. (2006). Interoperability at Local and Regional Level – A Logical Development in eGovernment. Proceedings of 1st European Summit on Interoperability in the iGovernment, Valencia, Spain.

ATHENA Consortium. (2003). Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications, FP6-2002-IST1, [Integrated Project Proposal]. Retrieved from http://athena.modelbased.net/index.html

Australian Government. (2011). Australian Government Architecture (AGA) Reference Models Version 3.0. Retrieved from http://goo.gl/KQVTVi

Baizyldayeva, U., Vlasov, O., Kuandykov, A. A., & Akhmetov, T. B. (2013). Multi-Criteria Decision Support Systems. Comparative Analysis. Middle-East Journal of Scientific Research, Vol. 16, Issue 12, pp. 1725-1730.

Bardin, L. (2011). Análise de Conteúdo. São Paulo: Edições 70, 229 p.

Berre, A., Elveaeter, B., Figay, N., Guglielmina, C., Johnsen, S., Karlsen, D., Knothe, T., & Lippe, S. (2007). The ATHENA Interoperability Framework. In 3rd International Conference on Interoperability for Enterprise Software and Applications (I-ESA 2007), Springer, pp. 771–782

Bettahar, F., Moulin, C., & Barthès, J. P. (2009). Towards a Semantic Interoperability in an e-Government Application. Electronic Journal of e-Government, Vol. 7, Issue 3, pp. 209-226.

Bollegala, D., Matsuo, Y., & Ishizuka, M. (2007). Measuring semantic similarity between words using web search engines. In Proceedings of the 16th International Conference on World Wide Web 2007, CM Press, Banff, Alberta, Canada, pp. 757–766.

Bollegala, D.T. (2009). A Study on Attributional and Relational Similarity between Word Pairs on the Web. (PhD Thesis). University of Tokyo.

Bouchereau, V., & Rowlands, H. (2000). Methods and techniques to help quality function deployment (QFD). Benchmarking: An International Journal, Vol. 7, Issue 1, pp. 8-20.

C4ISR (Interoperability Working Group). (1998). Levels of information systems interoperability (LISI), Tech. report, US Department of Defense, Washington, DC.

Camargo, A. R. (2009). Cidade e informática, contatos e interações: explorando manifestações de urbanização virtual. [Technical Report]. Pesquisa CNPq Proc 301383 /2005-7. Escola de Engenharia de São Carlos, USP, São Carlos, SP.

Cambridge Dictionaries Online. (n.d.). [Dictionary]. Retrieved from http://dictionary.cambridge.org/us

Cao, Y. (2013). Software Process Improvement Framework Based on CMMI Continuous Model Using QFD. International Journal of Computer Science Issues, Vol. 10, Issue 1, pp. 281 - 287.

CAPES Periódicos. (2013). Homepage. Retrieved from http://www.periodicos.capes.gov.br

Castro, A. C., Cestari, J. M. A. P., Loures, E. F. R., Lima, E. P. & Santos, E. A. P. (2015). Interoperability Frameworks in Public Administration Domain: Focus on Enterprise Assessment. In: Proceedings of the XXI International Conference on Industrial Engineering and Operations Management (ICIEOM-CIO-IIE-2015). July 06 to 08, University of Aveiro, Aveiro, Portugal.

CEPA (Comisión Econômica para America Latina y el Caribe). División de Desarrollo Productivo y Empresarial (DDPE). (2007). White Book of e-Government Interoperability for Latin America and the Caribbean, Version 3.0

Cestari, J. M. A. P., Loures, E. R., & Santos, E. A. P. (2013). Interoperability Assessment Approaches for Enterprise and Public Administration. In: Yan Tang Demey; Hervé Panetto. (Org.). On the Move to Meaningful Internet Systems: OTM 2013 Workshops. 1ed.Heidelberg: Springer, Vol. 8186, pp. 78-85.

Cestari, J. M. A. P., Loures, E. R., Santos, E. A. P. & Lezoche, M. (2014). A Research Strategy for Public Administration Interoperability Assessment. In Proceedings of Industrial & Systems Engineering Research Conference (ISERC), Retrieved from http://goo.gl/z26gDG, Montreal, Canada.

Cestari, J. M. A. P., Valle, A. M., de Lima, E. P., & Santos, E. A. P. (2013). Achieving maturity (and measuring performance) through model-based process improvement. Journal of Information Systems and Technology Management, Vol. 10, No. 2. DOI: 10.4301/S1807-17752013000200009

Cestari, J. M. A. P., Loures, E. F. R., & Santos, E. A. P. (2015a). Public Administration Interoperability Capability Model (PAIC) and Public Administration Interoperability Diagnosis Method (PAIDM). [Technical report]. PUCPR, Industrial and Systems Engineering Program, Curitiba, Brazil.

Cestari, J. M. A. P., Loures, E. F. R., & Santos, E. A. P. (2015b). Results of the Public Administration Interoperability Diagnosis Method (PAIDM) application cases. [Technical report]. PUCPR, Industrial and Systems Engineering Program, Curitiba, Brazil.

Chahin, A., Cunha, M. A., Knight, P. T., & Pinto, S. L. (2004). E-gov.br: A próxima revolução brasileira. São Paulo. Prentice Hall.

Chalmeta, R., & Pazos, V. (2014). A step-by-step methodology for enterprise interoperability projects. Enterprise Information Systems, Vol. 9, Issue 4, pp. 436-464. DOI: 10.1080/17517575.2013.879212

Charalabidis, Y., Lampathaki, F., Askounis, D., & Stassis, A. (2007). Shifting to Second Generation E-Government Interoperability Frameworks, in Proceedings of the International EGOV 2007 Conference, Regensburg (Germany), September 3-7.

Charalabidis, Y., Panetto, H., Loukis, E., & Mertins, K. (2008). Interoperability for Enterprises and Administrations Worldwide. The electronic journal for e-commerce tools and applications (eJeta), Vol. 2, Issue 3, pp.1-10. Retrieved from https://goo.gl/9lV3OB

Chen D., & Doumeingts, G. (2003). European initiatives to develop interoperability of enterprise applications—basic concepts, framework and roadmap, Annual Reviews in Control, Vol. 27, Issue 2, pp.153-162.

Chen, D., & Daclin, N. (2006). Framework for enterprise interoperability. Proceedings of the International Workshop on Enterprise Integration, Interoperability and Networking (EI2N'2006), Bordeaux, France.

Chen, D., & Shorter, D. (2008). Framework for Manufacturing Process Interoperability - CEN/ISO 11354, Standardisation workshop in conjunction to I-ESA, Berlin.

Chen, D., Dassisti, M., & Elvesaeter, B. (2006). DI.2: Enterprise Interoperability-Framework and knowledge corpus-Advanced report. Deliverable DI.2, INTEROP NoE (Network of Excellence on Interoperability research for Networked. Retrieved from https://hal.archives-ouvertes.fr/hal-00176354/en/

Chen, D., Vallespir, B., & Daclin, N. (2008). An Approach for Enterprise Interoperability Measurement, Proceedings of Model Driven Information Systems

Engineering: Enterprise, User and System Models (MoDISE-EUS'2008), Montpellier, France.

Chen, N., Kinshuk., Wei, C. W., & Chen, H. J. (2008). Mining e-Learning domain concept map from academic articles. Computers & Education, Vol. 50, Issue 3, pp. 1009-1021. DOI 10.1016/j.compedu.2006.10.001

Clark, T., & Jones, R. (1999). Organisational interoperability maturity model for c2. In Proc. of 1999 Command and Control Research and Technology Symposium, Washington.

