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FERNANDO DESCHAMPS

PROPOSAL FOR THE SYSTEMATIZATION OF ENTERPRISE ENGINEERING CONTRIBUTIONS: GUIDELINES FOR ENTERPRISE ENGINEERING INITIATIVES

CURITIBA

2013

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PROPOSAL FOR THE SYSTEMATIZATION OF ENTERPRISE ENGINEERING CONTRIBUTIONS: GUIDELINES FOR ENTERPRISE ENGINEERING INITIATIVES

Tese apresentada ao Programa de Pós-Graduação em Engenharia de Produção e Sistemas da Pontifícia Universidade Católica do Paraná como requisito parcial para a obtenção do título de Doutor em Engenharia de Produção e Sistemas.

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To the Fermino Deschamps girls,

Camila, Gisele and Ana Cristina,

with love

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ABSTRACT

Research in the enterprise engineering field has started in the beginning of the 1990s. Its main topics include reference models, business processes, virtual enterprises, ontologies, reference architectures and interoperability. Most of the contributions in these topics is in the form of prescriptive models or meta-models that are applied to a limited set of situations. There is a lack of general recommendations that may be used to guide the application of these models to the design, redesign or diagnosis of organizational systems. This work aims to develop a systematization of contributions to the enterprise engineering research field by proposing a set of guidelines applicable to enterprise engineering initiatives. The method used is based on a systematic literature review of the field, on a Delphi study and on a set of case studies using the proposed guidelines as a diagnosis tools. The first two methods contribute to the refinement of the set of guidelines, whereas the last method contributes to the verification of their application. The results of this work are the set of guidelines and an application protocol suitable for using them to the diagnosis of organizational systems, as well as the results of the case studies conducted.

Keywords: enterprise engineering, guidelines for enterprise engineering, organizational systems diagnosis

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1 INTRODUCTION

Enterprise engineering is a broad and multidisciplinary research field. Its main concern is the development of methods and tools for the design and implementation of organizational systems, encompassing elements such as enterprise architecture, organizational structure, information systems and business processes (Hoogervorst, 2009). It transparently combines existing knowledge of areas such as organizational sciences, information technology, and industrial and systems engineering, allowing an organization to use this knowledge to mobilize its resources according to its objectives in an efficient and effective manner (Vernadat, 2007).

Research in enterprise engineering may be characterized by its main topics, as shown in Chapter 3: modeling, integration, ontologies, virtual enterprises, business processes, reference models, interoperability and enterprise architectures. As a whole, these works are related to the different forms of representing abstract and general knowledge associated to the structure and behavior of organizational systems, the discussion of the application of different types of models to less abstract and more specific problems, such as the representation of business processes; and the discussion of technological aspects related to the application of ontologies and models to the design, implementation and integration of organizational systems.

Research in these topics is carried out in the different knowledge areas that comprise enterprise engineering with varying maturity degrees. For instance, when it comes to the integration and interoperability of business processes, technological issues such as the programming languages that can be applied have been extensively explored, whereas semantic and organizational issues still need to be further developed (Vernadat, 2010). In a paper published in the Industrial and Systems Engineering Research Conference (ISERC) 2013 and co-authored by this document’s main author, a maturity framework for a research field is proposed and the maturity of the enterprise engineering field is preliminarily assessed. Although this assessment is not comprehensive (only 32 papers out of 282 from the systematic literature review presented in Chapters 3 and 4 were randomly chosen to be used), it gives an idea about the evaluation of the maturity framework dimensions for the field. Although there are many contributing authors in diverse topics (which is also shown by the characterizations of the field in Chapters 3 and 4), the use of a limited number of methods focused on more theoretical approaches, usually presenting some kind of framework and presenting the results of its application to a specific situation, establishes that the field still needs to evolve – and that there is a need for more general empirical contributions.

As a confirmation of these findings, for instance, one can consider Panetto and Molina's (2008) five grand challenges for enterprise interoperability research: (i) the study of collaborative and networked organizations; (ii) enterprise modeling and reference models; (iii) enterprise interoperability and process models for interoperability; (iv) validation, verification, qualification and accreditation of enterprise models; and (v) model reuse and model repositories. More recently, Hvolby and Trienekens (2010) present another challenge: the application of existing *frameworks* for the development of business process management systems that support enterprise operation. All of these challenges are application-oriented and could benefit from a more thorough empirical investigation of the contributions to the area, building other contributions from a more well-structured core.

Chapter 4 shows that many different constructs such as tools, techniques, methods, procedures, and methodologies for enterprise engineering exist. Most of them were developed starting in the early 1990s, focusing on different enterprise engineering aspects such as modeling, architecture, implementation, and interoperability. It is not unusual for these constructs to be prescriptive and determine a set of restrictions or steps that have to be observed, as well as being partially applied in organizations (or even combined). The question then is whether there is a set of more general or core principles that can be observed in the application of any of these constructs, that is, are there recommendations general enough in order to serve as universally applicable guiding principles for an enterprise engineering initiative or project?

This research project, as is shown by its research question and research objectives, proposes a systematization of these contributions based on a more empirical approach. Systematization of these contributions would benefit: (i) researchers, for they could, in certain situations, start from a more well-defined body of knowledge for conducting their research; and (ii) practitioners, for they could use this systematization to better guide enterprise engineering initiatives inside their organizations.

1.1 RESEARCH QUESTION

Given that: (i) enterprise engineering is a broad field of study, encompassing several knowledge areas such as industrial engineering, information technology and organizational sciences, among others; and (ii) that knowledge developed in this area is not organized in an unique body, the following research question is proposed: *how may contributions related to the enterprise engineering field be systematized in order for them to be applied to enterprise engineering initiatives?*

1.2 RESEARCH OBJECTIVES

The following objective is proposed for this work, derived from the research question stated in the last section: *verify how contributions related to the enterprise engineering field may be systematized in order for them to be applied to enterprise engineering initiatives*. This objective is decomposed into four specific objectives (SO), shown in Table 1.1.

Table 1.1 - Specific objectives of this research project

SO #1	Characterize the enterprise engineering research field
SO #2	Characterize contributions related to this field
SO #3	Systematize these contributions in order for them to be applied to enterprise engineering initiatives
SO #4	Verify the application of this systematization to enterprise engineering initiatives

1.3 DOCUMENT STRUCTURE

This document is structured in eight chapters. Chapters 1 and 2 present the introduction and research method applied to this research project. Chapter 1 discusses the context of the research, the research question and the research objectives. Chapter 2 details the methods to be used in order to achieve the research objectives and to answer the research question, as well as expected results and the structure of the papers that will compose the final dissertation.

Chapters 3 through 7 present five articles that compose the dissertation and will be revised for submission to journals.

- Chapter 3 presents an article on the characterization of the enterprise engineering research field that was accomplished through the application of a systematic literature review approach based on author co-citation analysis. This characterization discusses the evolution of the field and identifies its main research topics, the main authors associated to these topics, and potential areas for future research. This article is related to SO #1.

- Chapter 4 presents an article on the characterization of contributions to the enterprise engineering research field that is developed from Chapter 3. This characterization was prepared in order to better understand these contributions and define the problem to be addressed by this dissertation. This article is related to SO #2.
- Chapter 5 presents an article on the development of enterprise engineering guidelines based on the works used to characterize the enterprise engineering field and its contributions, besides other supporting references such as performance excellence models, the enterprise transformation literature and a Delphi study with experts in the enterprise engineering research field. These guidelines are an initial model for the systematization of the contributions to the field. This paper is related to SO #3.
- Chapter 6 presents an article on the application of the guidelines presented in Chapter 5 to a set of case studies. These case studies serve as a test of the application of the guidelines to the diagnosis of organizational systems. This article is related to SO #4.
- Chapter 7 presents an article on the development of a system to aid data collection, organization and analysis for the verification of the systematization in different enterprise engineering initiatives. The paper assumes that enterprise engineering initiatives are very different in nature and that actions needed to accomplish them are defined during their execution. This paper is related to SO #4.

Chapter 8 presents final remarks about this work, its limitations, possible improvement points and perspectives for future research.

2 RESEARCH METHOD

From the research question in Section 1.1 and the research objectives in Section 1.2 it can be noted that the main task to be completed by this research project is the systematization of knowledge from a multitude of sources. Systematization, as defined by the Merriam-Webster Dictionary, is “to arrange in accord with a definite plan or scheme; to order”; The Cambridge English Dictionary & Thesaurus defines it as “to plan a system for something”; and the Oxford Dictionary defines it as “systematic organization; the act of organizing something according to a system or a rationale”. Systematization, hence, involves collecting, organizing and analyzing information about objects or situations under study in a rational way, so that patterns among these objects or situations can be identified. Systematization involves:

- deepening the knowledge a researcher or group of researchers has about objects or situations so that their different views can be better understood;
- grouping, comparing, matching and differentiating aspects, features or characteristics by thoroughly analyzing these objects and situations through adequate techniques in search for similarities and dissimilarities; and
- synthesizing and formalizing findings through a rationale that is able to adequately represent the patterns that were identified in the analysis.

Taking these activities into account, it can be noted that systematization is an exploratory and qualitative process. Although quantitative approaches such as descriptive statistics may play a role in the analysis of data collected for systematization, most of these activities rely on the researcher’s ability to derive order from unorganized data, iteratively manipulating these data until a satisfactory organization is found by considering different alternatives until a set of criteria are met. Many alternatives may meet the criteria, though, and the researcher has to choose the best one, lending subjectivity to this process.

Although exploratory and qualitative, systematization is not without structure. As a new interpretation of existing knowledge is formed, approaches that aim at translating unorganized and general information into more orderly, specific and useful knowledge are best suited. Typical exploratory approaches such as literature reviews, case studies and experimental development may be used. Strengths and weaknesses of these approaches have to be considered when choosing the most suitable one.

The resulting rationale or system of a systematization process can be expressed in several different ways: (i) argumentatively, through a textual description of common and different aspects, for instance; (ii) declaratively, through the use of statements that express general characteristics or aspects; or (iii) graphically, using pictorial representations and diagrams of structures, behaviors and relationships. All of these are different kinds of models that represent commonalities and dissimilarities in an abstraction level adequate for their context. Systematization may result in one or more of these models.

This research project searches for a systematization of contributions to the enterprise engineering field by means of a phased approach, as depicted in Figure 2.1 and detailed in Section 2.1. This figure shows that systematization is to be accomplished in three steps. First, a preliminary model is created according to the contributions published in the enterprise engineering literature through a systematic literature review – this approach is described in Subsection 2.1.1. Next, the preliminary model is refined and an initial model is generated by considering expert opinion through a Delphi study – this approach is described in Subsection 2.1.2. Finally, the initial model is verified through a series of case studies – this approach is described in Subsection 2.1.3. This verification process is carried out to assert the usefulness of the initial model and to incorporate into it observations from practice, particularly to the application of the guidelines in the diagnosis of organizational systems.

This approach tries to be as comprehensive and exhaustive as possible, reducing subjectivity and verifying the usability, applicability and utility of the rationale built for the systematization that is expressed through the final model. Comprehensiveness and exhaustiveness are achieved through the systematic literature review – a point covered in Subsection 2.1.1. Reduction of subjectivity is achieved through the use of the Delphi method – a point covered in Subsection 2.1.2. The verification of usability and utility are achieved through the use of the case study method – a point covered in Subsection 2.1.3.

The systematization formalism used in this research project is that of a declarative model, through the use of statements in the form of guidelines. A guideline is a recommended design practice or principle that allows some discretion in its interpretation and use. An enterprise engineering guideline is an enterprise design practice or principle related to the definition, structure, design and implementation of organizational systems as communication networks comprising their business knowledge, operational information, resources and organization relations. A detailed discussion about the criteria used for defining guidelines is found in Chapter 5.

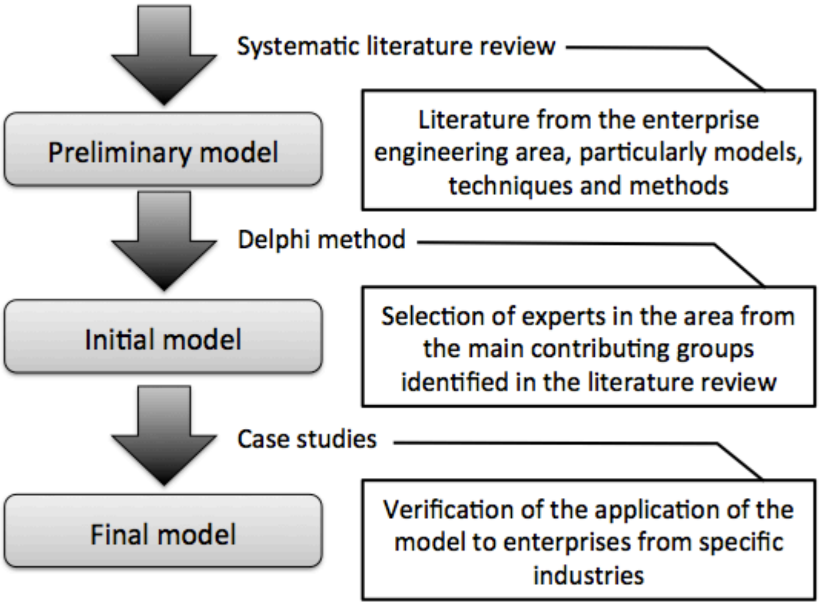

Figure 2.1 - Approach for the systematization proposed in this research project.

The next section details the research approach proposed for this work.

2.1 DESCRIPTION OF THE RESEARCH APPROACH

The overall research method for this work is outlined in Figure 2.2. This figure shows that this research project is divided into three phases. It also shows, for each phase, the main research type, the research method used (and its main reference), the main products and the related specific objectives. The research methods used in this project are detailed in the next subsections.

2.1.1 Systematic Literature Review

A systematic literature review is a research method used to provide a comprehensive and exhaustive summary of the literature of a given research topic or field (Kitchenham, 2004). It is comprehensive because it aims at gathering as many works as possible related to the subject under study. It is exhaustive because it thoroughly analyzes these works, assessing the quality of their methods and results, in order to draw conclusions. Systematic literature reviews are common in the medical and nursing domain, particularly for analyzing a set of cases that share the same background and generalizing their conclusions (Higgins and Green, 2008). Lately, it has been applied to other domains such as information systems, software engineering and industrial and systems engineering (Brereton et al, 2007).

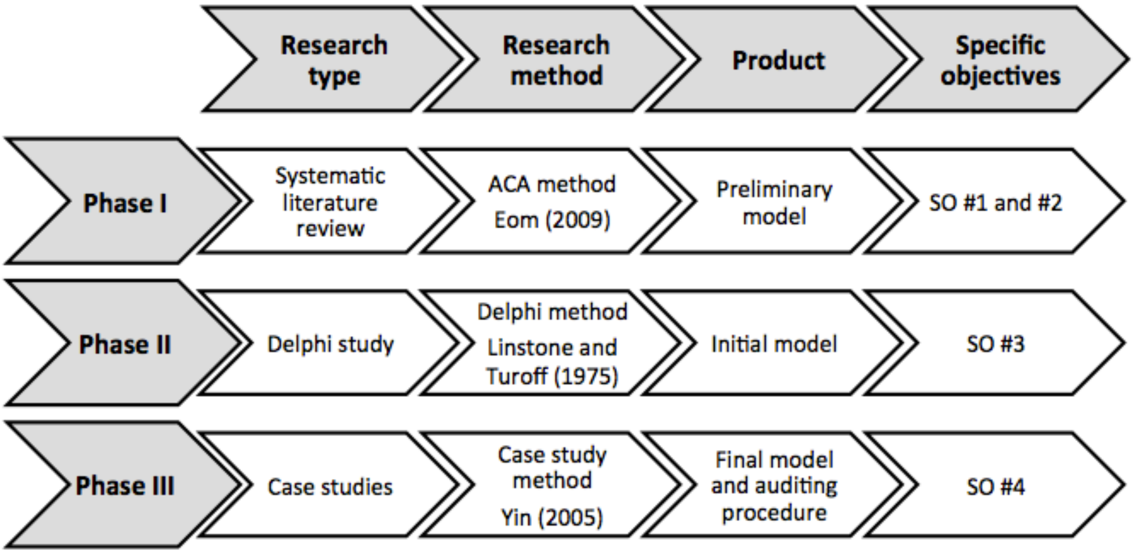

Figure 2.2 - Outline of the research method for this research project.

For a systematic literature review, the following steps have to be followed (White and Schmidt, 2005; Higgins and Green, 2008):

1. *Define the review question and develop criteria for including studies:* the review question is the objective of the review. From this objective, criteria for selecting the works that will be included in the review are defined – e.g., what reference databases to use and whether conference papers, works from a certain region or from a certain journal will be included.
2. *Searching for studies:* the sources that will be searched for works, such as reference databases, and search terms to be used when querying these databases are defined.
3. *Selecting studies and collecting data:* all works that were gathered have to be screened according to the defined criteria. Selected works are organized so that the necessary data from them are collected.
4. *Assessing risk of bias in included studies:* selected studies have to be screened for the risk of researcher bias in their results. If bias is identified in any work, this work has to be excluded from the analysis.

5. *Analyzing data and undertaking meta-analyses:* data from the selected studies is analyzed in this step through the application of a series of techniques. These techniques may be, for example, statistical, iterative or content-driven, and some of them will address the issue of performing meta-analyses by finding patterns within the data.
6. *Addressing reporting biases:* reporting biases due to the interpretation of the researcher leading the review procedure has to be eliminated. Multiple reviewers that repeat the analysis to determine if the same or similar results are found can be used.
7. *Presenting results and "summary of findings" tables:* the results of the analysis are organized in tables, figures, graphs, charts or other elements that properly summarize and convey them.
8. *Interpreting results and drawing conclusions:* conclusions are drawn from the results of the analysis. Conclusions usually try to be as general as possible.