CMMI Institute (n. d.). (2015). [Overview]. Retrieved from http://cmmiinstitute.com/

CMMI Product Team. (2010). CMMI for Development - Version 1.3. Technical Report. Software Engineering Institute (SEI). Retrieved from http://www.sei.cmu.edu/library/abstracts/reports/10tr033.cfm

Commission of the European Communities. (2003). Linking up Europe, the importance of interoperability for eGovernment services. (Working Paper). Ministerial conference on eGovernment, Como, Italy, 7-8 July.

Conforto, E. C., Amaral, D. C., & Silva, S.L. (2011). Roteiro para Revisão Bibliográfica Sistemática: aplicação no desenvolvimento de produtos e gerenciamento de projetos. In: 8o. Congresso Brasileiro de Gestão de Desenvolvimento de Produto (CBGDP), Porto Alegre, RS.

Cornu, C., Chapurlat, V., Quiot, J., & Irigoin, F. (2012). Interoperability Assessment in the Deployment of Technical Processes in Industry, in INCOM 2012, Bucharest, Romania.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. Journal of Applied Psychology. Vol. 78, N° 1, pp. 98-104.

CPqD & Wireless Mundi. Índice Brasil de Cidades Digitais. (2012). Retrieved from http://www.wirelessmundi.inf.br/indice-edicao-n-9/903-capa

Crosby, P. B. (1979). Quality Is Free: The Art of Making Quality Certain. New York: McGraw-Hill.

Cross, K.F., & Lynch, R. L. (1988). The SMART way to define and sustain success. National Productivity Review, Vol. 9, N° 1, pp. 23-33.

CSTRANSFORM. (2010). e-Government Interoperability. A ComparativeAnalysis of 30 countries. (White paper). Retrieved from http://www.cstransform.com/index.htm

da Cruz, P. E. B. E. (2012). Lean, Agile, Resilient and Green Supply Chain Management Interoperability Assessment Methodology. [Master's degree dissertation]. Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa. Retrieved from http://www.unidemi.com/papers/paper/id/151

Da Silva, F. S. C. (2009). Interoperability, Electronic Government and Electronic Governance in Latin America: Expectations and Results (White paper). Laboratory of Interactivity and Digital Entertainment Technology, University of São Paulo, São Paulo, SP, Brazil, Retrieved from http://goo.gl/FCRTqH

De Angelis, F. (2009). Interoperability in e-Government Services. Unpublished doctoral dissertation, Università Degli Studi di Camerino, School of Advanced Studies, Dipartimento di Matematica e Informatica, Camerino, Italy.

Deming, W. E. (1986). Out of the Crisis. Cambridge, MA: MIT Center for Advanced Engineering.

Deschamps, F. (2013). Proposal for the systematization of enterprise engineering contributions: guidelines for enterprise engineering initiatives. (PhD Thesis). Polytechnic School, Industrial and Systems Engineering Graduate Program, PUCPR, Curitiba-PR, Brazil.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The Evolution of Research on Collaborative Learning, In P. Reimann& H. Spada (Eds), Learning in humans and machines: Towards an interdisciplinary learning science, pp. 189-211. Oxford: Elsevier.

Eldrandaly, K., Ahmed, A. H., & Aziz, N. A. (2009). An Expert System for Choosing the Suitable MCDM Method for Solving a Spatial Decision Problem. In Proceedings of the 9th International Conference on Production Engineering, Design and Control, Alexandria-Egypt.

Elmir, B., & Bounabat, B. (2011). A Novel Approach for Periodic Assessment of Business Process Interoperability, IJCSI, Vol. 8, Issue 4, N° 1.

Estonian Government. (2011). Interoperability of the State Information System. Retrieved from http://www.riso.ee/en

European Commission. (2004). EIF 1.0 - European interoperability framework for pan-European eGovernment services [white paper]. Retrieved from http://goo.gl/HMhoJQ

European Commission. (2010). EIF 2.0 - European Interoperability Framework for European public services [white paper]. Brussels, Belgium. Retrieved from http://goo.gl/4ZZLPt

Ferchichi, A., Bigand, M., & Lefebvre, H. (2008). An Ontology for Quality Standards Integration in Software Collaborative Projects. In: First International Workshop on Model Driven Interoperability for Sustainable Information Systems, pp. 17–30, Montpellier.

Fetzner, M. A. M. (2010). Mudança, Afetividade e Resistência: uma perspectiva no âmbito individual para compreender a implementação de Sistemas de Informação nas organizações. (Unpublished PhD thesis). Federal University of Rio Grande de Sul, Porto Alegre, RS.

Ford, T. C. (2008). Interoperability Measurement. (PhD thesis). Presented to the Faculty Department of Systems and Engineering Management Graduate School of Engineering and Management. Air Force Institute of Technology.

Forza, C. (2002). Survey Research in Operations Management: a Process based Perspective. International Journal of Operations & Production Management, Vol. 22, N° 2, pp.152-194.

Freitas, H. & Janissek, R. (2000). Análise léxica e análise de conteúdo: técnicas complementares, seqüenciais e recorrentes para exploração de dados qualitativos. Porto Alegre, RS, SphinxSagra.

Freitas, H., Oliveira, M., Saccol, A. Z., & Moscarola, J. (2000). O método de pesquisa survey. Revista da Administração, São Paulo, Vol. 35, N° 3, pp. 105-112.

Gatautis, R., & Vitkauskaite, E. (2009). Towards e-government interoperability: Lithuania Case. IBIMA Business Review, Vol. 3, pp. 27-35.

Gatautis, R., Kulvietis, G., & Vitkauskaite, E. (2009). Lithuanian eGovernment Interoperability Model. Inzinerine Ekonomika (Engineering Economics), Vol. 62, N° 2, pp. 38-48.

German Government. (2008). Standards and Architectures for eGovernment Applications (SAGA) Version 4.0. Retrieved from http://goo.gl/ZVadE2

Ghalayini, A. M., Noble, J. S., & Crowe, T. J. (1997). An integrated dynamic performance measurement system for improving manufacturing competitiveness. International Journal of Production Economics, Vol. 48, N° 3, pp. 207-25.

Goldkuhl, G. (2008). The challenges of Interoperability in E-government: Towards a conceptual refinement. In Proceedings of pre-ICIS 2008 SIG eGovernment Workshop, Paris, France.

Gomes, C. F., Yasin, M. M., & Lisboa, J. V. (2004). A literature review of manufacturing performance measures and measurement in an organizational context: a framework and direction for future research. Journal of Manufacturing Technology Management, Vol. 15, N° 6, pp. 511-530.

Groves, R. M., Fowler, F. J., Couper, M.P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2009). Survey Methodology. New Jersey: John Wiley & Sons.

Guédria, W. (2012). Contribution to Enterprise Interoperability Maturity Assessment (PhD thesis). Université Bordeaux 1, France.

Guédria, W., Naudet, Y., & Chen, D. (2008). Interoperability Maturity Models: Survey and Comparison, OTM 2008 Workshops, LNCS 5333, pp. 273-282.

Guédria, W., Naudet, Y., & Chen, D. (2009). A Maturity Model for Enterprise Interoperability, OTM 2009 Workshops, LNCS 5872, pp. 216–225.

Guédria, W., Naudet, Y., & Chen, D. (2011a). Enterprise Interoperability Maturity: A Model using Fuzzy Metrics. In C. Salinesi and O. Pastor (Eds.): CAiSE Workshops, LNBIP 83, Heidelberg, pp. 69-80, Springer.

Guédria, W., Naudet, Y., & Chen, D. (2011b). A Maturity Model Assessing Interoperability Potential, In Halpin, T., Nurcan, S., Krogstie, J., Soffer, P., Proper, E., Schmidt, R., Bider, I. (eds.), Springer Heidelberg, Vol. 81, pp. 276–283.

Henry, P., & Moscovici, S. (1968). Problèmes de l'analyse de contenu. In Langages, Vol. 3, N° 11, pp. 36-60. Retrieved from http://goo.gl/Gj2kFi. DOI: 10.3406/lgge.1968.2900

Hong Kong Government. (2012). The HKSARG Interoperability Framework. Retrieved from http://goo.gl/Ejy5p7

Huijsman, K. L. L. G., Plomp, M. G. A., & Batenburg, R. S. (2012). Measuring Interoperability Maturity in Government Networks. European Journal of ePractice, n. 17, pp. 31- 43.

Humphrey, W. S. (1989). Managing the Software Process. Reading, MA: AddisonWesley.

IEEE. (1990). A compilation of IEEE standard computer glossaries, standard computer dictionary.

Indian Government. (2013). e-Governance standards (standards for e-governance applications). Retrieved from https://egovstandards.gov.in/

ISMCDM (International Society on Multiple Criteria Decision Making). (2015). Retrieved from http://www.mcdmsociety.org

ISO. (1998). International Organizational for Standardization 14258:1998 (ISO 14258:1998) - Industrial Automation Systems: Concepts and Rules for Enterprise Models. Genève, Switzerland: International Organization for Standardization.

ISO. (2015). International Organizational for Standardization 9001:2015 (ISO 9001:2015) - Quality management systems – Requirements. Genève, Switzerland: International Organization for Standardization.

ISO/IEC. (2015). International Organizational for Standardization/International Electrotechnical Commission 33001:2015 (ISO/IEC 33001:2015): Information technology-Process assessment-Concepts and terminology. Provides and introduction to the ISO/IEC 330xx family standards for process assessment. Genève, Switzerland: International Organization for Standardization.

Juran, J. M. (1988). Juran on Planning for Quality. New York: Macmillan.

Kaplan, R.S., & Norton, D. P. (1992). The balanced scorecard: measures that drive performance. Harvard Business Review, Vol. 70, N°1, pp. 71-9.

Keegan, D.P., Eiler, R.G. & Jones, C.R. (1989). Are your performance measures obsolete? Management Accounting, Vol. 71, pp. 45-50.

Keeling, J. (2012). Development of Systematic Knowledge Management for Public Health: A Public Health Law Ontology. (PhD Thesis). Graduate School of Arts and Sciences, Columbia University. Retrieved from http://hdl.handle.net/10022/AC:P:13317

Kingdom of Saudi Arabia Government. (2005). YEFI – Yesser Framework for Interoperability. Retrieved from http://goo.gl/4PkKTz

Kiu, C. C., Yuen, L.Y., & Tsui, E. (2010). Semantic interoperability for enhancing sharing and learning through egovernment knowledge-intensive portal services. Journal of E-Governance, Vol. 33, N° 2, pp. 108-116.

Laskaridis, G., Markellos, K., Markellou, P., Panayiotaki, A., Sakkopoulos, E., & Tsakalidis, A. (2007). E-government and Interoperability Issues. International Journal of Computer Science and Network Security, Vol. 7, N° 9, pp. 28-38.

Lean Office. (n.a.). (2015). [Web portal]. Retrieved from http://www.leanoffice.com.br/

Lee, J. H., & Segev, A. (2012). Knowledge maps for e-learning. Computers & Education, Vol. 59, Issue 2, pp. 353–364. DOI:10.1016/j.compedu.2012.01.017

Levy, Y., & Ellis, T. J. (2006). A systems approach to conduct an effective literature review in support of information systems research. Informing Science Journal, Vol. 9, pp.181–212.

Li, Y. (2007). An intelligent, knowledge-based multiple criteria decision making advisor for systems design (PhD Thesis). School of Aerospace Engineering, Georgia Institute of Technology.

Likert, R. (1932). A technique for the measurement of attitudes. Archives of Psychology, Vol. 22, N° 140, pp.5-55. Retrieved from http://goo.gl/48m3v5

Lynch, R.L., & Cross, K. F. (1991). Measure up: The Essential Guide to Measuring Business Performance. London, UK: Random House.

Malaysian Government. (2003). Standards, Policies and Guidelines – Malaysian Government Interoperability Framework (MyGIF) version 1.0. Retrieved from http://goo.gl/jYlmJ8

Marques, F., Dias, G.P., & Zòquete, A. (2011). A General Interoperability Architecture for e-Government based on Agents and Web Services. In 6th Iberian Conf. of Inf. Sys. and Tech., pp. 338–343.

Mattioda, R. A., Mazzi, A., Canciglieri Jr, O., & Scipioni, A. (2015). Determining the principal references of the social life cycle assessment of products. The International Journal of Life Cycle Assessment, Vol. 20, Issue 8, pp. 1155-1165, DOI:10.1007/s11367-015-0873-z

MaxQDA. (2014). The art of data analysis (Version 11) [Software]. Available from http://www.maxqda.com/

Mbale, J., & Staden, S. V. (2012). Interoperability Governance Model (IGM): Envisages Areas of Activities and Relationships to Establish Information

Interoperability within Government. Journal of Communication and Computer, Vol. 9, N° 11, pp. 1252-1257.

Ministério do Planejamento, Orçamento e Gestão. (2012). e-PING: Padrões de Interoperabilidade de Governo Eletrônico - Documento de Referência. Retrieved from http://www.governoeletronico.gov.br/interoperabilidade

Ministério do Planejamento, Orçamento e Gestão. (n.d.). [Histórico do Governo Eletrônico]. Retrieved from http://goo.gl/g46OQS

Mollaghasemi, M., & Pet-Edwards, J. (1997). Making Multi-Objective Decisions. IEEE Computer Society Press, California.

Mota, P. J. G. (2013). Comparative Analysis of Multicriteria Decision Making Methods [Master's Degree dissertation]. Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Lisboa, Portugal. Retrieved from http://run.unl.pt/.

Mozambique Government. (2010). eGovernment Interoperability Framework for Mozambique. Retrieved from http://goo.gl/gwECao

National Institute of Standards and Technology (NIST). (1993). Integration Definition for Function Modeling (IDEF0). Retrieved from http://www.idef.com/pdf/idef0.pdf

Neely, A., Richards, H., Mills, J., Platts, K, & Bourne, M. (1997). Designing performance measures: a structured approach. International Journal of Operations & Production Management, Vol. 17, N° 11, pp. 1131-1152.

NEHTA (National E-Health Transition Authority). (2007). Interoperability Framework - Version 2.0. Retrieved from https://goo.gl/7v55iz

Neumann, L., & Benda, P. (2005). Open ICT e-Government Architecture as an Interoperability Framework. In 5th European Conference on E-Government, University of Antwerp, Belgium, pp. 585-598.

New Zealand Government (State Services Commission - Te Kōmihana O Ngā Tari Kāwanatanga). (2008). New Zealand E-government Interoperability Framework (NZ e-GIF). Retrieved from http://goo.gl/Vb5rIU

Nils, B., Fluegge, M., & Schmidt. K. (2006). Interoperability in eGovernment through Cross-Ontology Semantic Web Service Composition. Proceedings Workshop Semantic Web for eGovernment, 3rd European Semantic Web Conference 2006, Budva, Montenegro.