The approach followed in this research project for the systematic literature review method starts with the approach proposed by Eom (2009), which encompasses the previously mentioned steps. This approach was especially conceived to understand the structure of a research field. Besides prescribing steps for gathering a set of works and analyzing them through statistical techniques, it also establishes author co-citation analysis as one of its main techniques. This approach is used to generate a systematic literature review of the enterprise engineering research field that is presented in Chapter 3. Works from this review are further analyzed in Chapter 4. The main objectives of these reviews are:

- to characterize the enterprise engineering research field, its main research topics, methods, authors and determine areas for future research, providing an overview of the area; and
- to define a set of relevant works that should have their results analyzed in order for the main contributions to the field to be found.

2.1.2 Delphi method

The Delphi method is a research method used when a structured communication approach among experts in a field is needed so that a complex problem can be handled (Linstone and Turoff, 1975). According to Hasson et al (2000), there are three main applications of the Delphi method:

- *to achieve consensus (conventional Delphi):* examples include gathering current and historical data not accurately known or available, examining the significance of historical events, or putting together the structure of a model;
- *to explore alternatives (scenario Delphi):* examples include exploring urban and regional planning options, evaluating possible budget allocations, and planning university campus and curriculum development; and
- *to develop policies (policy Delphi):* examples include delineating the advantages and disadvantages associated with potential policy options, and developing causal relationships in complex economic or social phenomena.

A Delphi study is usually organized in rounds, with a set of experts participating in each round. Experts' opinions are registered through surveys, interviews or panels, among other possible techniques or tools. Results are compiled and distributed to all participants before each round, except before the first round. Experts are usually asked to review their opinions according to the compiled results so that agreement can be reached. The number of rounds may vary according to the agreement of the experts or the observation that agreement will not be reached.

The application of the Delphi method is suitable for situations that possess one or more of the following characteristics (Linstone and Turoff, 1975):

1. the problem does not lend itself to be solved by analytical techniques, but can benefit from subjective analysis on a collective basis;
2. individuals needed to contribute to the examination of a complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise;
3. more individuals are needed than can effectively interact face-to-face;
4. time and cost make frequent group meetings unfeasible;
5. the efficiency of face-to-face meetings can be increased by a supplemental group communication process;
6. disagreements among individuals are so severe that the communication process must be refereed and/or anonymity assured; and
7. the heterogeneity of the participants must be preserved to assure validity of the results.

The Delphi method can be applied in a number of different ways. Hasson and Keeney (2011) typify ten different non-mutually exclusive forms of application: classical, modified, decision, policy, real-time/consensus conference, e-Delphi, technological, online, argument and disaggregative policy – for an in-depth discussion of these types, see the work by Hasson and Keeney (2011). These types differ in the elements of aim, target panelists, administration of the method, number of rounds, and the design of the first round.

For the purpose of this research project, a Delphi method to achieve agreement on the systematization of contributions to the enterprise engineering field was administered. A Delphi method was chosen for this situation because it presents characteristics 1 through 4 from Linstone and Turoff's (1975) list. The elements of this particular Delphi study are:

- **Aim:** achieving consensus.
- **Target panelists:** main authors from the enterprise engineering research field identified in the systematic literature review – top ten authors from each one of the main research topics.
- **Administration:** web survey.
- **Number of rounds:** at most 3 rounds – first round for agreement and collecting suggestions, second round for agreement, third round for classification of guidelines.
- **Round 1 design:** panelists will be provided with the preliminary model containing a set of statements for the guidelines and will be asked about their agreement in considering each one of the statements as a guideline for enterprise engineering initiatives.

This Delphi study can be classified as a modified e-Delphi according to Hasson and Keeney's (2011) types. This is because the first round has a format based on a set of pre-defined questions and the survey for each round was administered online. Chapter 5 discusses the development of the initial model through the use of the Delphi method.

Limitations to the Delphi method are the fact that even the most well planned Delphi study may yield an exhaustive not all-inclusive set of ideas, as it may be difficult, sometimes, to include all the right experts. Even if all the right experts are included, they may be prevented to come up with all the possible ideas for the study to be all-inclusive.

Another limitation is that, sometimes, additional research to validate or refine the findings should be undertaken (Hasson and Keeney, 2011). Adopting such approaches may also allow for informative theories to be developed. This, in particular, is the case of this project. The opinion of experts, although valuable, may sometimes not represent all nuances one has to consider in the practical application of a model. For extending the initial model resulting from the Delphi study in order for these nuances to be considered, research that uses the model and verifies its application has to be carried out. In this research project, the case study method was chosen as the approach to accomplish this and is described next.

2.1.3 Case study method

A case study is a research strategy that uses an empirical inquiry to investigate a phenomenon within its real-world context (Yin, 2003). The case study method can mean the study of single or multiple cases, can include qualitative and quantitative evidence, can rely on multiple sources of evidence, and can benefit from the prior development of theoretical propositions.

Stake (1995) defines three classes of case studies: (i) intrinsic cases, in which a researcher is led by his interest in the case itself and not in extending or generalizing theory; (ii) instrumental cases, in which the focus of the research is well-known in advance and research is designed around established theory or methods in order to better understand a phenomenon – the case itself is secondary; and (iii) collective case studies, in which a coordinated set of cases is comparatively analyzed to explore similarities and dissimilarities in order for a theory to be tested, verified or generalized.

There are three main aspects to be considered when applying the case study method: the case selection technique, the definition of the data collection protocol and the definition of the analysis protocol (Yin, 2003). Seawright and Gerring (2008) define seven different approaches for case selection: (i) typical, in which cases are typical examples of some cross-case relationship; (ii) diverse, in which cases exemplify diverse values of the population being analyzed; (iii) extreme, in which cases exemplify extreme or unusual values of the population; (iv) deviant, in which cases deviate from some cross-case relationship; (v) influential, in which cases have influential configurations of the independent variables; (vi) most similar, in which cases are similar on specified variables; and (vii) most different, in which cases are different on specified variables. Selection can either be done quantitatively, through the application of statistical methods, or qualitatively, when the universe of possible cases to be considered unknown, too large to be known or is not relevant due to the exploratory nature of the research.

The data collection protocol for these types of case studies makes use of a diversity of sources, such as interviews, observations, surveys and analysis of documents and records. Analysis procedures may involve qualitative and quantitative approaches and depend both on the type of cases and on the data collection protocol.

The approach used in this research project is that of a collective case study according to Stake's classification. A set of cases is selected in order for them to be analyzed according to a theory. The focus is not on the case itself, but on verifying the application of the systematization expressed in the initial model. This verification will serve for assessing the usability, applicability and utility of the systematization, and also for refining and extending it, incorporating nuances of the practical application of the model as mentioned in the previous subsection.

As the nature of cases to be developed is exploratory, the case selection technique chosen is by diversity. Choosing by diversity demands that the researcher defines variables relevant to the context of the research. Four variables are defined for this project:

- *Organizational system:* the unit of analysis of the case, whether it is a single process, an unstructured process or an organizational unit responsible for a set of processes. An organizational system pursues an objective by performing activities through the use of its resources.
- *Complexity:* defined as a set of elements such as the number of people, number of information systems used, degree of interaction with clients and other outside agents, among others. The more of these elements, the more complex the unit of analysis.
- *Time in operation:* the amount of time the unit of analysis has been performing its activities.

- *Initiative:* the type of enterprise engineering initiative or project to be developed in the unit of analysis.

Complexity, time in operation and initiative, in this research project, will be kept constant. Complexity will be chosen as medium to high – that is, the unit of analysis must not be a simple process involving one or two people with a couple of activities, but has to possess a larger amount of elements to make its analysis worth. Time in operation will be defined as at least 5 years, in order for the unit of analysis to possess a history of operation and some stable elements. Initiative will be defined as diagnosis – that is, the assessment of the unit of analysis. For this research, it will be the assessment of the alignment of the analysis unit to the systematization – whether the points defined in it are followed or not.

The organizational system variable will provide the diversity from which cases will be selected. An organizational system, for the purposes of this work, will be an organizational unit, a process, or a set of processes. Table 2.1 gives an overview of the cases to be analyzed in this research project, chosen qualitatively from the universe (which is comprised of all existing organizational systems, which is unknown and not relevant due to the exploratory nature of this research).

Table 2.1 - Cases to be analyzed in this research project.

Description	**Organizational system**
IT support unit of an oil and gas company	Organizational unit
Disaster response process of a healthcare organization	Unstructured process
Benefit programs unit of a city administration	Organizational unit
Production scheduling process of a cosmetics manufacturer	Process
Product development process of a home appliances manufacturer	Process

Regarding the procedure, the data collection protocol in this research project is based on the Cambridge process approach. This approach was originally designed for researching manufacturing strategy (Platts and Gregory, 1990; Platts, 1993). It later evolved as an approach for conducting well-structured interventions in real-world organizations when the involvement of the researcher is needed. There are four main points that need to be defined in this approach (Platts, 1994): (i) point of entry, to define expectations and the boundaries of the intervention; (ii) procedure, to define the necessary steps for collecting, organizing and analyzing information; (iii) participation, to engage people from the organization in the project; and (iv) project management, to define a timeframe for the initiative and the responsibilities for each task. Chapters 6 and 7 detail a pilot test of the data collection protocol. In particular, the second and fourth points of the process approach are covered. Chapter 7 emphasizes the data collection and analysis procedures based on the triangulation of multiple data sources (Jick, 1979), the use of worksheets and the agreement among raters (James et al, 1984). All of these approaches are used to reduce researcher bias.

Finally, three types of analysis will be conducted with the case study data:

- The analysis unit will be assessed, that is, conclusions about the alignment of the analysis unit to the systematization expressed in the initial model will be drawn.
- The procedure used to collect data and analyze them for each case will be evaluated. This procedure could give rise to a standardized diagnosis procedure based on the systematization. This type of analysis will cross-evaluate difficulties and problems encountered with the application of the procedure.
- The systematization expressed in the initial model will be evaluated through case analysis. Patterns of similarities and dissimilarities among the collected data will be searched for.

2.2 EXPECTED RESULTS

The following is a list of direct and indirect expected results from this research project:

- Systematization of the contributions to the enterprise engineering field in the form of a set of guidelines to be applied in enterprise engineering initiatives such as enterprise diagnosis, design, redesign or deployment of enterprise systems – this is the main expected result of the project.
- Procedure for the evaluation of the alignment of an organizational system (organizational unit or process) to the enterprise engineering guidelines – this procedure will be used for the case studies and can be adapted to be applied to enterprise diagnosis projects.
- Set of data collection instruments to operationalize the procedure, in the form of worksheets with information requirements to be filled out with the evidences from the organizational system analyzed.
- System that aids in the collection and organization of data through the worksheets that operationalize the procedure and also aids in the management of the application of the procedure, allowing the definition of steps during its execution.

- Reports of the application of the evaluation procedure to the organizations selected for the case studies.

2.3 ARTICLES IN THIS DISSERTATION

Table 2.2 shows the articles presented in this dissertation. The table presents the topic of the article, the specific objective related to it, the main method of the dissertation used in it and the intended journal for publication.

It is worth noting that articles 1 and 2 are part of the first phase of the project, article 3 is part of the second phase and articles 4 and 5 are part of the third phase.

Table 2.2 - Structure of articles that will compose the final dissertation.

#	Topic	Specific Objective	Method	Intended Journal for Publication
1	Characterization of the enterprise engineering research field, identifying main research topics, authors and potential areas for contribution	1	Author co-citation analysis	Journal of Enterprise Transformation
2	Characterization of enterprise engineering contributions, including reference models, methods, tools, techniques and procedures, among others	2	Systematic literature review	Computers in Industry
3	Development of enterprise engineering guidelines including the preliminary model developed as a result of the systematic literature review and the initial model developed as a result of the Delphi study	3	Delphi study	International Journal of Production Economics
4	Results and conclusions from the application of the initial model, with the evaluation procedure to the case studies and perspectives for the final model	4	Case study	International Journal of Operations and Production Management
5	Development of an evaluation procedure based on the initial model and its implementation in an information system and its pilot testing	4	Case study	Enterprise Information Systems

3 ARTICLE #1 – ENTERPRISE ENGINEERING RESEARCH FIELD CHARACTERIZATION

This article characterizes the enterprise engineering research field through the analysis of works published in the area until 2012. A set of 282 journal articles on enterprise engineering was collected from different reference databases. The complete list of references may be seen in Appendix A. The article identifies: main journals, main authors with publications in the field, main research topics, and areas for future research. This article is relevant to this research project because it identifies core contribution areas and core contributors to the field. The contributions are used in the review of contributions of article #2 and in the development of the preliminary model for the guidelines of article #3. The main contributors are used in the Delphi study of article #3 to create the initial model for the guidelines. Table 3.1 lists works whose results lead to this article.

Table 3.1 – Summary of works on the characterization of the enterprise engineering research field leading to article #1.

#	Description
1	Work from the Independent Study course taken in the second semester of 2011.
2	First version published in the Proceedings of the Industrial and Systems Engineering Research Conference 2012, held in Orlando, USA, from May 19th to 23rd, 2012, with a summary of results until 2011.

Enterprise engineering research field characterization: an analysis of publications until 2012

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Abstract

Enterprise engineering is a research field dealing with the development of methods and tools for organizational design concerning structure, information flow and process coordination. It combines elements of organizational sciences, information technology and industrial engineering. Because of its multidisciplinary nature, it is often difficult to determine the exact extent of the field and the research topics it encompasses. The objective of this work is to characterize the main contribution areas to enterprise engineering and present some topics in which research in the field could be further developed. For this purpose, an analysis of the enterprise engineering research field is performed through publications until 2012. The main authors are identified and network diagrams of co-authorship, keyword co-use and author co-citation are drawn and analyzed, intending to identify the contribution areas. Results show that the field has a core set of authors and that contributions can be characterized in two main topics, enterprise modeling and enterprise integration, and six other topics with changing relevance over time, from reference models and business processes to ontologies and virtual enterprises to enterprise architecture and interoperability. Further research is suggested based on the analysis of keywords and evolution of research focus.

Keywords: enterprise engineering, enterprise design, enterprise integration, research field characterization.

3.1 INTRODUCTION

Enterprises or organizations are a major part of the world's socio-economical environment. An enterprise may be defined as an overall term to represent a company, a business, a government institution, or any other intentional creation of human endeavor for the fulfillment of a determined purpose, with a certain degree of complexity and order [1], [2]. Enterprises achieve results that one person alone would not be able to accomplish through the organization and mobilization of its different resources – e.g., people, machines, information and knowledge. A regular person interacts with many enterprises in a daily basis throughout his life – e.g., workplaces, educational and government institutions, hospitals, retailers, manufacturers, and service providers, among others.

Because of their complexity and all-around presence, enterprises are the object of study of several different areas. Sociology, psychology, economics, politics, management, engineering and technology all address issues related to enterprises, their components, relationships, influence, functioning and structuring, among other aspects. One question often arising in areas related to management, technology and engineering is how should enterprises be designed or engineered in order for them to be able to achieve their objectives. Enterprise engineering, in this sense, is the field of study of the engineering of these complex entities for the attainment of a purpose, or as stated by Liles *et al* [3], "how to design and improve all elements associated with the total enterprise through the use of engineering and analysis methods and tools to more effectively achieve its goals and objectives".

Two of the first authors to define enterprise engineering were Brown and Watts [4]. In their definition, enterprise engineering is seen as a set of four continually maturing processes for learning and managing enterprise change for long-term success. These processes evolve continuously as part of a learning infrastructure and are strategic visioning, business re-engineering, total quality management and information engineering. In their view, enterprise engineering is about closely aligning the operation of an enterprise to its objectives, through quality and information management. They consider quality and information as ever changing components of an enterprise that define how the four processes should be conceived.

Vernadat [5] goes a step beyond this definition and states that enterprise engineering, besides embracing strategic planning, also embraces modeling, integration and other traditional activities of industrial engineering for the development of enterprise systems through analysis, optimization and reengineering. His view of enterprise systems is more comprehensive than only information and quality, being defined by business processes, information systems and organizational structures in an enterprise or an enterprise network – viewing that enterprises may, for some period of time, collaborate with one another. Kosanke *et al* [6] also contribute to this notion stating that enterprise engineering should "define, structure, design and implement enterprise operations as communication networks of business processes, which comprise all their related business knowledge, operational information, resources and organization relations". Processes, in this definition, are seen as transcending one particular enterprise.

Also contributing to this more comprehensive view, Liles and Presley [7] define enterprise engineering as a body of knowledge, principles and practices having to do with the analysis, design, implementation and operation of an enterprise, in a continually changing and competitive environment. In their definition, the enterprise is viewed as a complex system of processes that can be engineered to accomplish specific objectives. They add the notion that the environment plays a role in the enterprise engineering process and agree with Brown and Watts in the fact that change plays a key role in enterprise design.

Kosanke and Nell [8] define enterprise engineering in a different, indirect manner, by presenting its main knowledge domains: hardware, software, communication protocols, information, frameworks and architectures – the things, the connections among things, the information and its formats. More recently, Dietz and Hoogervorst [9] and Hoogervorst [10] state that enterprise engineering deals with the development of methods and tools for organizational design concerning structure, information flow and process coordination, combining elements of organizational sciences, information technology and industrial engineering.