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. Organization Science, Vol. 5, N° 1, pp. 14-37.

Novak, J. D., & Cañas, A. J. (2006). The Theory Underlying Concept Maps and How To Construct and Use Them. Institute for Human and Machine Cognition, retrieved from http://cmap.ihmc.us/docs/theory-of-concept-maps

Novakouski, M., & Lewis, G. (2012). Interoperability in the e-Government Context. [Technical note], CMU/SEI-2011-TN-014, Carnegie Mellon University, Pittsburgh, PA. Retrieved from http://www.sei.cmu.edu/reports/11tn014.pdf

Noy, N. F., & Musen, M. A. (1999). SMART: Automated support for ontology merging and alignment, In Proc. of the 12th Workshop on Knowledge Acquisition, Modelling, and Management (KAW'99), Banf, Canada.

Object Management Group (OMG) [Website Portal]. (n.d.). Retrieved from http://www.uml.org/

Oxford Dictionaries. (n.d.). [Dictionary]. Retrieved from http://www.oxforddictionaries.com/us

Panchenko, A. (2012). A Study of Heterogeneous Similarity Measures for Semantic Relation Extraction”. In Proceedings of 14e Rencontres des Étudiants Chercheurs en Informatique pour le Traitement Automatique des Langue.

Panchenko, A., & Morozova, O. (2012). A Study of Hybrid Similarity Measures for Semantic Relation Extraction. In Proceedings of Workshop of Innovative Hybrid Approaches to the Processing of Textual Data Workshop of European Chapter of the Association for Computational Linguistics, France, pp. 10 – 18.

Panchenko, A., Adeykin, S., Romanov, P., & Romanov, A. (2012a). Extraction of Semantic Relations between Concepts with KNN Algorithms on Wikipedia. In

Proceedings of Concept Discovery in Unstructured Data Workshop (CDUD) of International Conference on Formal Concept Analysis, Belgium, pp.78-88.

Panchenko, A., Morozova, O., & Naets, H. (2012b). A Semantic Similarity Measure Based on Lexico-Syntactic Patterns. In Proceedings of the Conference on Natural Language Processing, Vienna, Austria, pp.174 – 178.

Panchenko, A., Romanov, P., Morozova, O., Naets, H., Philippovich, A., Romanov, A., & Fairon, C. (2013a). Serelex: Search and Visualization of Semantically Related Words. Advances in Information Retrieval, Lecture Notes in Computer Science Volume 7814, Springer Berlin Heidelberg, pp 837-840. DOI 10.1007/978-3-642-36973-5_97

Panchenko, A., Romanov, P., Morozova, O., Naets, H., Philippovich, A., Romanov, A., & Fairon, C. (2013b). Serelex [API Software]. http://serelex.cental.be/page/about

Panetto, H. (2007). Towards a Classification Framework for Interoperability of Enterprise Applications. International Journal of CIM, Taylor & Francis. Retrieved from http://www.tandf.co.uk/journals

Pankowska, M. (2008). National frameworks' survey on standardization of e-Government documents and processes for interoperability. Journal of Theoretical and Applied Electronic Commerce Research, Vol. 3, Issue 3, pp. 64-82.

Pardo, T. A., & Burke, G. B. (2008a). Improving Government Interoperability: A Capability Assessment Framework for Government Managers. Technical report. Center for Technology in Government, University at Albany, NY, USA. Retrieved from http://www.ctg.albany.edu/publications/

Pardo, T. A., & Burke, G. B. (2008b). Government worth having: A briefing on interoperability for government leaders. Albany: Center for Technology in Government, Research Foundation of State University of New York. Retrieved from http://goo.gl/Jy9Ph2

Pardo, T., Nam, T. & Burke, B. (2012). E-Government interoperability: interaction of policy, management, and technology dimensions. Social Science Computer Review. DOI: 10.1177/0894439310392184.

Pierce, J. R. (1980). An introduction to information theory: symbols, signals & noise by John Robinson Pierce. Dover Publications, Subsequent edition, p. 336.

Portal Action. (2015). Action [Teste de Wilcoxon-Amostra Única] [Excel Plugin]. Version 2.9.29.368.534 (June). Retrieved from http://www.portalaction.com.br

Princeton University. (2010). WordNet [lexical database of English]. Princeton University. Retrieved from http://wordnet.princeton.edu

Project Management Institute. (2013). A guide to the project management body of knowledge (PMBOK guide). Fifth Edition. Newtown Square, Pennsylvania: Project Management Institute.

Pruse, I., & Zeiris, E. (2010). eRiga.lv: Local Government Interoperability Framework. MeTTeG10 Proceedings of the 4th International Conference on Methodologies, Technologies and Tools enabling e-Government, Olten, Switzerland, 1-2 July, pp.11-20.

QFD Online [House of Quality Examples]. (n.d.). Retrieved from http://www.qfdonline.com/

Qualtrics. (n.a.). (2015). [Web Software]. Retrieved from http://qualtrics.com/

Rocha, A. R., Montoni, M., Santos, G., Oliveira, K., Natali, A. C., Mian, P., Conte, T., Mafra, S., Barreto, A., Figueiredo, S., Soares, A., Bianchi, F., Cabral, R., & Dias, A. (2005). Fatores de Sucesso e Dificuldades na Implementação de Processos de Software Utilizando o MR-MPS e o CMMI. (White paper). Pro Quality. Retrieved from http://goo.gl/qttDWA.

Rohatgi, M., & Friedman, G. (2010). A structured approach for assessing & analyzing technical & nontechnical interoperability in socio-technical systems. In Systems Conference, 2010 4th Annual IEEE, San Diego, CA, IEEE, pp. 581-586. DOI: 10.1109/SYSTEMS.2010.5482337

Rosa, A. G. (2010). A study of local E-Government from the back-office perspective: a discourse analysis of Organisational Interoperability. [Unpublished master's degree dissertation]. University of Sheffield, Sheffield, UK. Retrieved from http://goo.gl/0nRmXk.

Ruggaber, R. (2006). ATHENA - Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications. Interoperability of Enterprise Software and Applications, Springer London, pp. 459-460, DOI: 10.1007/1-84628-152-0_45

Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used, Mathematical Modelling, Vol. 9, Issues 3–5, pp. 161–176.

Saaty, R. W. (1999). Fundamentals of the Analytic Network Process, In International Symposium on the Analytic Hierarchy Process - 1999, Kobe, Japan, August 12-14.

Saekow, A., & Boonmee, C. (2009a). Towards a practical approach for electronic government interoperability framework (e-GIF). Proceedings of the 42nd Annual Hawaii International Conference on IEEE volume, Hawaii, USA.

Saekow, A., & Boonmee, C. (2009b). A pragmatic approach to interoperability practical implementation support (IPIS) for e-government interoperability. Electronic Journal of e-Government, Vol. 7, Issue 4, pp. 403 – 414.

Santos, E. M., & Reinhard, N. (2012). Electronic government interoperability: identifying the barriers for frameworks adoption. Social Science Computer Review, Vol. 30, Issue 1, pp. 71-82.

Sarantis, D., Charalabidis, Y., & Psarras, J. (2008). Towards standardising interoperability levels for information systems of public administrations. Electronic Journal for e-Commerce Tools & Applications (eJETA).

SCAMPI Upgrade Team. (2011). Standard CMMI Appraisal Method for Process Improvement (SCAMPI) A, Version 1.3: Method Definition Document (CMU/SEI-2011-HB-001). Retrieved from the Software Engineering Institute, Carnegie Mellon University, http://goo.gl/iz4Dk4

Scheuren, F. What is a Survey? (2013). Taken from the American Statistical Association, 2004. Retrieved from http://www.whatisasurvey.info

Scholl, H. J., Kubicek, H., Cimander, R., & Klischewski; R. (2012). Process integration, information sharing, and system interoperation in government: a comparative case analysis. Government Information Quarterly, Vol. 29, Issue 3, pp. 313-323.

SciELO (Scientific Electronic Library Online). (2013). Homepage. Retrieved from http://www.scielo.org/php/index.php

SEI (Software Engineering Institute). (2010). CMMI® for Development, Version 1.3., Technical Report, Carnegie Mellon University, Pittsburgh, PA.

SEI (Software Engineering Institute). (2012). CMMI® for SCAMPI Class A Appraisal Results 2012, September Mid-Year Update, Carnegie Mellon University, Pittsburgh, PA.

Shvaiko, P., Villafiorita, A., Zorer, A., Chemane, L., Fumo, T., & Hinkkanen, J. (2009). eGovernment Interoperability Framework for Mozambique. Maria A. Wimmer Hans J. Scholl, Marijn Janssen Roland Traunmüller (Eds.). Electronic Government 8th International Conference, EGOV 2009, Linz, Austria, August 31 - September 3, 2009. Lecture Notes in Computer Science, 5693, pp. 328-340, Springer.

Singh, A., & Malik., S. K. (2014). Major MCDM Techniques and their application-A Review. International Organization of Scientific Research - Journal of Engineering (IOSR-JEN), Vol. 04, Issue 05, pp. 15-25.

Soares, D., & Amaral, L. (2011). Information systems interoperability in public administration: identifying the major acting forces through a Delphi study. Journal of Theoretical and Applied Electronic Commerce Research, Vol. 6, Issue 1, pp. 61-94.

SOFTEX. (2012). Associação para Promoção da Excelência do Software Brasileiro - SOFTEX. MPS.BR – Guia Geral MPS de Software. Retrieved from http://www.softex.br.

Solli-Saether, H. (2011). A framework for analysing interoperability in electronic government. International Journal of Electronic Finance, Vol. 5, N° 1, pp.32-48.

Soydan, G.H. & Kokar, M. (2006). An OWL Ontology for Representing the CMMI-SW Model. Proc. of 2nd Int. Workshop on Semantic Web Enabled Software Engineering.

Staden, S. V., & Mbale, J. (2012). The information systems interoperability maturity model (ISIMM): towards standardizing technical interoperability and assessment within government. International Journal of Information Engineering and Electronic Business, Vol. 4, N° 5, pp. 36-41.

Stefanus, V. S. & Jameson, M. (2012). The Information Systems Interoperability Maturity Model (ISIMM): Towards Standardizing Technical Interoperability and Assessment within Government. International Journal of Information Engineering and Electronic Business (IJIEEB), Vol. 4, N° 5, pp. 36-41.

Swan, J., Newell, S., Scarbrough, H. & Hislop, D. (1999). Knowledge management and innovation: networks and networking. Journal of Knowledge Management, Vol. 3, Issue 4, pp. 262-275. DOI 10.1108/13673279910304014

Tambouris, E., Tarabanis, K., Peristeras, V., & Liotas, N. (2007). Study on Interoperability at Local and Regional Level – Final Version - Version 2.0 [MODINIS LOT 2 Program]. Retrieved from http://goo.gl/wlWn0A

Teknomo, K. Analytic Hierarchy Process (AHP) [Tutorial]. (2006). Retrieved from http://people.revoledu.com/kardi/tutorial/AHP/

The Stanford Natural Language Processing Group. (n.d.). Stanford POS Tagger [NLP software]. Retrieved from http://nlp.stanford.edu/software/tagger.shtml

The UMBC Ebiquity Research Group. (2013). UMBC Semantic Similarity Service [API Software], University of Maryland, Baltimore County (UMBC). Retrieved from http://swoogle.umbc.edu/SimService/api.html

Tolk, A., & Muguira, J. A. (2003). The levels of conceptual interoperability model, In 2003 Fall Simulation Interoperability Workshop, USA.

Toloie-Eshlaghy, A., & Homayonfar, M. (2011). MCDM Methodologies and Applications: A Literature Review from 1999 to 2009. Research Journal of International Studies, Vol. 21, pp. 86-137.

Toutanova, K., Klein, D., Manning, C., & Singer, Y. (2003). Feature-Rich Part-of-Speech Tagging with a Cyclic Dependency Network. In Proceedings of North American Chapter of the Association for Computational Linguistics – Human Language Technologies (NAACL-HLT) 2003, pp. 252-259.

Ullberg, J., Chen, D., & Johnson, P. (2009). Barriers to Enterprise Interoperability, Enterprise Interoperability, Lecture Notes in Business Information Processing, Vol. 38, Springer Berlin Heidelberg, pp. 13-24.

UNDP (United Nations Development Program). (2007). *e-Government interoperability: Guide*. Bangkok, Thailand. Retrieved from http://goo.gl/remXwm

UNDP (United Nations Development Programme). (2008). *e-Government Interoperability*. *e-Primers for the information economy, society and polity*. Bangkok, Thailand. Retrieved from http://goo.gl/lx7Wya

United Kingdom Government. (2005). e-Government Interoperability Framework 6.1. Retrieved from http://goo.gl/EB1eeK

United Nations (Department of Economic and Social Affairs). (2012). United Nations e-government survey 2012: e-government for the people. Retrieved from http://unpan3.un.org/egovkb

US Government. (2013). Federal Enterprise Architecture Framework - Version 2. Retrieved from https://goo.gl/rEGvTM

Usero, J. A., Orenes, P. B., Comeche, J. A., & Segundo, R. S. (2006). Model for interoperability evaluation in e-government services. In Proceedings MICTE. Current Developments in Technology-Assisted Education, Seville, Spain.

Valdés, G., Solar, M., Astudillo, H., Iribarren, M., Concha, G., & Visconti, M. (2011). Conception, development and implementation of an e-government maturity model in public agencies. Government Information Quarterly, Vol. 28, Issue 2, pp. 176-187.

Valle, A. M. (2015). Process Mining Extension to SCAMPI - Um método para aplicação de técnicas de mineração de processos em avaliações de processo de software. (Unpublished PhD thesis). Polytechnic School, Industrial and Systems Engineering Graduate Program, PUCPR, Curitiba-PR, Brazil.

Van Overeem, A., Witters, J., & Peristeras, V. (2007). An Interoperability Framework for Pan-European E-Government Services (PEGS). Proceedings of the 40th Annual Hawaii International Conference on System Sciences, p.7, January 03-06.

Vatuiu, T., & Popeanga, V. (2008). The role in enabling government to organize and operate itself in a more efficient and cost effective manner by using the information technology. Constantin Bracusi University of Targu Jiu. Munich Personal RePEc Archive. Retrieved from http://mpra.ub.uni-muenchen.de/12392/

Vocabulary Dictionary [Dictionary]. (n.d.). Retrieved from http://www.vocabulary.com/

Vogel, T., Schmidt, A., Lemm, A. & Österle, H. (2008). Service and Document Based Interoperability for European eCustoms Solutions. Journal of Theoretical and Applied Electronic Commerce Research, Vol. 3, Issue 3, pp. 17-37.