All of these are very broad definitions, including several research topics and contribution areas as diverse as modeling, optimization, analysis, reference models, business processes, information systems, organizational design, enterprise collaborations, organizational structure, organizational objectives, strategic planning and others. Figure 3.1 synthesizes these definitions in the form of a concept map [11]. However, what is the actual extent of current research in enterprise engineering? What are the main topics researched and the main contribution areas? How can research in the field evolve? What are the possibilities for further works and what should be researched? This work deals with these issues, characterizing enterprise engineering research through the analysis of publications in the field until 2012. It is organized as follows: section 3.2 presents the research method used, based on a modification of Eom's author co-citation analysis framework; section 3.3 presents the characterization of enterprise engineering research as result of the analysis of works published in the field; section 3.4 presents research opportunities derived from an analysis of keyword co-use and evolution of the research field focus;

and finally, section 3.5 draws conclusions from this work, its limitations and improvement opportunities.

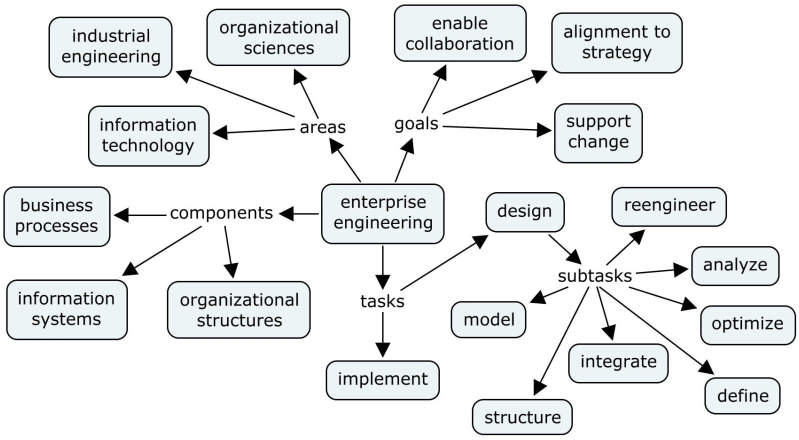

Figure 3.1 - Concept map summarizing different definitions for enterprise engineering.

3.2 RESEARCH METHOD

Research in this paper was conducted using an approach based on a modification of Eom's author co-citation analysis framework [12]. Through this method, published research was analyzed to characterize enterprise engineering research and identify opportunities for future research. Results of the characterization are presented in Section 3.3, whereas results of the identification of opportunities for future research are presented in Section 3.4. This modified procedure is composed of four steps, as follows:

- **Loose screening:** in this step, scientific reference databases are searched for works related to the field in an informal, loose fashion. There are two main goals with this approach. The first one is to identify search terms that generate relevant search results. The second goal is to identify reference databases that contain relevant works with the search terms. The output of the loose screening step is a set of reference databases and a set of search terms to be used.
- **Construction of the collection of published works:** in this step, the selected reference databases are searched for works including one or more of the search terms in their records. The full records of the articles are extracted from the reference databases. Records include information such as authors, journal, publication year, keywords, references and abstract. Whenever possible, the full text of the works is also retrieved from the database. These records, for the purpose of this paper, are organized using reference management software.

Records are then analyzed, one by one, to filter duplicates and works not related to the enterprise engineering research field. This is made by means of analysis of the title, abstract and keywords and, when necessary, of the full text. The list of works with their records is later exported to an electronic spreadsheet, in which they may be treated and analyzed.

- **Analysis:** once the collection of published works is constructed, analysis was conducted through a series of descriptive statistics and network analysis techniques. First, works are characterized by year and journal and most cited works are presented. Next, co-authorship, keyword co-use, and author co-citation analysis are conducted aiming at identifying the main research topics and authors. This analysis is performed through the creation of correlation matrices in an electronic spreadsheet and the use of the UCINET software [13]. Besides generating the network diagrams representing the correlations to help identify authors and topics, other analysis techniques implemented in the software are used [14], such as the calculation of Freeman's degree centrality (to determine authors and keywords with the most number of connections with other authors and keywords), Freeman's betweenness centrality (to determine authors and keywords that connect the most number of authors and keywords), Johnson's hierarchical clustering, and multi-dimensional scaling (the last two to determine groupings of authors and keywords). Finally, a characterization of works according to their main focus is done. Each of the works in the database is classified as either dealing with conceptualization, model building, tool development and application. The development of the field is discussed by means of the analysis of the pattern emerging from this classification. Research topics are identified and presented as a result of the analysis of these results.
- **Discussion:** future research opportunities are identified through analysis of the authors and keywords in the networks generated in the analysis step. Missing connections and nodes are considered as sources for potential future research. Main references of each one of the groups defined in the first phase are also examined. These works, specially the most recently published ones, were read and notes were taken in order to identify some contribution areas. The discussion step presents some of the contribution areas identified as research gaps or the logical continuation of research topics already under development.

3.3 ENTERPRISE ENGINEERING CHARACTERIZATION

This section presents the results of the characterization of enterprise engineering research. Results for the first three steps described in section 3.2 are detailed and discussed, beginning with the loose screening step.

Search terms were identified through the analysis of the enterprise engineering definitions presented in section 3.1. Besides “enterprise engineering” and derived search terms such as “engineering of enterprises” and “engineering of an enterprise”, search terms related to the word “design” and “organization” were also used. “Design” was chosen because the main goal of enterprise engineering, as noted in the definitions of section 3.1 and in the concept map of Figure 3.1, is the “design” of an enterprise. “Organization” was chosen because it was determined that it is closely related to the meaning of “enterprise” in most of the works in this area. Search terms used were, hence, a combination of four main terms – *engineering*, *design*, *enterprise* and *organization*: enterprise engineering, enterprise design, organizational engineering, and organizational design, among others. Variant and plural forms were accounted for, e.g., organisational design and design of enterprises.

Other search terms such as “enterprise integration”, “enterprise modelling”, “enterprise architecture” and “ontology” were also tried. All of them resulted in a meaningful number of works from the area. However, although meaningful, the use of such terms would bias the results because they are related to themes, tools, technologies, methods and areas that are used in enterprise engineering. “Enterprise systems implementation” and derivations such as “organizational systems implementation” and “implementation of enterprise systems” were also tried as search terms. They did not, however, provide meaningful results.

A search term that resulted in many works was “organizational design” and its variants. This is mainly due to the fact that works from areas such as social sciences are included in these results. Most of these works were not included in the analysis because they were not related to the concepts discussed in section 3.1. In particular, they lacked the integrative view proclaimed by the enterprise engineering definitions presented in that section.

It also resulted from this initial approach that the reference databases with the most relevant works and, therefore, to be searched, were ACM Digital Library, IEEE

Xplore, Emerald, Web of Knowledge, Science Direct, Springer Link and Taylor and Francis Online. Table 3.1 shows the number of works retrieved with the search for each search term in these reference databases. The search was restricted to works published in or before 2012. After filtering for duplicates and performing a first selection of works clearly unrelated to the field or the objectives of this work, the total number of works found was 813.

For the second step, the construction of the collection of works, all of the 813 works found had their records retrieved and were analyzed. As noted in section 3.2, this analysis was carried out work by work and the title, abstract, keywords and in some cases, the full text of the works were skimmed. For a work to be included in the collection it had to be published in a scientific journal and had to be related to the broad definition of enterprise engineering as presented in section 3.1 and summarized in the concept map of Figure 3.1. Authors of this article performed this analysis. After the analysis, 282 works were included in the collection and a list of them and their records was exported to an electronic spreadsheet for analysis to be started.

Table 3.2: Number of works from each reference database for each of the search terms.

	ACM Digital Library	IEEE Xplore	Emerald	Web of Knowledge	Science Direct	Springer Link	Taylor and Francis
Enterprise engineering	96	48	57	49	254	98	115
Organiz(s)ational Engineering	1	13	20	12	70	39	21
Enterprise design	0	20	86	60	124	107	227
Organiz(s)ational design	28	113	219	261	242	281	141
Engineering of (an) enterprise(s)	0	1	37	0	10	14	18
Engineering of (an) organiz(s)ation	0	0	78	0	9	5	24
Design of (an) enterprise(s)	0	10	13	34	5	33	12
Design of (an) organiz(s)ation	7	9	5	45	11	130	47

The results of the analysis step are presented in two parts. The first part involves the description of some characteristics of the set of works in the collection, such as publication year, journal, most cited works, keywords and main focus. The second part discusses the results of co-authorship, keyword co-use, and author co-citation analysis, presenting network diagrams representing the relationships among keywords and among authors.

Figure 3.2 shows the publication profile of the works in the collection by year. It can be seen that there are two major publication peaks: one in 1999 and one in 2009. The peak in 1999 can be understood as part of the growing interest of the scientific community in enterprise engineering, establishing it as a research field. After 1999, the number of publications in the area decreased because of the exhaustion of some research topics, specifically the ones related to enterprise reference models and the conceptualization of enterprise modeling and enterprise integration, as shown later in this section. The peak in 2009 is due to new research topics being addressed by the scientific community, in particular ontologies, virtual enterprises, enterprise architecture and interoperability – this is also explained later, when addressing keywords. Since 2009, the number of publications by year is lower. Despite this decrease, it can be noted that after 2006, this number has stayed at a higher level in comparison to previous years.

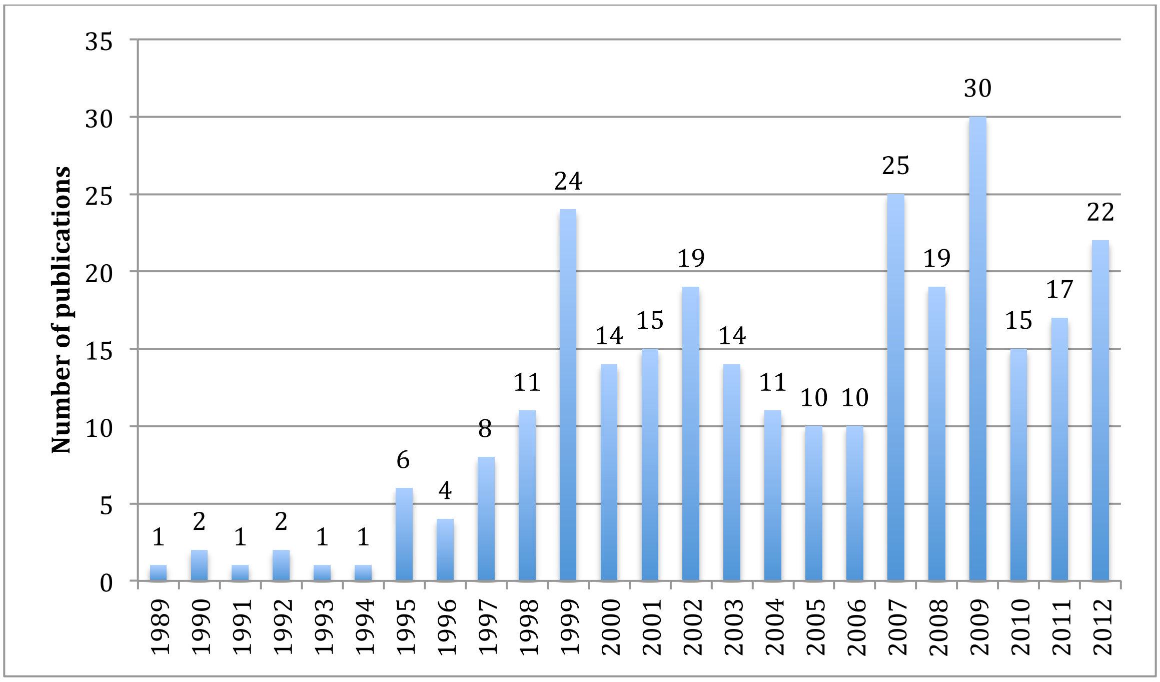

Figure 3.2 - Number of publications on enterprise engineering by year.

To facilitate further analysis, four different time periods are defined, each one with 20% to 30% of the works in the collection: the first one from 1989 until 2000 (75 works), that corresponds to the period of publication growth and establishment of enterprise engineering as a research field; and three subsequent four-year periods, from 2001 until 2004 (61 works), from 2005 until 2008 (64 works), and from 2009 until 2012 (84 works).

There are 542 different authors in the dataset. Top authors are presented in Table 3.3.

Table 3.3 – Authors with the largest number of publications on enterprise engineering and total number of works published.

Weston, R.H.	17	Chen, D.	5	Chatha, K.A.	4	Morel, G.	4
Vernadat, F.B.	12	Doumeingts, G.	5	Gruninger, M.	4	Panetto, H.	4
Harding, J.A.	9	Gabbar, H.A.	5	Kamsu-Foguem, B.	4	Sarkis, J.	4
Ortiz, A.	8	Ros, L.	5	Kim, K.	4	Shimada, Y.	4
Kim, C.H.	6	Ajaefobi, J.O.	4	Kosanke, K.	4	Suzuki, K.	4
Bernus, P.	5	Chapurlat, V.	4	Lario, F.C.	4	Zelm, M.	4

Figure 3.3 presents the evolution of the top 10 authors' publications by year. It can be noted that although some authors have had an almost constant number of publications throughout all periods (L. Ros, G. Doumeingts, D. Chen and R.H. Weston – this last one with an extensive number of publications), some authors have had a major influence only in some of the periods (F.B. Vernadat, J.A. Harding, P. Bernus, C.H. Kim, H.A. Gabbar). It must be noted, however, that total publications in the collection by this top 10 authors group has decreased since 2001. This shows that there is a more diverse set of authors publishing in the area, especially considering that the period from 2009-2012 is the one with the largest number of works.

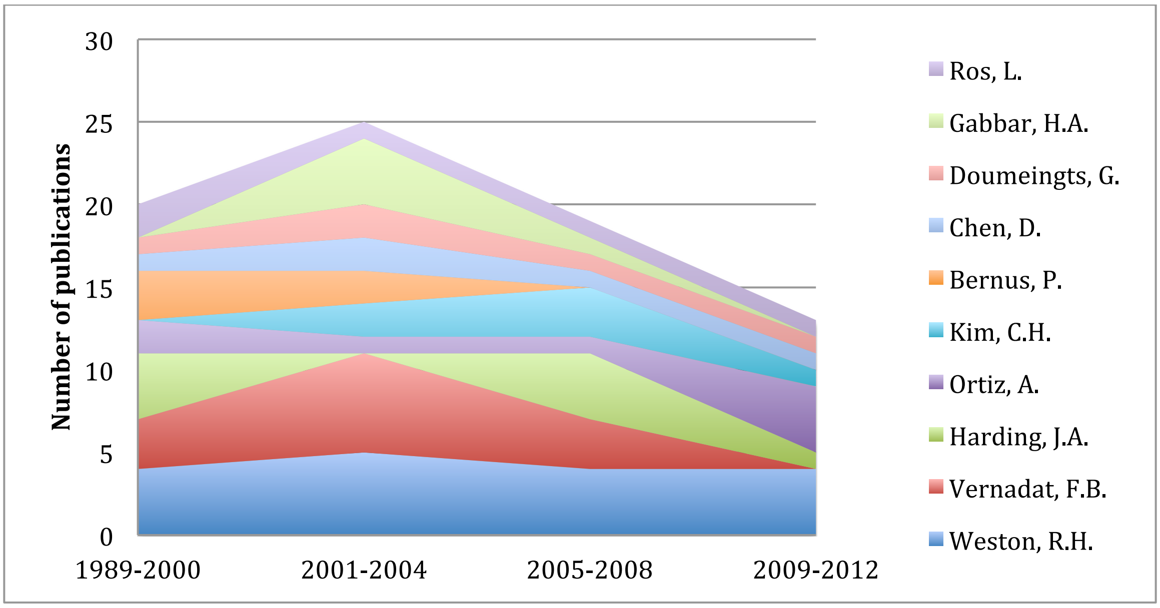

Figure 3.3 - Evolution of publications by author by period.

There are 93 different journals with works published in the dataset. Table 3.4 lists the top journals in the area with the number of works that were published in them. It can be observed from this table that journals which have as a main interest areas related to applied industrial technology, such as Computers in Industry, the International Journal of Computer Integrated Manufacturing, and Annual Reviews in Control lead the number of publications – other journals with these interest areas appear throughout the list, such as The International Journal of Advanced Manufacturing Technology, Advanced Engineering Informatics and Computers & Industrial Engineering. Journals whose main topics cover industrial and systems engineering and engineering management, such as the International Journal of Production Research, the International Journal of Production Economics and Production Planning & Control come next. Journals whose main theme is information systems and technology also appear on this list, such as Enterprise Information Systems, Journal of Systems and Software, Information Systems and Procedia Technology. From this numbers, it can be argued that research focus in the area has been on technology application to enterprise engineering.

Table 3.4 - Journals with the largest number of publications on enterprise engineering and number of works published.

Computers in Industry	54
International Journal of Computer Integrated Manufacturing	31
International Journal of Production Research	18
Annual Reviews in Control	10
International Journal of Production Economics	9
Production Planning & Control	9
International Journal of Flexible Manufacturing Systems	7
Enterprise Information Systems	6
The International Journal of Advanced Manufacturing Technology	6
Journal of Systems and Software	5
Advanced Engineering Informatics	4
Computers & Industrial Engineering	4
Information Systems	4
Journal of Intelligent Manufacturing	4
Procedia Technology	4
Robotics and Computer-Integrated Manufacturing	4

Throughout the years, it can be observed a shift from the concentration of the works in the collection from their publication in a few to a larger number of journals. Until 2000, Computers in Industry largely concentrated publications in the area, as can be seen in Figure 3.4. Lately, other journals have seen an increase in the number of publications, specifically journals whose main interest areas are industrial and systems engineering and engineering management, such as the International

Journal of Production Research and Production Planning & Control. Despite this, journals whose interest area are applied technology, such as Computers in Industry and the International Journal of Computer Integrated Manufacturing still play an important role.