Von Krogh, G. (1998). Care in knowledge Creation. California Management Review, Vol. 40, N° 3 (spring), pp. 133-153.

Watts, J. (2013, June 21). Brazil erupts in protest: more than a million on the streets. *The Guardian*. Retrieved from http://goo.gl/mvJxNS

Whitman, L. E., & Panetto, H. (2006). The missing link: Culture and language barriers to interoperability. Annual Reviews in Control, Vol. 30, Issue 2, pp. 233-241. DOI: 10.1016/j.arcontrol.2006.09.008

Widodo, A. P., Istiyanto, J. E., Wardoyo, R., & Santoso, P. (2013). E-Government Interoperability Framework based on a Real Time Architecture. International Journal of Computer Science Issues (IJCSI), Vol. 10, Issue 1, N° 2.

Xiao, Y., Xiao, M., & Zhao, H. (2007). An ontology for e-government knowledge modeling and interoperability. Proceedings of the Proceedings of International Conference on Wireless Communications, Networking and Mobile Computing, (WiCOM 2007), Shanghai, 21-27 September 2007, pp. 3600-3603.

Yahia, E. (2011). Contribution à l'Evaluation de l'Interopérabilité Sémantique entre Systèmes d'Information d'Entreprises: Application aux Systèmes d'Information de Pilotage de la Production. (PhD Thesis). Université Henri Poincaré, Nancy I.

Yahia, E., Aubry, A., & Panetto, H. (2012). Formal measures for semantic interoperability assessment in cooperative enterprise information systems, Computers in Industry, pp. 443-457.

Yin, R. K. (2014). Case Study Research: Design and Methods, 5th edition, Sage Publications, pp. 312.

Zanoni, G., de Lima, E. P., Mattioda, R. A., & da Costa, S. G. (2013). Modelo para avaliação de níveis de maturidade na relação comprador-fornecedor: um estudo de fornecedores da indústria automobilística. Revista Produção Online, Florianópolis, SC, Vol. 13, N° 2, pp. 703-736.

Zardari, N.H., Ahmed, K., Shirazi, S.M., & Yusop, Z.B. (2015). Weighting Methods and their Effects on Multi-Criteria Decision Making Model Outcomes in Water. Chapter 2. Springer International Publishing. Springer Briefs in Water Science and Technology. DOI 10.1007/978-3-319-12586-2_2

Zutshi, A., Grilo, A., & Jardim-Gonçalves, R. (2012). The Business Interoperability Quotient Measurement Model. Computers in Industry, Vol. 63, Issue 5, pp. 389-404, DOI:10.1016/j.compind.2012.01.002

APPENDIX 1: GENERAL CONTRIBUTIONS DURING THE PHD PROGRAM

This appendix exposes some results and generated contributions obtained during the whole PhD research period, considering the entire involvement into the Graduate Program in Production Engineering and Systems (freely translated from "Programa de Pós-Graduação em Engenharia de Produção e Sistemas" – PPGEPS), including the subject exposed in this document and other related and complementary subjects.

Table 145: Conferences, papers and other participation regarding the PPGEPS involvement

#	Contributions	Type	Vehicle	Year
1	Project with PUCPR/PPGEPS and "Agência PUC" and some undergraduate students. Development of an applicable software prototype, in a format of a Web Portal related to the "Interoperability Diagnosis".	Agency x University Cooperation	Research and Development	2015 to 2016
2	Implementation (together with Prof. Dr. Eduardo de F. R. Loures and Prof. Dr. Fernando Deschamps) of a research cooperation between Instituto Curitiba de Informática (ICI) and PPGEPS. Funding for scholarships and other activities.	Company x University Cooperation	Research and Innovation cooperation	2014 to 2015
3	Support the engagement of other students in order to research aspects related to the multi-criteria decision-making analysis, performance measurement, maturity models and interoperability aspects.	Engagement	PPGEPS	2013 to 2015
4	Collaboration with Université de Lorraine, Vandoeuvre-lès-Nancy, France	Engagement	PPGEPS and University of Lorraine	2013 to 2015
5	Implementation (together with Prof. Dr. Edson Pinheiro de Lima) of a research cooperation between Sofhar Gestão & Tecnologia S.A and PPGEPS. Funding for scholarships and other activities.	Company x University Cooperation	Research and Innovation cooperation	2012 to 2013
6	Interoperability Frameworks in Public Administration Domain: Focus on Enterprise Assessment. In: Proceedings of the XXI International Conference on Industrial Engineering and Operations Management (ICIEOM-CIO-IIE-2015). July 06 to 08, University of Aveiro, Aveiro, Portugal.	Paper	International conference	2015
7	Performance Measurement Systems for designing and managing Interoperability Performance Measures: A literature analysis. In: Proceedings of the XXI International Conference on Industrial Engineering and Operations Management	Paper	International conference	2015

#	Contributions	Type	Vehicle	Year
	(ICIEOM-CIO-IIE-2015). July 06 to 08, University of Aveiro, Aveiro, Portugal.			
8	A Methodology for Discovering Bayesian Networks Based on Process Mining. Paper finalist for the best paper award. In: Proceedings of 2015 Industrial and Systems Engineering Research Conference (ISERC), Nashville, United States. S. Cetinkaya and J. K. Ryan, eds. Norcross/USA: Institute of Industrial Engineers - IIE, 2015. v. 1. p. 1-10. From 30/05 to 02/06/2015.	Paper/Oral Presentation	International conference	2015
9	Knowledge management for sustainable performance in industrial maintenance. In: Proceedings of 2015 Industrial and Systems Engineering Research Conference (ISERC), Nashville, United States. S. Cetinkaya and J. K. Ryan, eds. Norcross/USA: Institute of Industrial Engineers - IIE, 2015. v. 1. p. 1-10. From 30/05 to 02/06/2015.	Paper/Oral Presentation	International conference	2015
10	Improving operations performance analysis and use. In: Proceedings of 2015 Industrial and Systems Engineering Research Conference (ISERC), Nashville, United States. S. Cetinkaya and J. K. Ryan, eds. Norcross/USA: Institute of Industrial Engineers - IIE, 2015. v. 1. p. 1-10. From 30/05 to 02/06/2015.	Paper	International conference	2015
11	Interoperability Frameworks in Public Administration Domain – Focus on Enterprise Assessment. Abstract. In: Proceedings of 2015 Industrial and Systems Engineering Research Conference (ISERC), Nashville, United States. S. Cetinkaya and J. K. Ryan, eds. Norcross/USA: Institute of Industrial Engineers - IIE, 2015. v. 1. p. 1-10. From 30/05 to 02/06/2015.	Abstract/Oral Presentation	International conference	2015
12	An Overview of Attributes Characterization for Interoperability Assessment from the Public Administration Perspective. Lecture Notes in Computer Science. 1ed. Springer Berlin Heidelberg, 2014, Vol. 8842, pp. 329-338.	Paper	Journal (Book chapter)	2014
13	Implementation Sequence of ITSM Processes for SMEs. In: 7th International Conference on Production Research / American Region (ICPR-AR-2014), Lima, Peru.	Paper	International conference	2014

#	Contributions	Type	Vehicle	Year
14	A Research Strategy for Public Administration Interoperability Assessment. In Proceedings of the 2014 Industrial and Systems Engineering Research Conference (ISERC 2014), Montreal, Canada.	Paper/Oral Presentation	International conference	2014
15	Framework for applying Process Mining techniques in Software Process Assessments. In Industrial & Systems Engineering Research Conference (ISERC 2014), Montreal, Canada.	Paper/Oral Presentation	International conference	2014
16	Enhancing flexibility in business process management using declarative languages, In: Industrial & Systems Engineering Research Conference (ISERC 2014), Montreal, Canada.	Paper/Oral Presentation	International conference	2014
17	A Method for eGovernment concepts Interoperability Assessment. In Proceedings of the 4th International Conference on Information Society Technology and Management (ICIST) 2014.	Paper (Book chapter)	International conference	2014
18	Accepted project for the Science Without Borders program in partnership with Lorraine University, Nancy, France. *Not implemented because private issues.*	Granted scholarship	National Research Scholarship Program	2014
19	Interoperability Assessment Approaches for Enterprise and Public Administration. In: Yan Tang Demey; Hervé Panetto. (Org.). On the Move to Meaningful Internet Systems: OTM 2013 Workshops. 1ed.Heidelberg: Springer, 2013, Vol. 8186, pp. 78-85. Graz, Austria.	Paper/Oral Presentation	International conference + book chapter	2013
20	An overview of enterprise interoperability assessment. In: 22nd International Conference on Production Research. Challenges for Sustainable Operations. 2013, 22nd International Conference on Production Research, 2013. Vol. 1, pp. 1-8. Foz do Iguaçu, Brazil.	Paper/Oral Presentation	International conference	2013
21	Achieving maturity (and measuring performance) through model-based process improvement. Revista de Gestão da Tecnologia e Sistemas de Informação, Vol. 10, pp. 339-356, 2013.	Paper	Journal	2013
22	Developing a sustainable operations maturity model (SOMM). In: 22nd International Conference on Production Research. Challenges for Sustainable Operations., 2013, Foz do Iguaçu. 22nd International Conference on Production Research. 2013. Vol. 1, pp. 1-10.	Paper	International conference	2013

#	Contributions	Type	Vehicle	Year
23	Correlation process in content analysis for a BPM modeling project. In: 22nd International Conference on Production Research. Challenges for Sustainable Operations., 2013, Foz do Iguaçu. 22nd International Conference on Production Research, 2013. Vol. 1, pp. 1-8.	Paper	International conference	2013
24	Sustainability standards and guidelines requirements for integrated management. In: 22nd International Conference on Production Research. Challenges for Sustainable Operations., 2013, Foz do Iguaçu. 22st International Conference on Production Research, 2013. Vol. 1, pp. 1-9.	Paper	International conference	2013
25	Best Paper Award for a Young Researcher (Developing a sustainable operations maturity model - SOMM), IFPR/ABEPRO - 22nd International Conference on Production Research (ICPR 22).	Paper	Prize. International conference	2013
26	"Desenvolvimento de modelos e processos para produção sustentável" First prize in the 6o. Edition of "Prêmio Ozires Silva de Empreendedorismo Sustentável", category: medium and large companies.	Innovation Project (Company x University Partnership)	Prize. Regional	2013
27	Quantitative benefits of model-based improvement in a SME unit. In: 19th EuroSPI2, 2012. Industrial Proceedings - 19th EuroSPI2 Conference. Copenhagen: DELTA, 2012. Vol. 1, pp. 21-29. Vienna, Austria.	Paper/Oral Presentation	International conference	2012
28	Indicators formulation process for sustainable operations management. In: ICPR-AR-2012 (International Conference of Production Research America's 2012), 2012, Santiago. ICPR-AR-2012.	Paper	International conference	2012
29	O processo de formulação de indicadores para operações sustentáveis. Poster. First place in technology category, at "XIV Mostra de Pesquisa em Pós-Graduação da PUCPR".	Abstract/Poster	Regional prize	2012

APPENDIX 2: SURVEY

APPENDIX 2A – PRESENTATION LETTER (E-MAIL)

Subject: PhD Research: Aspects of Interoperability in Public Administration related entities.

Good morning

My name is Marcelo Cestari, and I am a PhD student at the Graduate Program in Industrial and Systems Engineering at Pontifical Catholic University of Paraná (http://www.pucpr.br/en/), Curitiba, Brazil. Our research area is related to interoperability aspects (including its assessments) within public administration entities directly or indirectly related to public administration.

Your expert opinion will contribute in our research and in the evaluation of the already extracted attributes (influence factors) associated with the interoperability aspects cited above. In a few days, we will send you a brief questionnaire (with more instructions) so you can help to corroborate those attributes, insert some other more and present your point of view and suggestions to improve our research.

We would be honored in having you as our respondent.

If, for any reason, you cannot respond our questionnaire, we ask you kindly to let us know until DD/MM/YYYY.

If you want to receive more information regarding the research, please feel free to contact us at jose.cestari@pucpr.br.

Thank you very much.
Kind regards.
José Marcelo A. P. Cestari (http://br.linkedin.com/in/jmacestari)

APPENDIX 2B – SURVEY E-MAIL

Good morning

According to the presentation e-mail sent previously, we greatly appreciate your willingness to answer our questionnaire.

My name is Marcelo Cestari, and I am a PhD student at the Graduate Program in Industrial and Systems Engineering at Pontifical Catholic University of Paraná, Curitiba, Brazil. Our research area is related to interoperability aspects (including its assessments) within public administration entities directly or indirectly related to public administration.

Your expert opinion will contribute in our research and in the evaluation of the already extracted attributes (influence factors) associated with the interoperability aspects cited above.

We are honored in having you as our respondent and the link for the questionnaire is below.

Follow this link to the Survey:

${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:

${l://SurveyURL}

Follow the link to opt out of future emails:

${l://OptOutLink?d=Click here to unsubscribe}

If you want to receive more information regarding the research, please feel free to contact us at jose.cestari@pucpr.br.

Thank you very much.

Kind regards.