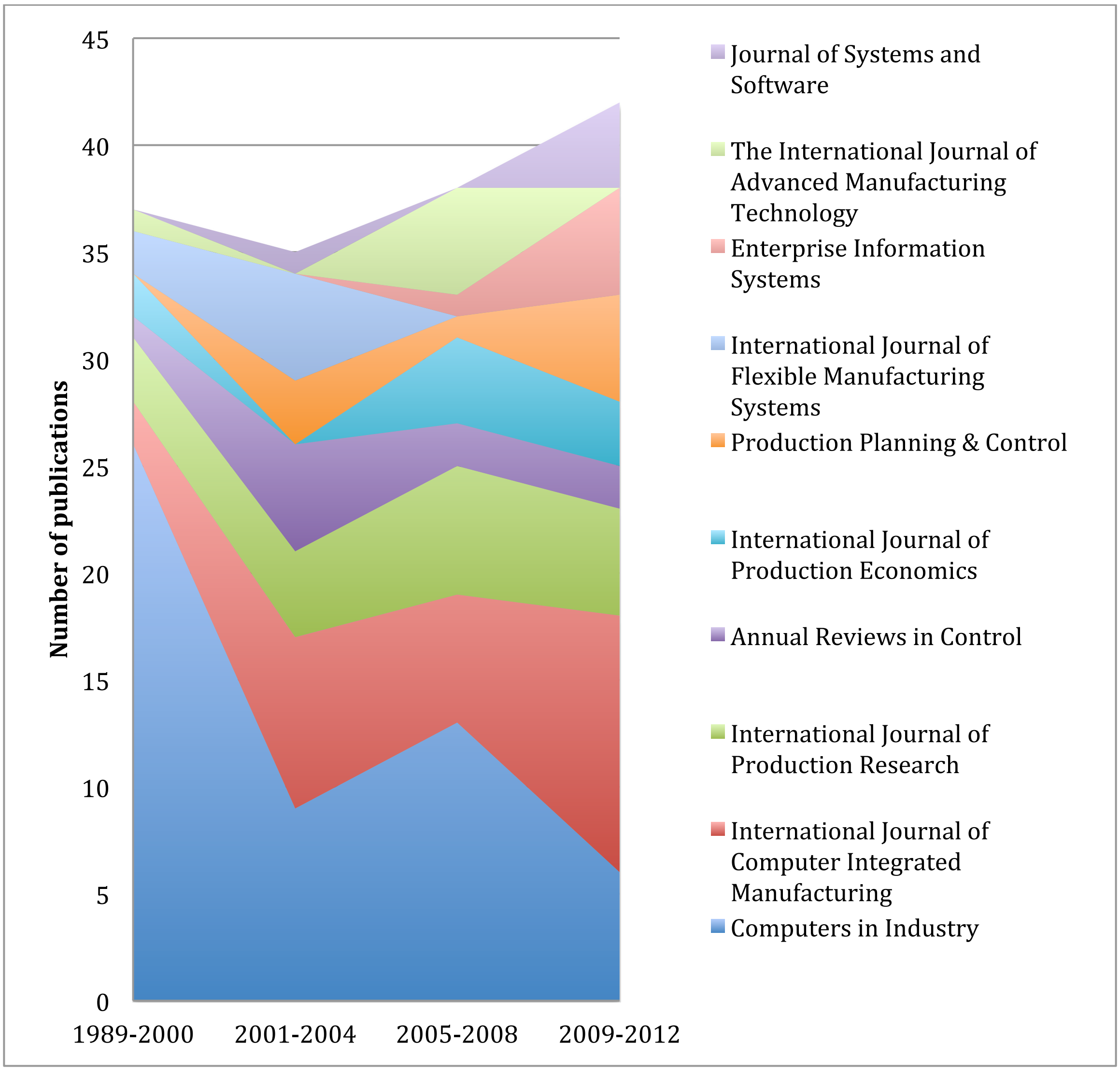

Figure 3.4 – Evolution of publications by journal by period.

Table 3.4 shows the top 10 most cited works from papers in the dataset. The number of citations for each work was obtained solely among the works included in the collection. It must be noted that the three most cited works are related to enterprise engineering reference models (CIMOSA [15], [16] and GERAM [17]). There is also a work about standards [18], which organizes the main standardization efforts for enterprise engineering and some works about themes as diverse as knowledge management [19], interoperability [20], reconfiguration [21] and modeling approaches

[10, 12]. The last work in this list deals with a revision of methods and techniques applied to the field [24].

Table 3.5: Most cited works in the collection.

Work	Authors	Year	Times Cited	Reference
CIMOSA: enterprise engineering and integration	K. Kosanke and F. B. Vernadat	1999	13	[15]
A framework to define a generic enterprise reference architecture and methodology	B. Bernus and L. Nemes	1996	12	[17]
New developments in enterprise modeling using CIMOSA	G. Berio and F. B. Vernadat	1999	11	[16]
Reconfigurable component-based systems and the role of enterprise engineering concepts	R. H. Weston	1999	11	[21]
The complementary use of IDEF and UML modeling approaches	C. H. Kim, R. H. Weston, A. Hodgson and K. H. Lee	2003	10	[22]
IT-based competency modeling and management: from theory to practice in enterprise engineering and operations	M. Harzallah and F. B. Vernadat	2002	9	[23]
Standards on enterprise integration and engineering - state of the art	D. Chen and F. B. Vernadat	2004	8	[18]
Developing a distributed knowledge model for knowledge management in collaborative development and implementation of an enterprise system	C. T. Ho and Y. M. Chen	2004	7	[19]
A modeling framework for agile and interoperable virtual enterprises	T. Y. Kim	2006	7	[20]
Architectures, methods and tools for enterprise engineering	K. Mertins	2005	7	[24]

Table 3.6 shows the main keywords by each period. It can be observed that “enterprise modeling” and “enterprise integration” are frequent keywords until 2008. Modeling and integration are the main aspects within enterprise engineering, associated to many of the works – modeling can be understood as the process through which the concept of an enterprise system may be expressed, whereas integration is one of the objectives of such a concept. In the first period, from 1989 until 2000, “CIMOSA” is another frequent keyword. This is due to the fact that major advances in the development of this reference model were achieved during this period. In the second and third periods, from 2001 until 2008, “ontology” and “virtual enterprise” are frequent keywords, representing works that aimed at creating a meta-representation for enterprises and their different aspects and for developing technologies that could be used to interconnect different organizational systems, in the same or different enterprises. In the last period, from 2009 until 2012, the most frequent keywords are “enterprise architecture” and “interoperability”, denoting the

change in focus from ontology creation to architectural implementation and from virtual enterprise foundational technology to its effective use.

Table 3.6 - Most frequent keywords by period.

1989-2000		**2001-2004**	
enterprise modelling	14	enterprise modelling	10
CIMOSA	13	enterprise integration	4
enterprise integration	7	ontology	3
enterprise engineering	4	virtual enterprise	3
business process modelling	3		
2005-2008		**2009-2012**	
enterprise modelling	8	enterprise architecture	7
enterprise integration	5	interoperability	4
ontology	4	UML	3
virtual enterprise	4	effectiveness	3
modelling	3		
verification	3		

The evolution of keyword use can be better visualized in Figure 3.5, in which the use of the top 12 keywords is shown for each one of the previously defined periods. The dominance of the keywords "enterprise modeling", "enterprise integration" and "CIMOSA" can be seen in the first period, as well as the decrease of their use in subsequent periods, although "enterprise modeling" and "enterprise integration" remained dominant in the second and third periods.

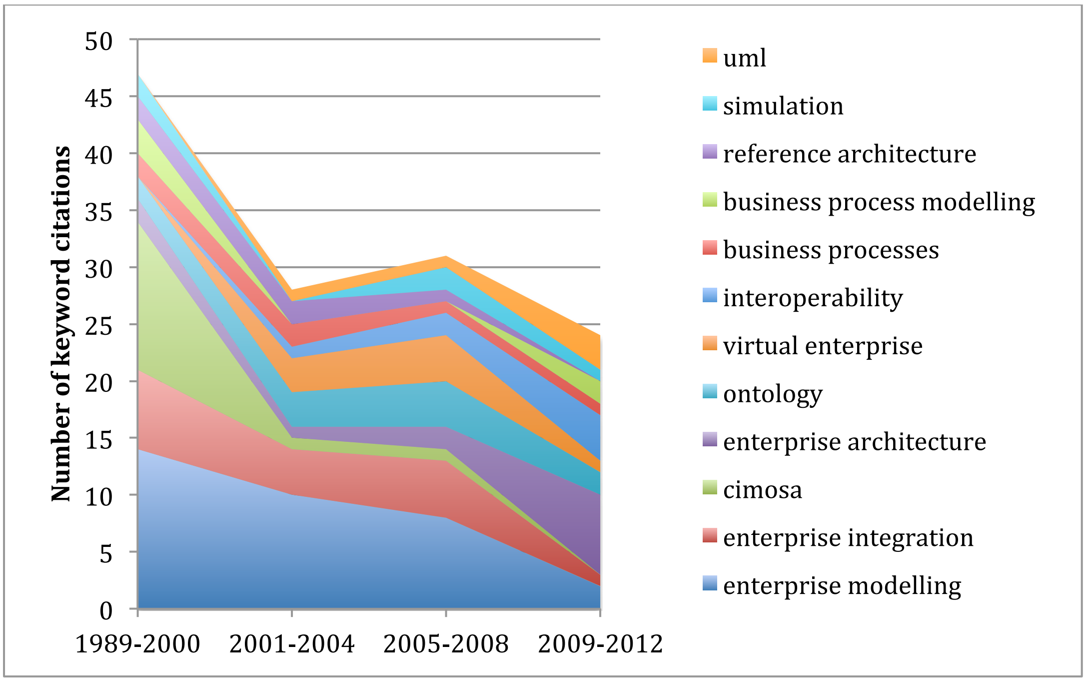

Figure 3.5 - Evolution of keywords by period.

A co-authorship analysis of the authors in the dataset reveals that there are two main groups of authors collaborating. Figure 3.6 shows the co-authorship network for authors with at least 2 publications in the dataset, and the two main groups of authors in blue and red after application of Johnson's clustering algorithm in UCINET. The thickness of the line in this figure is proportional to the number of works two authors have published together. According to Freeman's Degree Centrality (normalized, in parenthesis) implemented in UCINET, the group in blue has as its most central authors, A. Ortiz (4.494), L. Ros (3.090) and F.B. Vernadat (2.809), whereas the group in red has as its most central authors R.H. Weston (6.180), C.H. Kim (3.090) and K. Kim (1.966). According to Freeman's Betweenness Centrality (normalized, in parenthesis), the group in blue has as its most central authors F.B. Vernadat (1.569), A. Ortiz (0.907) and G. Doumeingts (0.524), whereas the group in red has as its most central authors R.H. Weston (1.570), C.H. Kim (1.098) and B. Grabot (0.332). When the works of both groups are analyzed, it may be seen that the group in red focuses on enterprise modeling and integration in general, developing methods and tools, whereas the group in blue focuses on enterprise modeling through the use of reference models such as CIMOSA. Other relevant groups in this diagram are the group in gray (with a focus on interoperability), the group in navy blue with a focus on organizational change, and the groups in black and in light green on the bottom of the diagram, with a focus on ontology,

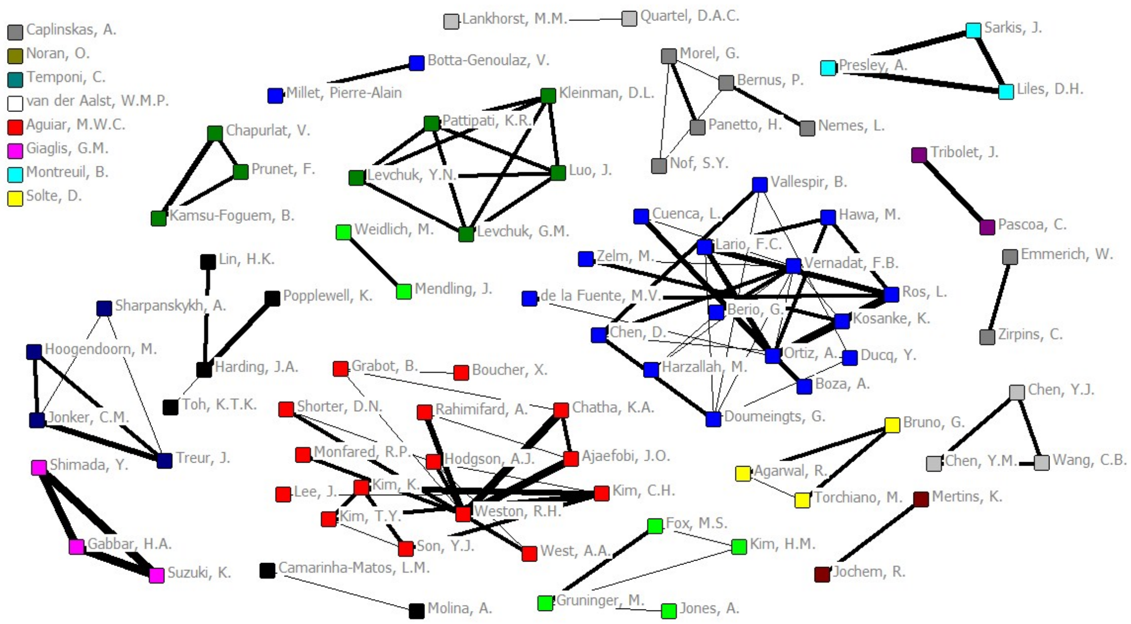

Figure 3.6 - Co-authorship social network for authors with at least 2 publications.

A keyword co-use analysis was also conducted to identify the relationships among the most cited keywords. Figure 3.7 shows the keyword co-use network for keywords cited at least 2 times – the thickness of the line between keywords is proportional to the number of times they are used together. From this figure it is possible to see a core group of keywords, in the center of the diagram and in red, related to many other keyword groups in other colors – colors were used to show one of the possible cluster combinations from the application of UCINET’s implementation of Johnson’s clustering algorithm. Four other groups in the periphery are meaningful in this diagram: the group in blue, on the top of the diagram, with “interoperability” and “ontology” being the most central keywords (centrality here is calculated using UCINET’s implementation of Freeman’s degree centrality algorithm); the group in black, on the bottom of the diagram, with “virtual enterprise” as the most central keyword; the group in gray, on the top right of the diagram, with “information technology” as the most central keyword; and the group in cyan, on the left of the diagram, with the most central keyword being “supply chain”. In this same figure, it is possible to note the strong relationship between “CIMOSA” and “enterprise modelling”, “enterprise modelling” and “enterprise integration”, and “enterprise architecture” and “enterprise integration”. The first two relationships are due to the large number of works published until 2000 that had these common keywords. The last relationship evidences the importance of enterprise architecture as a means for better integrating an enterprise that started in 2005 and is still in place today, as a consequence of the development of reference models and ontologies.

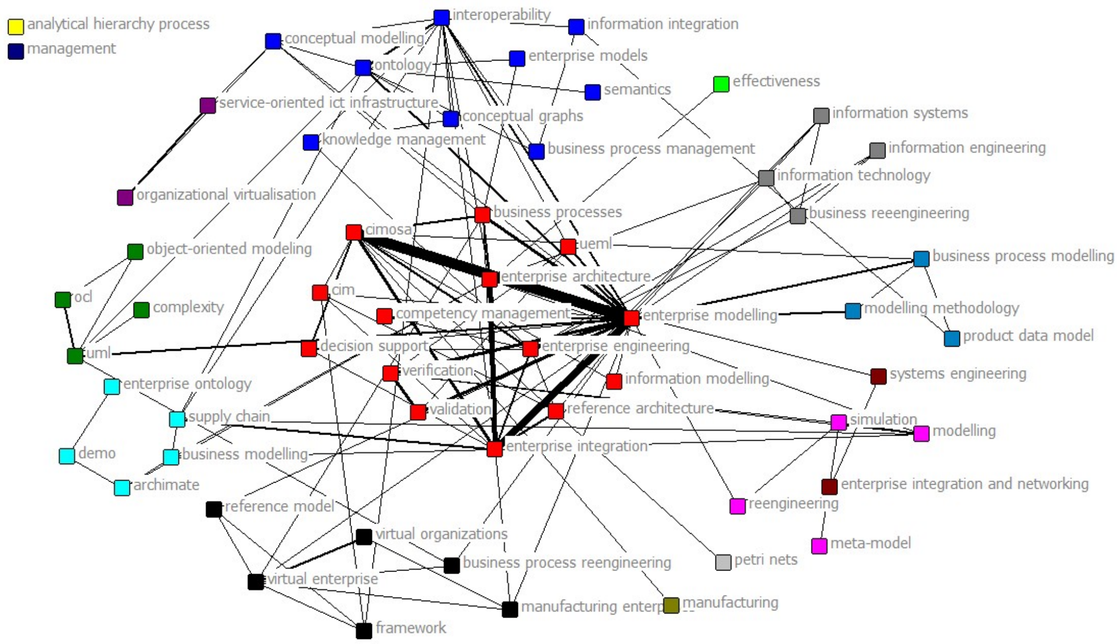

Figure 3.7 - Keyword co-use network for keywords used at least 2 times.