José Marcelo A. P. Cestari at http://br.linkedin.com/in/jmacestari

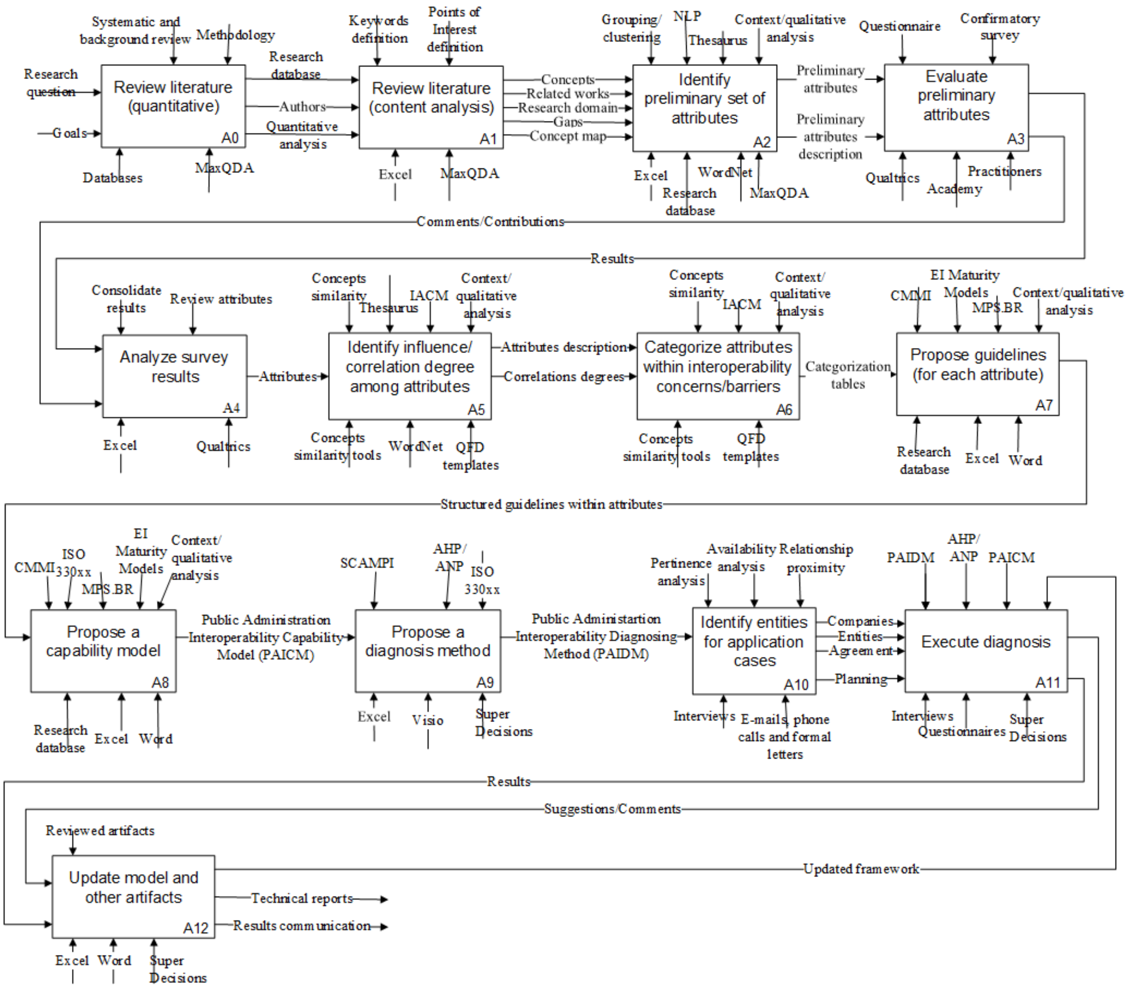
APPENDIX 2C - SURVEY QUESTIONNAIRE

This is a questionnaire related to a PhD research conducted by the student José Marcelo A. P. Cestari and his advisors (Prof. Dr. Eduardo de F. R. Loures and Prof. Dr. Eduardo A. Portela dos Santos). The research is associated with the Industrial and Systems Engineering Graduate Program at Pontifical Catholic University of Paraná (http://www.pucpr.br/en/), Curitiba, Brazil and is related to interoperability aspects (including its assessments) within public administration entities and/or entities directly or indirectly related to public administration.

If you want a little bit more information about interoperability, please click here. Research context: A series of attributes (influence factors, requirements, parameters, principles, areas, perspective, categories) associated with the interoperability aspects in public administration related entities were extracted from the literature review (using quantitative and qualitative analysis and also some application of Natural Language Processing tools). These attributes will help the creation of guidelines in order to better diagnose a certain degree of interoperability capability level. An overview of the research structure is represented in the following figure, and this questionnaire is applied within the process A3.

Your expert opinion will contribute to our research regarding the evaluation of the extracted attributes (i.e., are they pertinent? Are there others?). You will probably take around 10 minutes to answer the questions, and we appreciate for your time.

Thank you very much. Kind regards. José Marcelo A. P. Cestari
(LinkedIn profile: http://br.linkedin.com/in/jmacestari)
If you want to receive more information (including some papers regarding the research), please feel free to write me at jose.cestari@pucpr.br.



Q1. Select the item that best suits the type of experience (or involvement, knowledge, participation) you have with interoperability. Select only one alternative.

- ❍ Professional
- ❍ Academic
- ❍ Both (professional and academic)
- ❍ Other: ___________________

Q2. For how long (years) do you have experience in interoperability?

______ Years

Q3. Select the item that best suits the type of experience (or involvement, knowledge, participation) you have with public administration (government issues, eGovernment entities, etc.). Select only one alternative.

- ❍ Professional
- ❍ Academic
- ❍ Both (professional and academic)
- ❍ Other: ___________________

Q4. For how long (years) do you have experience in public administration aspects?
______ Years

Q6. The following attributes were extracted from the literature using quantitative and qualitative analysis. Do you think that the attributes (influence factors) can be considered relevant/pertinent regarding public administration interoperability? You can click on the words to obtain more information about the item and help your evaluation.

Attributes	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Collaboration (collaborative)	❍	❍	❍	❍	❍
Commitment (Support)	❍	❍	❍	❍	❍
Communication (communicational)	❍	❍	❍	❍	❍
Conflicts (conflictive, conflictual)	❍	❍	❍	❍	❍
Cooperation	❍	❍	❍	❍	❍
Culture (behavior, sociological)	❍	❍	❍	❍	❍
Human Resources	❍	❍	❍	❍	❍
Economy (financial)	❍	❍	❍	❍	❍
Efficiency	❍	❍	❍	❍	❍
Governance (governability)	❍	❍	❍	❍	❍
Infrastructure	❍	❍	❍	❍	❍
Accessibility	❍	❍	❍	❍	❍
Security	❍	❍	❍	❍	❍
Integration (integrate)	❍	❍	❍	❍	❍
Legality (Legal Aspects)	❍	❍	❍	❍	❍
Policy and regulations	❍	❍	❍	❍	❍
Political (politic, politics)	❍	❍	❍	❍	❍
Monitoring (Management)	❍	❍	❍	❍	❍
Standardization (standard, standardizable)	❍	❍	❍	❍	❍
Adaptable (Adaptability)	❍	❍	❍	❍	❍
Tools (Technology)	❍	❍	❍	❍	❍
Responsibility (responsible, roles)	❍	❍	❍	❍	❍

Q7. Are there other attributes (influence factors) that you consider important for public administration interoperability?

❍ Yes
❍ No

Answer If Is there other attributes (influence factors) that you think it is important? Yes Is Selected

Q8. You chose "Yes" in the previous question. According to your expertise (and opinion), please fill in which are the other attributes that must be considered when dealing with public administration interoperability.

Atribute-1: _________
Atribute-2: _________
Atribute-3: _________
Others (comma separated): _____, ______, ______ …

Q9. Would you like to submit suggestions, opinions and other comments regarding the subject?

❍ Yes
❍ No

Answer If “Would you like to inform your name and e-mail?” Yes Is Selected

Q10. Please enter your comments: _________________________________

APPENDIX 3: PROTOTYPE SOFTWARE

There is an ongoing project in partnership with the Pontifical Catholic University of Parana and some undergraduate students. The main goal of the project is the development of an applicable software prototype, in a format of a Web Portal related to the "Interoperability Diagnosis". The "Interoperability Diagnosis Portal – IDP" will have four major modules:

- **Administration**: insertion and maintenance of the attributes, capability levels, descriptions and other information related to a capability model (in this case, specifically related to the "Public Administration Interoperability Model – PAICM" proposed in this research).
- **Data gathering**: interface where the "auditor" can register the results of the interviews according to a pairwise comparison.
- **Rate calculations**: based on the AHP/ANP, execute the rate calculations according to the data gathered.
- **Reports**: presents reports with the results (graphics and other information).

Some "subgoals" are the following:

Subgoals	Macro description
Subgoal 1	Elaborate the project vision. Initial schedule. Elicit requirements. Use case modeling.
Subgoal 2	Graphic interface definition. Implementation (unit tests, server deploy, etc.).

The duration of the project is around 4 months, and must be concluded by January/February 2016.