If only keywords used more than 5 times are included, the result is that shown in Figure 3.8. From this network it is possible to conclude that “enterprise modeling” is a central concept transcending all other main areas: “enterprise integration”, “interoperability”, “virtual enterprise”, “ontology”, “business processes”, “enterprise architecture” and “CIMOSA” (which, as already mentioned, is a proxy for “reference models”). A case can also be made for “enterprise integration” as an overall topic, particularly if it development over time is examined, as was shown in Figure 3.5.

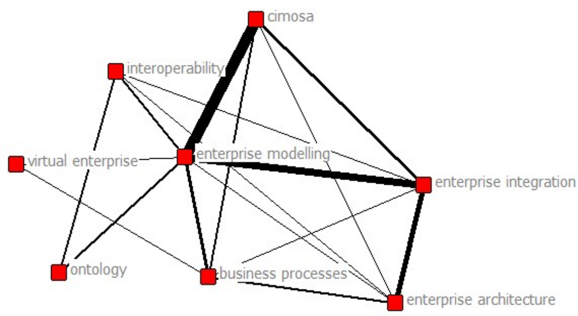

Figure 3.8 - Keyword co-use network for keywords used at least 5 times.

A co-citation analysis was also performed to identify authors that most influenced works in the collection and identify groups of authors that are most central to the research field. Among all 282 works, 4232 authors were cited at least once. The author co-citation network for authors cited at least 5 times is shown in Figure 3.9.

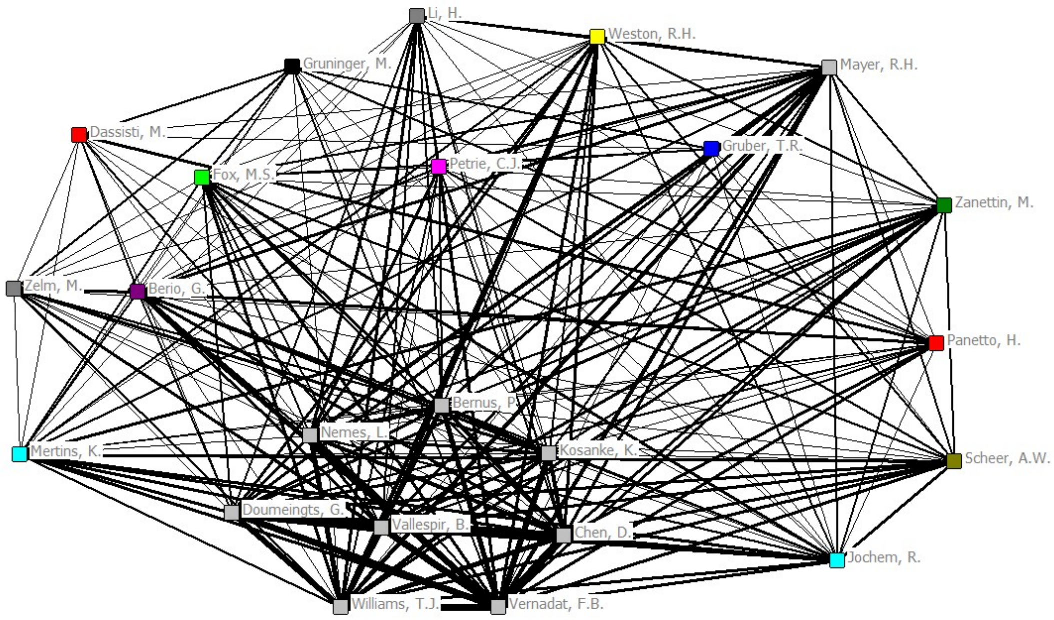

Figure 3.9 – Author co-citation network of the 23 authors cited at least 5 times in the works of the collection.

Authors most central to the social network, according to Freeman's degree centrality as implemented in UCINET are F. B. Vernadat (42.761), D. Chen (35.354), B. Vallespir (33.670), T.J. Williams (31.987) and G. Doumeingts (30.640). Three of these authors are among the top authors with publications in the field according to Table 3.3 (F.B. Vernadat, D. Chen and G. Doumeingts), and all of them figure as authors with publications in the area. After application of Johnson's hierarchical clustering algorithm, a group of 8 authors appear as a central cluster in Figure 3.9, colored in light gray – F.B. Vernadat, D. Chen, G. Doumeingts, Y.J. Williams, B. Vallespir, L. Nemes, P. Bernus and K. Kosanke). All other authors in this network are also relevant and possess a large number of citations with other authors in this core group. It is worth noting, though, that from this most cited group of authors, only T.R. Gruber does not author any work in the collection. This means that authors from the enterprise engineering research field are referenced in the works of this field, what makes it difficult to identify any other disciplines that serve as pillars for sustaining the field.

Lastly, classification of published works was performed according to their main concern, in a modification of the research cycle proposed by Neely [25], adapted to the types of works seen in enterprise engineering. Works in a research field usually start by discussing theoretical grounds and evolve to the definition of application models. Next, the development of tools and techniques that bundle the developed knowledge and application models in a set of useful methods is performed, followed by empirical research that uses and tests them. The process is restarted when theory fails or must be complemented, in particular when conditions under which this theory was developed are no longer valid or when there is the need for the advancement of knowledge in the field to solve new problems. In this article, works in the collection are classified according to their main focus in a specialization of the previously mentioned framework. In this case, the main focus of a work may be conceptualization, model building, tool development and application. Table 3.7 shows the distribution of the works in the collection classified according to this scheme. A work may be classified in more than one category.

Table 3.7 shows that most of the works in the collection have as their main focus model building. If one were to analyze the collection only by looking at the total numbers, it could be said that the point of evolution of the enterprise engineering research field is that of definition of application models to be further studied for organization and application. However, it is worth noting that a significant number of works is classified in the tool development and application concerns. To obtain a better picture of the research field and its current point of evolution, the evolution of the focus according to a time period must be considered, as shown in Figure 3.10.

Table 3.7: Distribution of works according to the concern classification scheme.

Concern	Works	%
Conceptualization	70	25%
Model building	109	39%
Tool development	67	24%
Application	73	26%

From Figure 3.10, it is noted that after a first period dedicated mainly to conceptualization, the focus changed to model building. As model building slightly decreased its importance in relation to the total number of works, tool development and application increased theirs. It may be stated, from the analysis of this figure, that the enterprise engineering research field is entering a stage in which tool development and application are gaining ground as the main concern, with what was done in conceptualization and model building being put into practice. Probably, a next cycle of works will include more tool development and application works, preparing for a new conceptualization phase for the identification of new problems to be addressed. This analysis provides evidence to the fact that application of enterprise architecture frameworks is somewhat a consequence of the development of ontologies, which is a consequence of the development of reference models.

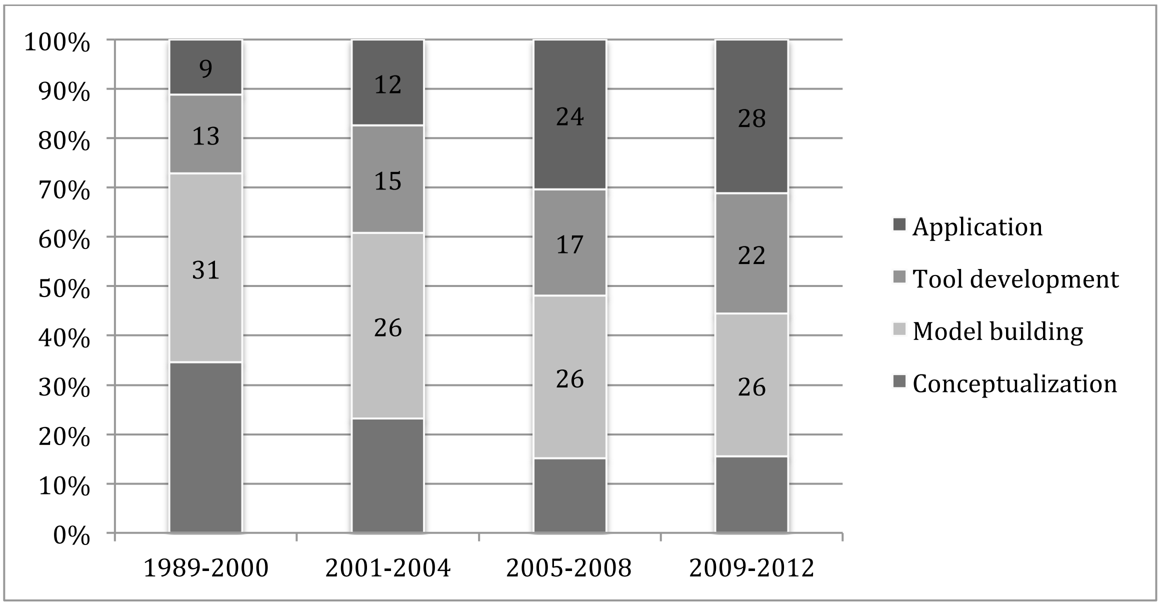

Figure 3.10 - 100% stacked chart of works according to main concern in each 4-year period (numbers are absolute count of works).

Finally, from this analysis, considering mainly the keyword co-use and co-authorship diagrams and their respective analysis, there are two main research topics that underlie the enterprise engineering research field and six other topics that evolved over time. Underlying topics are modeling and integration, and the other topics are reference models, business processes, ontologies, virtual enterprises, enterprise architecture and interoperability. All of these topics are seen as keywords in Figure 3.8. Some considerations about this topics are made next.

- **Modeling and integration:** modeling and integration are cross-disciplinary concerns in enterprise engineering and are present throughout all periods. There are several works dealing with these two topics and they usually come in combination with the other topics, such as “process modeling” or “process integration”. However, there are some works specifically on modeling and integration, particularly the ones on modeling and integration methodologies [26], [27], [28], [29], [30].
- **Reference models:** works in this group discuss the creation and application of enterprise-wide reference models [15], [16], [31], [32], [33], [34], [35], [36]. The

application of these reference models to different domains and areas, such as product development [37], production planning [38], and production systems and processes [39], [40], [41]. The operationalization of reference models through the development of tools is also a theme [42], [43], [44], [45], [46], [47]. [7], [26], [48], [49].

- **Business processes:** the concept of business processes as the core element for modeling and integrating enterprises is discussed in works of this area [50], [51], [52], [53]. Business processes are also treated as part of reference models and enterprise architectures.
- **Ontologies:** in this topic, themes are related to researching ontologies as an aid in enterprise modeling and integration [54], [55], [56], [57], [58], and the application of ontologies to enterprise engineering problems of different domains, such as product development [59] and quality management [60].
- **Virtual enterprises:** themes in this topic are mostly related to modeling and implementation of virtual enterprises [20], [61], [62], [63], [64] and application of virtual enterprise technology to specific domains such as performance measurement [65] and quality management [66].
- **Interoperability:** themes are related to the role of interoperability in integrating enterprises both internally and with other enterprises [67], [68], [69] and practical aspects of interoperability, such as networks, protocols, systems and languages [20], [70], [71], [72].
- **Enterprise architectures:** works in this topic discuss the role of enterprise architecture in modeling and integrating enterprises [73], [74], [75], the use of architectures for enterprise integration and interoperability, such as Zachman's framework [76], [77], [78].

3.4 RESEARCH OPPORTUNITIES

Some research opportunities based on the analysis presented in the previous section are presented next. These opportunities are predominantly derived from the keyword co-use diagrams presented in Figure 3.7 and Figure 3.8, through analysis of missing and possible links and nodes, and from the evolution of the focus of research presented in Figure 3.10.

- *The relationship between enterprise architecture/integration and ontologies could be better defined:* there are no works that relate these two topics. Research could be undertaken to define the ontological representation of a set of enterprise architecture frameworks to determine their common aspects. Doing this would also help address interoperability issues among enterprises using these enterprise architectures.
- *The relationships between enterprise architecture/integration and virtual enterprises could be better defined:* although there are some works about the architecture of virtual enterprises aiming at their representation, there are no works that relate enterprise architectures to virtual enterprises. The design of virtual enterprises taking into account an enterprise architecture could also help addressing issues related to the interoperability of virtual enterprises.
- *Modeling languages in the context of interoperability and enterprise architecture:* although modeling languages for interoperability have already been created, they have not already been a focus of attention or research. Adapting these languages for handling the most popular interoperability and enterprise architecture frameworks could lead to their widespread use.
- *Relationship between structural organizational aspects and modeling:* there are many works dealing with modeling in the context of reference models, ontology, virtual enterprises and even information systems, though in a lesser number. However, there are no works that relate structural aspects of organizations, such as organizational structure, and its influence in modeling and integrating enterprises.
- *Design methods for enterprise engineering:* although design methods for enterprise engineering exist, they receive far less attention than the constructs that enable enterprise engineering and design. More research is needed in order to integrate different aspects of enterprise engineering in a coherent manner.
- *Verification and validation of interoperability and virtual enterprise frameworks:* Although interoperability and enterprise architecture frameworks exist, they have not been extensively verified and validated in the literature.
- *Increase the focus on tool development and application of enterprise engineering constructs*: reference models, ontologies, enterprise architectures, interoperability frameworks, all of these topics on enterprise engineering are created to be

applied to real world situations. The development of tools that enable their application and their application to different situations will provide information about their usefulness and utility.

3.5 CONCLUSIONS

The main objective of this work was to characterize the enterprise engineering research field and present some contribution areas to be explored in further works. This was accomplished by the analysis of the works published in the field until 2012, in a total of 282. It was found that:

- The number of publications in the area has peaked twice, the first time, in 1999, after a considerable amount of works on the development of reference models and the second time, in 2009, after a considerable amount of works on ontologies and virtual enterprises.
- Despite an initial concentration of publications in a few journals, the research field is becoming more diverse, with publications being distributed among more journals of different interest areas. The same is happening to the authors who publish works in the field.
- There is a core set of authors in the field that are frequently co-referenced in publications. This core group of authors published their works mainly in the first period (until 2000) and is mostly identified with conceptualizing the field.
- There is a core set of research topics and main topics have changed over time from reference models and business processes to ontologies and virtual enterprises to enterprise architectures and interoperability. Enterprise modeling and enterprise integration are underlying topics in all periods.
- Research in enterprise engineering is progressing to the development of tools and techniques towards the application of developed models and concepts to the solution of enterprise engineering problems.

Although care was taken in the selection of the works related to the field, the process is subjective. It must be noted that different interpretations may lead to different results. However, the authors believe that the general picture obtained is accurate and that even if different results are obtained, they will not greatly differ from the ones presented here. Major variation sources for the results presented may be: (i) the use of a different definition for enterprise engineering, which may lead to different search terms and a different set of works in the dataset; and (ii) the use of different reference databases, which may also result in a different set of papers in the dataset. The remainder of the method applied is straightforward and reliable and does not allow for much variation. The work could be further extended particularly in the analysis step and in the second phase. The analysis step could be enhanced by the use of the structural holes analysis technique from social network analysis in order for the main disruptions in the network to be identified, leading to the proposal of contribution areas to fill these holes. The second phase, as well as benefiting from this previous proposal, could also benefit from other analysis techniques, such as a specialists panels and brainstorming, with expert people from the field discussing future research directions and the importance of contribution areas.

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4 ARTICLE #2 – REVIEW OF CONTRIBUTIONS

This paper reviews the main contributions to the enterprise engineering research field from works selected from the analysis in Chapter 3. The relevance of this paper to the dissertation is that it aims at understanding contributions to the field and defining research opportunities. Some of the works revised are used in the development of the preliminary model for the guidelines in Chapter 5. Table 4.1 presents works whose results contributed to this article.

Table 4.1 – Works related to the review of enterprise engineering contributions whose results contributed to this article.

Revision	Notes
1	Work from the Process Mapping and Evaluation I and II courses taken in the first and second semesters of 2011.
2	Published in the Proceedings of the International Conference on Industrial Engineering and Operations Management 2012, held in Guimarães, Portugal, from July 9th to 11th, 2012.

Characterization of enterprise engineering contributions

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Abstract

One of the main concerns in enterprise engineering is the development of techniques and tools for organizational design, encompassing structure, information flow and process coordination. For this, the development of models and their application are core issues. Models for enterprise engineering and integration found in the literature deal with different aspects of organizational design - architectures, frameworks, methods and techniques. As these models abound, there is a need for their organization, enabling their application. This work addresses this problem by analyzing and characterizing the main contributions for enterprise engineering in the form of models. First, a review of these models is conducted including works from the late 1980s to the late 1990s, focusing on the development of enterprise-wide models and architectures, and from the late 1990s to today, focusing on the further development of models, architectures and their interoperability. Secondly, these models are characterized based on a set of six variables - primary literature reference, origin, tool support, application domain, concerns addressed and evaluation results. This characterization is then used to propose further research topics in the area, including the development of enterprise engineering methods incorporating an improvement and evolutionary perspective and a governance concern, the search for enterprise models for specific areas, the integration and application of interoperability frameworks and the need for proper enterprise engineering project management.

Keywords: enterprise engineering; process models; model characterization.

4.1 INTRODUCTION AND OVERVIEW

Enterprise engineering is a broad field of study – its main concern is the development of tools and techniques to be applied for business design, encompassing areas such as organizational structure, information flow and process coordination. It combines elements from different fields such as organizational sciences and information systems in order to unify and integrate those areas in a seamless manner, so that an enterprise can operate and mobilize its resources towards its goals (Hoogervorst, 2009). Enterprise engineering has developed significantly in the last decade.

Given this definition, enterprise integration and interoperability aspects can be considered key aspects in any enterprise engineering endeavor, playing a vital role. Both of these themes have received an increasing amount of attention in the last decade. Nevertheless, some open issues still exist and need to be addressed. Panetto and Molina (2008) describe five grand challenges to enterprise integration and interoperability in enterprise engineering: (1) collaborative networked organizations; (2) enterprise modeling and reference models; (3) enterprise and processes models interoperability; (4) validation, verification, qualification and accreditation of enterprise models; and (5) model reuse and repositories. More recently, Hvolby and Trienekens (2010) present another challenge in the application of existing frameworks to the development of business applications which support the operation of an enterprise. Vernadat (2010) also argues that although enterprise integration and interoperability are mature areas in the technical domain, they are still areas under development in the organizational and semantic domains.

One can conclude from these challenges that models, their definition and their application are one of the core points in enterprise engineering. Models that support enterprise engineering, enterprise interoperability and enterprise integration can be found in the literature for architectures, frameworks, methods and techniques (Chalmeta, Campos and Grangel, 2001; Chen, Doumeingts and Vernadat, 2008; Mertins and Jochem, 2005). Even some standards formally describe some of these models and their application (Chen and Vernadat, 2004; Kosanke and Nell, 1999). Additionally, processes are also among these core points. Process modeling, implementation and coordination are the basis for driving any enterprise engineering effort.

As these models abound, there is a clear need for their organization and characterization in order for them to be correctly applied. Some of the questions that arise when the application of a model is considered, among others, are: (i) in what level and context can they be applied; (ii) what is necessary for their application; and (iii) what is the basis for their correct application.

This paper tries to address this problem by characterizing and analyzing the main models used for enterprise engineering, enterprise integration and enterprise interoperability in a process related context. First, a review of the main models for the before mentioned areas is presented. Secondly, the characterization elements are presented and the models are characterized. Finally, conclusions and perspectives for future works are drawn.

4.2 REVIEW OF MAIN PROCESS RELATED MODELS

The models and ideas reviewed and presented here were found based on a literature research in the ACM Digital Library, Emerald, IEEE Xplore, Sicence Direct and Wiley Online Library, as well as conference proceedings from the IFAC (International Federation for Automatic Control). Only models based in an enterprise engineering approach, as previously defined in the introduction, were considered. Additionally, these works had to be process related, that is, their scope of work had to relate to a process context – mainly, the representation or support for process modeling, structuring or execution or the definition of what process areas should be considered.

Broadly speaking, the works studied can be categorized in two main phases. Phase 1 goes from the late 1980s until the late 1990s and is mainly concerned with the development of enterprise-wide models and architectures which can describe, in detail, how an enterprise should be organized and operate. Phase 2 starts in the late 1990s and has two main concerns: (i) the further development of the models and architectures by means of new modeling constructs, languages and methods and (ii) the interoperability of enterprise models. The following discussion will be started with some of the main models in the first phase: TOVE, CIMOSA, PERA, and GERAM.

Fox (1992) describes both a framework and a software tool to support the process of gathering organizational knowledge and representing it for further reference and visualization. His framework is based on the definition of a simple ontology, structured from the functional level of an organizational downwards. The aim of this ontology is to help describe organizational elements, among them processes and their interactions. The software tool was mainly used to model and visualize the ontology, applying it to a specific organizational context, not to implement the necessary processes for each functional level and orchestrate them. This work was later extended and the resulting extension called TOVE (TOronto Virtual Enterprise). TOVE is characterized by a methodology and set of meta-ontologies used to model enterprises (Fox, Gruninger and Zhan, 1994). This set of meta-ontologies was later specialized, so that it could model particular aspects of an enterprise, such as quality management systems and activity-based costing systems, and help enterprise models achieve conformance to regulatory standards (Kim, Fox and Segupta, 2007). TOVE also defines the Process Interface Format (PIF), a common language for the representation and interchange of process specifications that enables them to be reused in the modeling of different organizational contexts.

Sarkis, Presley and Liles (1995) presented a structured methodology for the strategic management of technology in an integrated manufacturing context. The methodology covered organizational, cultural, process and technological issues, being referred to by the authors as sociotechnical and was based on four main elements: corporate vision and management commitment, an enterprise reference architecture, tools for analysis and design and the methodology itself. The methodology was specified using a process notation (IDEF – Integration Definition for Function Modeling) and the main processes for it were: (i) develop vision and strategy; (ii) change culture; (iii) integrate and improve the enterprise; and (iv) develop technological solutions. The focus of such an approach, thus, relies on a strategy breakdown with the integration of the enterprise just another activity to be performed. This activity was detailed to be composed of four main processes: (i) understand the needs; (ii) design the system/solution; (iii) construct the system/solution modules; and (iv) implement a system solution. In this detailed model, there were no feedback loops to reinforce the fact that the system could evolve over time.

Extending the above mentioned methodology, Liles and Presley (1996) presented an enterprise modeling framework for enterprise engineering which is based on a five-view approach. They advocate that, as well as following the processes defined before, only through the use of these views is that an enterprise can be completely modeled. These views are the information view, the activity view, the business process view, the resource view and the organization view. These set of views were inspired in some of the more general models discussed in the sequence and are also influential to future works in the area.

Perhaps the best-known initiative in enterprise modeling is CIMOSA – Computer Integrated Manufacturing Open Systems Architecture (ESPRIT Consortium AMICE, 1993; Zelm, Vernadat and Kosanke, 1995, Kosanke, Vernadat and Zelm, 1999; Kosanke and Zelm, 1999). In the beginning of the 1990s, a consortium named AMICE (reverse for European CIM Architecture) was formed to develop the necessary infrastructure to facilitate the implementation of CIM – Computer-

Integrated Manufacturing systems. As well as an integrating infrastructure that supports the execution of a particular model, the consortium developed a generic modeling framework in order to generate these models. CIMOSA has three main dimensions. The views dimension is composed of the organization, resource, information and function views. The generic dimension is composed of the generic, partial and particular views. The life-cycle dimension is composed of the requirements definition, design specification and implementation description stages. The results of the consortium were later detailed in a series of publications.

Also in the early 1990s, the Purdue Enterprise Reference Architecture – PERA was proposed (Williams, 1994). PERA uses the concepts of enterprise elements (facilities, people and control and information systems) and enterprise phases (enterprise definition, conceptual engineering, preliminary engineering, detailed engineering, construction, operations, decommissioning and enterprise dissolution). PERA understands that anything in an enterprise, at a given point in time, can be described by the combination of elements in a given phase. The scope of PERA is to define an enterprise reference architecture that comprises the enterprise elements in each one of the enterprise phases. Although PERA is supposed to be generic, that is, applicable to organizations of any domain, it was developed with industrial organizations in mind.

In the late 1990s, an IFIP/IFAC task force on architectures for enterprise integration dedicated itself to the development of a generic enterprise reference architecture and methodology, the acronym for GERAM (Bernus and Nemes, 1996). GERAM started with the evaluation of the main existing enterprise integration frameworks at the time, such as TOVE, CIMOSA, GRAI/GIM and PERA. The idea was to create a meta-model for enterprise reference architectures and methodologies, described by an ontology that stated the main elements that had to be defined by them. This ontology covered eight main elements: (1) the GERA – Generic Enterprise Reference Architecture, which described the elements to be considered and applied in the process of generating the enterprise model; (2) the GEEM – Generic Enterprise Engineering Methodology, describing how to proceed in the application of the reference architecture and reference models in order to obtain a viable and implementable enterprise model; (3) the GEML – Generic Enterprise Modeling Language, describing what language and notation should be applied; (4) the GEMT –

Generic Enterprise Modeling Tools, describing the tools which could be used to construct enterprise models; (5) the OT – Onthological Theories, describing the basic properties and axioms which should be respected in modeling; (6) the GEMs – Generic Enterprise Models, describing models of particular aspects which could be reused in modeling; (7) the GMs – Generic Modules, describing technologies which could be readily applied in the implementation of the constructed model; and (8) the EMs – Enterprise Models, which described how the enterprise would operate. Some mappings of the previous enterprise models into GERAM were later developed, one example being that developed by Chen, Vallespir and Doumeingts (1998), which mapped GRAI/GIM into GERAM.

In the late 1990s, an ISA – International Society for Automation workgroup started its work in a standard to bridge the gap between enterprise and manufacturing control systems. The resulting work was published as ISA standard 95 and was later accepted as IEC standard 62264. This standard defines three sets of models to be used for specifying the integration between enterprise and control systems: a functional model, representing what are the main functions to be addressed by these models, an object model, defining what objects are relevant and activity models of manufacturing operations. These models are to be used as references for the instantiation of specific systems and should help in their development. For instance, the functional models are specified as dataflow diagrams, the object models as UML class diagrams and the activity models as UML activity diagrams.

Although extremely comprehensive in nature, all of the previously mentioned models, and particularly GERAM, defined ontologies for obtaining a particular model of an enterprise through the application of a set of predefined elements. It does not, however, define how one should implement the defined ontology or the elements by itself. Some initiatives tried to be more specific in the way the treated models, marking the start of the second phase of enterprise engineering efforts.

The ARDIN project was one of these initiatives (Chalmeta, Campos and Rangel, 2001). ARDIN is both an organized set of steps, reference models and tools to be applied to enterprise engineering and integration. ARDIN uses most of the concepts developed by GERAM and based on a discussion about methodology and modeling requirements for a complete enterprise architecture, it defines five dimensions for enterprise engineering: (i) support tools; (ii) an integration model; (iii) enterprise structures; (iv) a development methodology; and (v) a change management approach. It is perhaps the first project in the area to address change management concerns, although not already in a continuous improvement effort.

Another such initiative was IMEE – Integrated Methodology for Enterprise Engineering (Kim, Weston and Woo, 2001). IMEE in fact defines a set of models to be constructed in order for networks of enterprises to be modeled in three dimensions: function, information and behavior. For each dimension to be modeled, IMEE defines a set of straightforward steps and artifacts to be constructed. IMEE is mapped onto the CIMOSA framework, so that each CIMOSA construct has an equivalent IMEE construct.

The Zachmann Framework, originally proposed by Zachman (1987) and later extended by Sowa and Zachman (1992) is a form of classification of architectural elements used for modeling the architecture of an enterprise. The framework is built in the form of a six by six matrix, the rows representing the different architectural views and the columns representing the different architectural perspectives in each view. The views, from top to bottom are the scope (planner's view), the business model (owner's view), the information systems model (designer's view), the technology model (builder's view), the detailed specifications (subcontractor's view) and the functioning enterprise. The perspectives, from left to right are the data description (what), the function description (how), the network description (where), the people description (who), the time description (when) and the motivation description (why).

In the last several years, the area of enterprise interoperability has drawn attention and seen the development of frameworks for its development in the enterprise architecture domain. Interoperability frameworks were created as a means to reconcile the different views of diverse areas such as software engineering, computer science and industrial engineering (Vernadat, 2010). The four main interoperability frameworks are TOGAF – The Open Group Architecture Framework, the Levels of Information Systems Interoperability Reference Model, the ATHENA Interoperability framework and the European Interoperability Framework. These frameworks will not be discussed in detail here. What will be noted, however, is that all of them deal with the components and infrastructure necessary for different functions in an enterprise to interoperate, as well as for enterprises to interoperate. For a more in-depth discussion on enterprise interoperability, one can consult Kim et al (2006), Vernadat (2007) and Paneto and Molina (2008).

Hvolby and Trienekens (2010) classify yet other models as representative of a process related effort to enterprise modeling. They present SCOR (Supply Chain Operations Reference Model), CFPR (Collaborative Planning, Forecasting, and Replenishment) and other integrated specifications by the Open Architecture Group as such models. The authors also define the key elements of business systems integration as being information integration, workflow coordination and synchronized planning and argue that most of the enterprise systems used today by enterprises will be integrated into one process-based system. Application in different areas became more frequent in the last decade.

Another focus of research has been on the development of modeling languages which could be used for enterprise modeling and which could depict their main characteristics. There are many modeling languages that can be used to express different views of an organization – for instance, its structure, its behavior and its interfaces – and it is difficult to find a language that can bridge the gaps among all of these views (Anaya et al, 2010). Thus, other modeling languages were proposed to address these problems, such as UEML – Unified Enterprise Modeling Language, an specialization of UML – Unified Modeling Language. UEML and other proposed languages have in common the fact that they define a set of constructs that can help integrate different models for different views of an enterprise, constructing, thus, an unified understanding of it.

Ros, Fuente and Ortiz (2009) argue that most of the models and their application methodologies use a classical straightforward approach to designing and implementing enterprise entities. This approach, however, does not fit well into a continuous improvement effort, which the organizations must pursue given a competitive context. Thus, they propose that a cyclic reengineering approach should be used. For that, they build on the work of Berrah et al (2001). Berrah et al define seven phases for the reengineering project, naming it the cyclic reengineering method: (i) identification of the necessity within a given domain; (ii) strategic analysis of the given business entities; (iii) analysis of the organization of relevant business entities (as-is analysis); (iv) reengineering decision and planning of the to-be phase; (v) organization redesign (to-be analysis); (vi) implementation of the new organisation; and (vii) closing the project. The proposed methodology by Ros, Fuente and Ortiz, named ERE-GIO, is based on two phases. Phase one is the reverse engineering phase, which consists of three steps: (i) identification of the business entity, (ii) conceptualization of the business entity; and (iii) processes analysis (identification of the system, system description, as-is model specification and specification of the to-be model). Phase two is the forward engineering phase, which consists of seven steps: (i) action plan for change; (ii) processes definition; (iii) processes design; (iv) system implementation description; (v) system construction; (vi) system startup; and (vii) system dismantling. This approach was applied in the metal-mechanic industry, mainly for the reengineering of its supply chain processes (Fuente, Ros and Cardos, 2008).

Given this background, the next section will describe the approach used to characterize these works.

4.3 ANALYSIS AND CHARACTERIZATION OF PROCESS RELATED MODELS

The usual approach for classifying models, architectures and methodologies is to categorize them either in levels related to where they are applied (strategic or corporate level, management level, control level and shop-floor level, for instance) or in the set of elements or views they describe (structure, behavior and interfaces, among others). The approach sought by this work is neither of these.

The approach used for the characterization will be adapted from that used by Fettke, Loos and Zwicker (2005) for business process management models. Their approach was to survey the literature for reference models and characterize them according to three sets of information, each set containing a number of variables. The sets and their variables are: (i) general characterization set – name, primary reference, origin, responsibility for modeling, access and tool support; (ii) construction set – domain, modeling language, modeling framework, size, construction method and evaluation; and (iii) application set – application method, reuse/customization and use case. The characterization of this work maintains some of these variables, excludes or adapts others and includes new ones, as discussed next.

Name and primary reference are maintained so that the model can be referred to and further information for it can be consulted. Origin is maintained so that it is known if the model is derived from a scientific or a practical approach. Responsibility for modeling and access is excluded, as only open models are considered. Tool support is maintained so that it is known if there is computational support for its use, either commercial or implemented by the author or group that proposed the model. Domain is adapted into application domain, so that it is known what is the area for which the model can be applied (strategy, manufacturing, logistics and others). Modeling language and modeling framework are excluded, as both of these variables are treated in a new variable named concerns. Size is excluded because our interest rests on the characterization, not quantification of the models. The whole application set of variables is excluded, as the main information of this set is treated in the application domain variable. Finally, two new variables are added: (i) standard, in order to capture whether the model is defined in a standard published by any standardization body such as ANSI, ISO, ISA or ITC; and (ii) concerns, which is explained next.

The concerns variable represents the main problems the model addresses. Regarding this assertion, a model can be classified as a reference model, an architecture/framework, a methodology or a technique. It is a reference model if it establishes a set of elements to be considered in the modeling effort. It is an architecture/framework if it defines how the basic elements of the system are to be combined, integrated or interfaced. It is a method or defines a method if it describes the set of steps through which a process issue, like modeling, is to be resolved. Finally, it is a technique if it defines a technology to be used or categorizes technologies.

Table 4.2 of Appendix 4.1 summarizes the classification applied to the models of the models reviewed in the previous section.

4.4 CONCLUSIONS

To conclude this work, in first place, some of its limitations will be addressed. First, some observations about the characterization and further developments of the work are discussed.

The work is limited to the models found in the researched databases. More models could be added by either searching other databases for models which could meet the criteria to be included here – models that are both process related and aimed at an enterprise engineering context and by the analysis of proprietary models. Analyzing proprietary models, nonetheless, would require access to them, which may not be possible in some cases. Proprietary models also have limited applicability, as they would not be available to the general public.

Another limitation of this work is the classification used. The main objective was the characterization of models (i.e., to show characteristics of the model such as application area and main concern), not their categorization (i.e., to group each model into a specific category). Model categorization is extensively treated in other works. Nonetheless, the relationship between model characterization and model categorization could be better explored, so that a better characterization through the use of categorization could be reached.

With respect to further developments which could extend this work, there are four main areas to be noted: (i) the development of enterprise engineering methods which incorporate an improvement and evolutionary perspective; (ii) the search for enterprise models for specific areas; (iii) the integration and application of interoperability frameworks; and (iv) the need for proper enterprise engineering project management.

With regard to the development of enterprise engineering methods, it is noted that since the early 2000s, there has not been much discussion about this matter. Most of the works trying to address this question did so by applying a straightforward set of steps. An exception to this is the work of Ros, Fuente and Ortiz (2009), which is a development of earlier work by the same authors who tried to address the question about improvement in the process of enterprise engineering itself. This can be greatly enhanced, with novel contributions to the area, if a business process management life-cycle such as those described by Houy, Fettke and Loos (2010) were incorporated and adapted in the enterprise engineering process. Another point to be noted about the enterprise engineering method is that it should support the ever-changing nature of enterprises and should promote the evolution of models used and their instantiation into functioning elements. This could also be addressed by a business process management life-cycle and its adaptation.

In later years, there has been increased interest in the application of enterprise engineering concepts, particularly models, to different areas, specially those related to some kind of standardization such as quality management, occupational health and safety and the environment. Other traditional areas strongly influenced by process development also have seen increasing interest, such as strategy and performance measurement (Pun, 2004; Pinheiro de Lima, Gouvea da Costa and Reis de Faria, 2009; Costa et al, 2010). The main issue here is the creation of meta-models or meta-ontologies that can help the modeling and implementation of enterprises that have activities related to such areas or drive standardization efforts in them. This is also related to an increasing interest in knowledge representation of models and their reuse (Whitman and Huffman, 2009).

Interoperabillity frameworks, as quoted by Vernadat (2010), lie on the convergence vertex of three major areas: software engineering, computer science and industrial engineering. Computer scientists primarily deal with the technology necessary to implement such frameworks. Software engineers occupy themselves with the correct application of such constructs. Industrial engineers deal with the integration aspects of these frameworks so that they are correctly aligned and used to improve business goals. The technology behind this must be developed and validated by computer scientists and software engineers. Nevertheless, there are still open issues to be worked out when considering the application of the frameworks developed in the enterprise – mainly their validation and practical implementation aspects (Kim et al, 2006; Vernadat, 2007; Paneto and Molina, 2008).

The management of enterprise engineering projects is another issue identified as a gap in the literature. There is a very limited number of works that deal with this question. Although many authors are concerned with the development of models, interoperability, and the necessary technology and infrastructure, little attention has been dedicated to practical implementation aspects. Given an enterprise engineering project, there are many possibilities for its realization - for instance, one could aim to develop an information systems for manufacturing control or improve an existing quality management system in a service-oriented organization. There is great scope variance in such projects and the scope breakdown in activities and resources allocation, consequently, also varies greatly. In addition to this, different architectures and techniques that adequately treat the necessities of each of such processes will have to be employed.

As a final remark, in order to propose further development of this work, if one considers the Cambridge process approach (Platts, 1993) and its characteristics (Platts, 1994) – procedure, participation, project management and point of entry, it can be argued that many of the issues previously presented could be addressed by such an approach. Two issues that become clear in this analysis are the procedure and project management characteristics. The latter is clear from the analysis in the previous paragraph. The procedure characteristic, on the other hand, emerges when one considers that the different existing methods for enterprise engineering are still in early development stages, not yet properly tackling the problem and all of its complexities.

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APPENDIX 4.1

Table 4.2 - Characterization of process related models for enterprise engineering.

Number	Name	Primary literature	Origin	Tool support	Application domain	Concerns	Evaluation	Standard
1	TOVE	Fox (1992)	Scientific	Proprietary tool developed by the author and his group	Proposed to be general, but with applications to quality management systems and activity-based costing	Method	Models developed for quality management systems and activity-based costing	None
2	Sarkey, Presley and Liles approach to enterprise engineering	Liles and Presley (1996)	Scientific	Proprietary tool developed by the author and his group	General	Method	None	None
3	CIMOSA	ESPRIT Consortium AMICE (1993)	Scientific	Several, proprietary and open source	Computer-Integrated Manufacturing	Reference model	Served for the instantiation of several other models	None
4	PERA	Williams (1994)	Scientific	Proprietary systems developed case by case for its application	Industrial (manufacturing and process control)	Reference model	Application to some industrial domain problems	None
5	GERAM	Bernus and Nemes (1996)	Scientific	None	General	Method and architecture	Through the mapping of other frameworks into it	ISO 19439:2006
6	ARDIN	Chalmeta, Campos and Rangel, 2001	Scientific	None	General	Reference model, method and technique	Application to an industrial case by the authors	None

Number	Name	Primary literature	Origin	Tool support	Application domain	Concerns	Evaluation	Standard
7	IMEE	(Kim, Weston and Woo, 2001)	Scientific	Tools used to develop and construct the prescribed models	General, networks of enterprises	Method and technique	Application to an industrial case by the authors	None
8	IEC 62264/ISA 95	ISO/IEC 62264 and ISA 95 standards	Scientific and practical	Some tools to support modeling, specially the required prescribed models	Enterprise and control systems integration	Reference model	Applied to a wide variety of cases in the industrial domain	IEC 62264/ISA 95
9	Zachmann Framework	Sowa and Zachman (1992)	Practical	Several tools to model each construct defined by the framework	Information systems and enterprise architecture	Technique	Several cases of application	None
10	TOGAF and other architecture frameworks	Proprietary specifications of each framework	Practical	Some proprietary tools	Enterprise architecture	Architecture	Several cases of application	None
11	UEML	Anaya et al (2010)	Scientific	Open-source tool	Enterprise models in general	Technique	Examples and case studies	None
12	Cyclic reegineering method	Berrah et al (2001)	Scientific	None	General	Method	Unkown	None
13	ERE-GIO	Ros, Fuente and Ortiz (2009)	Scientific	None	General	Method	Applied in a metal-mechanic industry	None

5 ARTICLE #3 – DEVELOPMENT OF ENTERPRISE ENGINEERING GUIDELINES

Article #3 presents: (i) the preliminary model for the guidelines developed from the contributions to the enterprise engineering research field identified in the characterization of the research in Chapter 3 and the review of contributions in Chapter 4; and (ii) the initial model for the guidelines developed from the Delphi study conducted with experts in the enterprise engineering research field. Table 5.1 presents works whose results contributed to this article.

Table 5.1 – Related works whose results contributed to this article.

#	Notes
1	Work from the Independent Study course taken in the first semester of 2012, organized the references for the development of the guidelines.
2	First version of the paper, with the preliminary model, published in the Proceedings of the Industrial and Systems Engineering Research Conference 2013, held in San Juan, Puerto Rico, from May 18th to 22nd. This preliminary model was later adjusted based on the Delphi study.

Enterprise Engineering Guidelines for Enterprise Engineering Initiatives: a Delphi Study

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Abstract

Enterprise engineering initiatives have been focused on the application of enterprise-wide reference architectures and models for organizational design. The application of such models, although usually straightforward, has found some barriers related to the existence of an established enterprise structure (mainly represented by collections of processes and resources) that is already adapted to a specific business context, making change difficult in most cases. There is a need for a more general framework to guide these initiatives. This work addresses this issue by proposing a set of guidelines to be used for diagnosing and (re)designing organizations. The method for generating these guidelines is comprised of two steps, with analysis of different information sources and expert input. In the first step, the existing literature on enterprise engineering was analyzed and searched for contributions that could be synthesized in statements to form a preliminary set of guidelines. Reference models, performance excellence models, and enterprise transformation frameworks were also analyzed in this step in search for support of the guidelines, their components and categorization. In the second step, a Delphi study with experts in enterprise engineering was conducted to obtain feedback on the guidelines. After two rounds of the Delphi study, an initial model for the guidelines was developed, which can be tested in application projects. Perspectives for the refinement and application of these guidelines to the diagnosis and (re)design of organizations are drawn.

Keywords: Enterprise engineering, enterprise engineering guidelines, enterprise diagnosis, enterprise redesign.

5.1 INTRODUCTION

Enterprise engineering is a multidisciplinary field of study, involving knowledge in diverse areas such as organizational sciences, information technology and industrial engineering [1], [2], [3]. It deals with the design and implementation of either entire organizations or organizational subunits. One of its main foci is on processes and how they are conceived, deployed and executed, as well as on their interaction within an organization and with external entities [4].

In previously published work [5][1], the following research areas were characterized as being relevant to the enterprise engineering research field: modeling and integration as underlying topics and reference models, business processes, virtual enterprises, ontologies, enterprise architecture and ontologies as specific topics. There are several contributions from different authors with different backgrounds to these areas. These contributions include diverse constructs such as tools, procedures, techniques, methods, and methodologies for process design, deployment and execution [2]. Some contributions try to develop general reference models to be used for modeling organizations of any size and industry [6], [7], [8].

Most of these constructs were developed from the early 1990s until today, focusing on different enterprise engineering aspects such as modeling, architecture, ontologies, implementation, and interoperability [9]. It is not unusual for these constructs to be prescriptive and determine a set of restrictions or steps that have to be observed, being also, in some cases, partially applied or even combined. The application of such constructs has found some barriers related to the existence of established enterprise structures already adapted to specific business contexts, mainly represented by collections of processes and their resources, making change difficult in most cases. The question then is whether there is a set of higher-level guiding principles that may be observed in the application of any of these constructs, i.e., are there recommendations that are general enough to serve as universally applicable guiding principles for any enterprise engineering initiative?

This work addresses this issue by proposing a set of enterprise engineering guidelines to be used for diagnosing and (re)designing organizations. In the context of this work, a guideline is defined as a recommended enterprise design practice or principle that allows some discretion in its interpretation, use, or implementation. An enterprise engineering guideline is defined as an enterprise design practice or

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[1] This reference is one of the works whose results lead to article #1. In this paper, results that reflect modifications incorporated in article #1 are used.

principle related to the definition, structure, design and implementation of enterprise operations as communication networks of business processes, which comprise all their related business knowledge, operational information, resources and organizational relationships.

As noted, two dimensions are addressed by the guidelines: diagnosis and (re)design. The diagnosis dimension takes into account the fact that the guidelines can be used to assess an organization or organizational unit as to how well it is structured and operates through its structure. The (re)design dimension, on the other hand, takes into account the fact that guidelines can be used to promote change and that a new organizational system is generated that should operate according to them. Both of these dimensions must be kept in mind in the process of defining the guidelines.

This paper is organized as follows: in the next section, the research method applied for creating the guidelines is explained. Section **Error! Reference source not found.** briefly presents some of the most relevant foundations used in this process. In section 5.4, the preliminary set of guidelines is presented and discussed and the relationships among them are shown and explained. Section **Error! Reference source not found.** describes the results of the Delphi study conducted with experts in the enterprise engineering field and proposes the revised set of guidelines. Finally, in section 5.6, conclusions are drawn for the further development of the guidelines and their application as both design and diagnosis principles.

5.2 RESEARCH METHOD

This work used a two-step approach for building, refining and consolidating the enterprise engineering guidelines. These steps are described next.

- *Step #1:* Works analyzed in previously-performed characterization of the enterprise engineering research field [5][2] and systematic literature review on enterprise engineering [9][3] were reviewed in order to determine whether they should be considered for the extraction of recommendations that could lead to the statement of guidelines. Thus, 282 published works in the enterprise engineering field were screened for recommendations that met the following criteria:

[2] See footnote 1.

[3] This article is one of the works whose results lead to article #2. In this article, results that reflect modifications in article #2 are used.

1. *A recommendation should be derived from the synthesis of the literature review of the work, from the results of the work and/or from its conclusions – that is, a recommendation should represent either revised or new knowledge.*
2. *A recommendation should be applicable to as many different enterprise engineering initiatives as possible. This means that a guideline should not be restricted to a particular tool, technique, method, procedure, methodology, or organizational context and that it should address design, analysis and implementation. Its statement should also be as general as possible.*

A table was created in which all recommendations found were listed with their references. Recommendations addressing the same issues were later grouped together and once more reviewed. Finally, statements were written to reflect the general idea of the recommendations in each group, forming the first version of the guidelines. Guidelines were then classified according to the main issue addressed, whether context, process or structure, in a derivation of Pettigrew's framework [10, 11].

Step #2: After compilation of the first version of the guidelines from the recommendations, reference models related to enterprise engineering mentioned in the works used to perform the systematic literature review were studied. Most of these reference models can also be found in another published work [9][4]. These models were screened for: (i) checking for the consistency of the guidelines with models already being applied; (ii) improving the framing of the guidelines in order to better reflect the original statements; and (iii) checking whether new guidelines could be derived from the grouping of commonalities among the reference models. Some of the main performance excellence models and the enterprise transformation literature were also reviewed with the same objectives. This analysis resulted in a second, updated version of the statements to be used as a preliminary set of guidelines.

- *Step #3:* The statements in the preliminary model for the guidelines were used as input for a Delphi study [12] conducted with experts in the enterprise engineering research field identified through previous work on its characterization [5][5]. The

[4] See footnote 3.

[5] See footnote 1.

objective of the Delphi study is to allow for the knowledge of experts in the area to be captured, so that their agreement with the statements as guidelines could be assessed and other suggestions could be identified, either for rephrasing a guideline or developing new ones. The Delphi study conducted here is classified as a modified e-Delphi according to Hasson's framework [13], given that it started with a set of already compiled results as its inputs and was administered through a Web survey. After two rounds, a refined set of guidelines resulted from this study.

5.3 BACKGROUND

This section discusses the foundations for the preliminary set of guidelines discussed in the next section. These foundations are presented for each one of the information sources listed in the first step, starting with the enterprise engineering literature.

5.3.1 Enterprise engineering literature

The enterprise engineering literature was the primary source for the recommendations that led to the development of the guidelines. As mentioned in the introduction, there are many different contributions to this area. Although 282 papers were reviewed, only 32 had recommendations which could be used as sources for guidelines according to the definition in this work.

Most of the works containing recommendations suited for the statement of guidelines are either derived from observations about the application of reference models or the discussion about how different methods, tools and procedures should be applied.

Some characteristics of the enterprise engineering literature that stand out and can be contrasted to the other sources that will be presented next are that most of the reference models do not incorporate an improvement approach to enterprise engineering – that is, they do not view an enterprise engineering initiative as a set of closed-loop actions that could lead to successive improvements in performance by changing structure, process or context, despite the concern for improvement stated in some of the enterprise engineering definitions.

5.3.2 Enterprise engineering reference models

During the review of the enterprise engineering literature, the important role played by reference models became evident. Although not directly suited for recommendations, works dealing with reference models can contribute to the statement of guidelines by either providing elements that support them or helping in their clarification, specifically in what concerns the terminology used.

A number of different enterprise engineering reference models have been developed over the last two decades. Some of these are GIM (GRAI Integrated Methodology) [14], TOVE (TOronto Virtual Enterprise) [15], CIMOSA (Computer-Integrated Manufacturing Open-Systems Architecture) [6], [16], [17], [18], [19], PERA (Purdue Enterprise Reference Architecture) [7], and GERAM (Generic Enterprise Reference Architecture and Methodology) [20]. Table 5.2 summarizes these models and their main characteristics such as the key concern of the reference model (whether it presents a structured method for enterprise engineering or a set of modeling constructs to be applied), the existence of tool support, the application domain, and main components [9].

Most of these reference models are very prescriptive, defining models, their elements and how these should be used. There are some results related to their application to real-world enterprise systems, especially CIMOSA [21], [22], [23], [24], [25], [26], [27], [28], which is the most well-known reference model of these. Perhaps one of the most interesting reference models is GERAM, which defines a generic enterprise reference architecture. GERAM is very comprehensive and most of the other reference models can be mapped into its elemental ontology.

Table 5.2: Summary of enterprise engineering reference models.

Reference Model	Key concern	Tool support	Application domain	Main components
GIM [14]	Method	None	Computer Integrated Manufacturing (CIM)	Global model, describing the invariant parts of an enterprise system; a modeling framework with formalisms to represent the physical and functional aspects of a system and a structured approach to guide the application of the methodology
TOVE [15]	Method	Proprietary tool developed by the author and his group	General, with applications to quality management	Methodology and set of meta-ontologies used to model enterprises
CIMOSA [6], [16], [17], [18], [19]	Models	Proprietary and open source tools	Computer-Integrated Manufacturing (CIM)	Views dimension (organization, resource, information and function elements), generic dimension (generic, partial and particular elements) and life-cycle dimension (requirements definition, design specification and implementation description stages)

Reference Model	Key concern	Tool support	Application domain	Main components
PERA [7]	Models	Proprietary systems developed for each application	Industrial (manufacturing and process control)	Enterprise elements (facilities, people and control and information systems) and enterprise phases (enterprise definition, conceptual, preliminary and detailed engineering, construction, operations, decommissioning and dissolution)
GERAM [20]	Method and Models	None	General	Meta-model for enterprise reference architectures and methodologies described by an ontology composed of eight main elements

It is also worth noting that these reference models are the ones most frequently appearing in the enterprise engineering literature, with extensive documentation. Other frameworks and extensions to these reference models exist [29], [30], [31], [32] but were not used in this work.

5.3.3 Performance excellence models

Nowadays, the concern with performance excellence is present in most organizations and performance excellence models help organizations in seeking excellence. Performance excellence models first appeared as a response to quality demands on products and services by customers and have evolved to address the concept of organizational performance management in later years [33]. This is a continuous process that must be incorporated into everyday activities.

Performance excellence models, thus, are strongly related to enterprise engineering. First, as enterprise systems are (re)designed and implemented, they must address the criteria for excellence defined to be relevant to the organization. Secondly, both performance excellence criteria and enterprise engineering guidelines can be understood as requirements, the first for performance excellence and the later for the soundness of the structure and processes of an enterprise. Both of these points justify the inclusion of performance excellence models as supporting sources for the enterprise engineering guidelines presented in this work.

Three performance excellence models were reviewed: the Baldrige Criteria for Performance Excellence [34], the European Foundation for Quality Management Excellence Model Criteria (EFQM) [35] and the Brazilian Management Excellence Model Criteria (PNQ) [36]. Table 5.3 summarizes the main characteristics of these excellence models.

Table 5.3: Summary of performance excellence reference models.

Name/Primary Literature	Key aspects	Fundamental concepts
Baldrige [34]	Leadership; strategic planning; customer focus; measurement; analysis and knowledge management; workforce focus; operations focus; and results	Criteria: products and processes; customers; workforce; leadership and governance; and finance and markets. Focus is on common needs not common procedures and on results, not procedures, tools or structure
EFQM [35]	Leadership; strategy; people; partnerships and resources; processes, products and services; customer results; society results; and business results	Sustaining outstanding results; adding value for customers; creating a sustainable future; developing organizational capabilities; harnessing creativity and innovation; leading with vision, inspiration and integrity; managing with agility; and succeeding through the talent of people
PNQ [36]	Leadership; plans and strategies; customers; society; information and knowledge; people; processes; and results	Systemic thinking; organizational learning; innovation culture; leadership and purpose; process orientation and information; future vision; value creation; value of people; knowledge about the client and the market; and partnership development and social responsibility

All three of these models have common aspects and, in general terms, provide a framework for aligning the operation of an enterprise to its goals while maximizing its results, minimizing its impacts and guaranteeing that the right resources will be available at the right time.

5.3.4 Enterprise transformation literature

Enterprise transformation is a research area concerned with the fundamental changes through which an organization undergoes in order to modify how it interacts with some key aspects of its operation [37]. These aspects include, but are not limited to strategy, products, customers, organizational structure and processes, among others. Enterprise transformation deals with the response of an enterprise as a complex system, to radical changes in context [38].

Enterprise transformation, in this sense, is related to enterprise engineering in that both deal with change. Whereas enterprise engineering initiatives sometimes do not encompass a fundamental change (when they deal, for instance, with simple process improvements), in some cases they can be thought as a part of a larger transformation project. When this happens, these initiatives can benefit from the approaches in the enterprise transformation literature developed to address issues presented by these fundamental changes.

Two different frameworks for enterprise transformation were analyzed in the context of this work in order to support the proposed guidelines. In Rouse's framework [37], the source for the transformation comes from one of the elements in the enterprise context: the economy, the market, the enterprise, or the intraprise. Given the context, the ends, the scope, and the means must be defined and a ten-step methodology applied. These steps are: stimulate need for change; identify value deficiencies; map deficiencies to work processes; (re)design work processes; assess required investments; frame, make and commit to decisions; plan implementation of change; execute via enterprise social networks; monitor and adapt plan implementation; and institutionalize change. In Nightingale's framework [37, 38], called the Lean Enterprise Transformation Roadmap, any transformation should make use of seven principles through the consideration of seven architectural views. The principles are: adopt a holistic approach to enterprise transformation, identify relevant stakeholders and determine their value propositions; focus on enterprise effectiveness before efficiency; address internal and external enterprise interdependencies; ensure stability and flow within and across the enterprise; cultivate leadership to support and drive enterprise behaviors; and emphasize organizational learning. The seven views are strategy, policy/external environment; process; organization; knowledge; information; product and services. For this to be possible, these principles and views were incorporated into an eight-step cycle. These steps are: determine strategic imperative; engage leadership to transformation; understand current state; envision and design future enterprise; align enterprise infrastructure; create transformation plan; implement and coordinate transformation plan and nurture, process and imbed lean enterprise thinking.

It can be noted that both of these approaches are concerned more with how change is going to be conducted and the elements for a successful implementation of change than with the content of change itself. In contrast, it can be argued that most of the enterprise engineering reference models presented in Table 5.2 are concerned with the content of change.

5.4 PRELIMINARY SET OF GUIDELINES

Table 5.4 presents the 12 guidelines extracted from the literature and other references using the method described in Section 2. As well as numbering and stating them, the references from which recommendations for the statement of the guidelines are also listed, as well as the supporting source (enterprise engineering reference models (EERM), performance excellence models (PEM), and enterprise transformation literature (ETL)) and their categorization. Some of the aspects of these guidelines are explained next.

Table 5.4: Proposed enterprise engineering guidelines, references, supporting sources and categorization.

#	Guideline	Recommendation references	Supporting Source	Category
1	Process design and execution must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)	[29], [41], [42], [43], [44]	PEM, ETL	Context
2	People involved in a process must participate in its design	[29], [42]	PEM, ETL	Context
3	Processes must be clearly defined (e.g., objectives, roles, responsibilities, capabilities, performance, information and interfaces)	[41], [43], [45], [46], [47]	EERM, PEM	Structure
4	Capabilities of resources in a process must be aligned with expected process performance	[41], [43], [46], [48]	PEM	Structure
5	Information structure must be based on open standards to ensure interoperability with different systems	[45], [49]	EERM	Structure
6	Specifications for the interface channels within a process value chain must be defined	[29], [47]	EERM, PEM	Structure
7	Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared throughout the organization and its value chain	[47], [50]	PEM	Process
8	Processes must explicitly support management/control (e.g., synchronization, decision-making, delegation and coordination) within a process and with other processes	[45], [47], [50], [51], [52]	EERM	Process
9	Process design must address different types of exceptions	[47]	PEM	Process
10	Process design and execution must incorporate mechanisms for change/improvement detection/management	[29], [47], [52]	PEM	Process
11	Process semantics must be coherent and consistent throughout all processes	[42], [46], [47], [53], [54]	EERM	Structure
12	Information related to the performance of the process and the organization must be collected	[46], [52]	PEM	Process

1. *Process design and execution must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people).* This is a recurring point in works suggesting how to proceed in the modeling and implementation of enterprise systems and is strongly supported by performance excellence models and the

enterprise transformation literature, which define this alignment as one of the basic conditions for both excellence and change.

2. *People involved in a process must participate in its design.* Also a recurring point in works suggesting how to proceed in the modeling of enterprise systems, this is supported by the involvement of people as a principle in most excellence models and by the engagement of people in enterprise transformation initiatives.

3. *Processes must be clearly defined (e.g., objectives, roles, responsibilities, capabilities, performance, information and interfaces).* Recommendations for this guideline derive from works related to the application of modeling techniques to enterprise design problems. Reference models support this guideline by prescribing the use of different elements to formalize several aspects of an enterprise, as noted in Table 5.2. Process definition is also a key aspect of excellence models for the proper operation of an enterprise to be achieved.

4. *Capabilities of resources in a process must be aligned with expected process performance.* This guideline is also derived from recommendations in works dealing with modeling enterprise systems. This guideline is supported by excellence models, in which alignment of organizational resources to organizational goals is a key aspect.

5. *Information structure must be based on open standards to ensure interoperability with different systems.* Interoperability has been one of the key aspects of enterprise engineering in more recent years. The use of open standards is a strong catalyst to interoperability, as it ensures that both parties involved in an exchange will have the same information structure, facilitating it. Enterprise reference models are open-standards per se and most of them have information as one of their standardized elements.

6. *Specifications for the interface channels within a process value chain must be defined.* This guideline results from recommendations regarding exchanges occurring among different actors participating in a process. The way these exchanges are supposed to happen should be documented. Support for this guideline is provided by both reference and excellence models. Reference models usually establish this as part of the necessity for documentation. Excellence models emphasize the relationships among processes and the

definition of rules to be applied anytime processes interact, even when outside the organization.

7. *Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared throughout the organization and its value chain.* As well as being documented, these elements must be shared, that is, so that continuity and improvement can occur. This is supported by the continuous improvement principle in most excellence models.

8. *Processes must explicitly support management/control (e.g., synchronization, decision-making, delegation and coordination) within a process and with other processes.* Recommendations related to these guidelines come from modeling and implementation works that state the need to establish process flow and the roles each part play in the execution of a process. Enterprise reference models support this as they include how processes should interact and be managed/controlled.

9. *Process design must address different types of exceptions.* There should normally be no exceptions during process execution, but when an exception happens, a procedure for dealing with it must have been established. This is supported by excellence models, which suggest that mechanisms for dealing with unexpected or unresolved issues should be in place.

10. *Process design and execution must incorporate mechanisms for change/improvement detection/management.* Change and improvement have been issues rising in importance in later works in enterprise engineering . Works with recommendations related to these guidelines usually observe that most enterprise engineering methods, tools, or techniques do not incorporate change/improvement mechanisms. This guideline is supported by excellence models, which strongly advocate for the incorporation of change/improvement mechanisms in all levels of the organization, including their processes.

11. *Process semantics must be coherent and consistent throughout all processes.* For a process to be consistently executed, proper terminology must be used among all processes and throughout the life cycle of a process. This enhances communication and the interaction among involved people. This guideline is

supported by most reference models, which establish these semantics in their definitions.

12. *Information related to the performance of the process and the organization must be collected.* Works with recommendations related to this guideline state that in order for performance to be a concern – see guidelines 1, 4 and 10 – information for its assessment must be gathered. This is strongly supported by excellence models, for most of which the collection of information for performance measurement is a foundation.

It can be noted that most of the guidelines have processes as their base element. This can be understood by the fact that processes are a central concern in enterprise engineering and that most of the models, frameworks, architectures and similar constructs have processes as a foundational element. Business processes are also one of the main topics of research in enterprise engineering [5], [9].

Although it might seem, at a first glance, that these guidelines are unrelated or weakly linked,

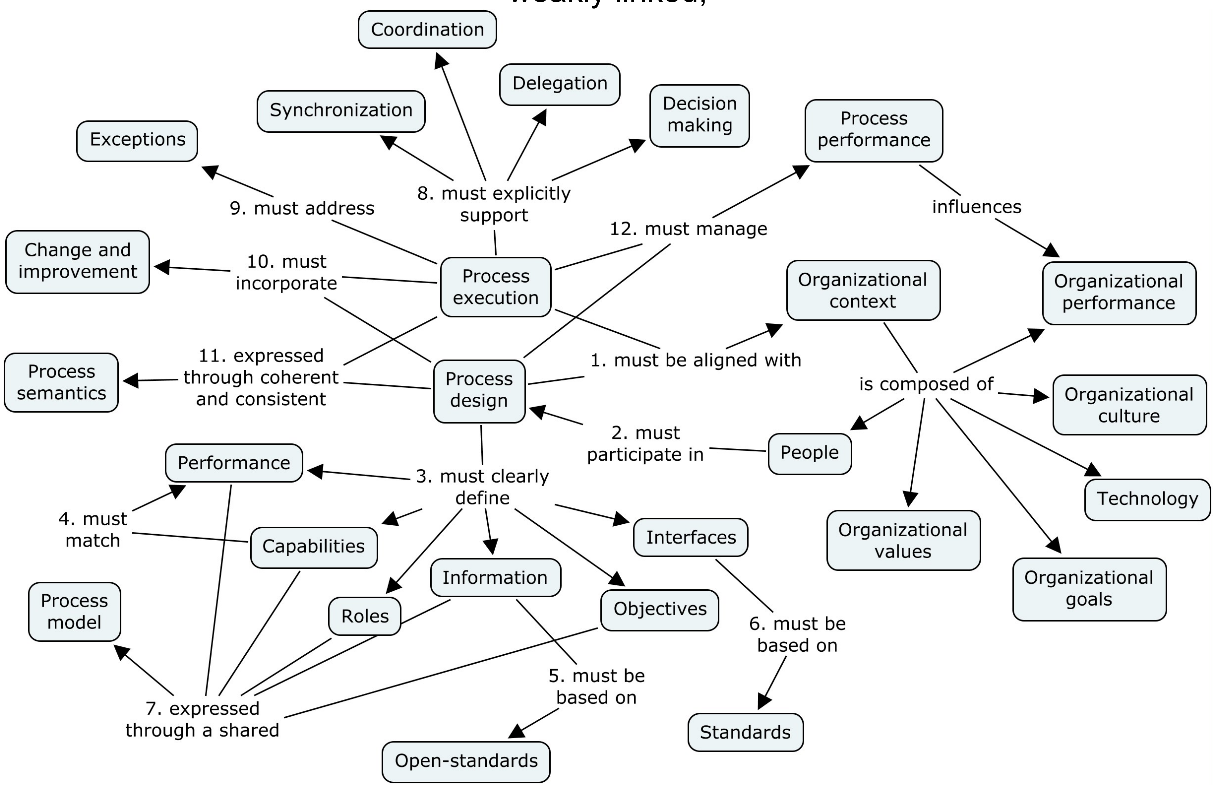

Figure 5.1 shows otherwise. This is a concept map [55] built from the guidelines, depicting their main constructs and relationships. It may be noted, through the analysis of this map, that guidelines are strongly coupled and that the relationships that appear sometimes cross the boundaries of a single guideline. For instance, if the

elements of guidelines 3, 4 and 7 are combined, it may be stated that process design must clearly define capabilities matching performance, and both of these must be expressed through a shared process model.

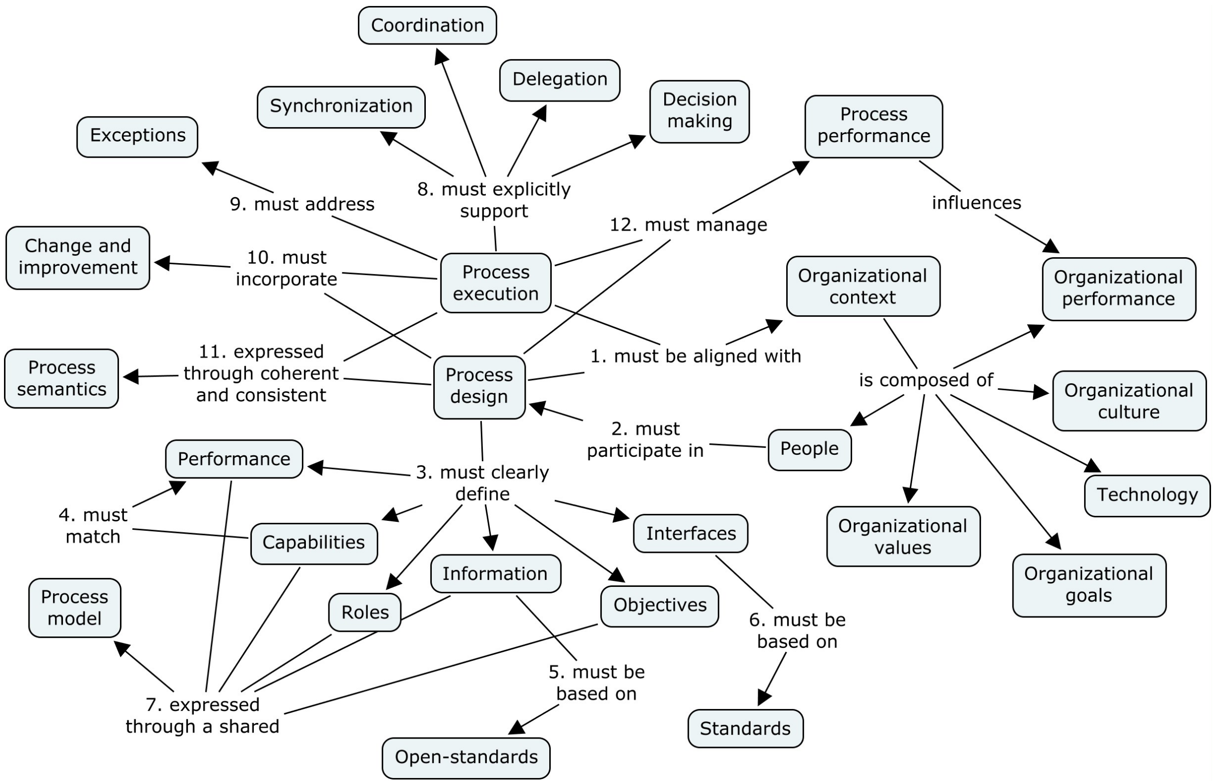

Figure 5.1: Concept map depicting the proposed preliminary version for enterprise engineering guidelines and their main constructs.

5.5 INITIAL SET OF GUIDELINES

For the refinement of the preliminary model for the guidelines, a Delphi study was conducted with experts in the enterprise engineering research field, as already mentioned previously. Invited experts were identified in previous work [5] and were chosen among authors with the largest number of publications in the field and those most cited. Invited authors can be seen in Table 3.3.

Table 5.5 – Experts in enterprise engineering invited to participate in the Delphi study.

Weston, R.H.	Chen, D.	Chatha, K.A.	Morel, G.
Vernadat, F.B.	Doumeingts, G.	Gruninger, M.	Panetto, H.
Harding, J.A.	Gabbar, H.A.	Kamsu-Foguem, B.	Sarkis, J.
Ortiz, A.	Ros, L.	Kim, K.	Shimada, Y.
Kim, C.H.	Ajaefobi, J.O.	Kosanke, K.	Suzuki, K.
Bernus, P.	Chapurlat, V.	Lario, F.C.	Zelm, M.
Berio, G.	Boucher, X.	Bruno, G.	Caplinskas, A.
Cuenca, L.	Jochem, R.	Jonker, C.M.	Liles, D.H.
Noran, O.	Pascoa, C.	Popplewell, K.	Presley, A.
Hoogervorst, H.	Dietz, J.L.G.	Molina, A.	Fox, M.S.

The Delphi study consisted of two rounds, both of them operationalized through a web survey. In the first round, experts were asked to rate their agreement with the guidelines presented in section 5.4 according to a six-point scale (strongly disagree, disagree, somewhat disagree, somewhat agree, agree and strongly agree). If their rating was on the disagreement part of the scale, the expert was presented with some alternative versions of the guideline and asked to rate his agreement with these alternative versions. Respondents were also presented with a text box in which they could explain the reasons for disagreeing with the original or alternative versions of the guideline. At the end of the survey, a text box for general comments or remarks, including the proposal of new guidelines was provided. After compilation of the results, guidelines were adjusted and a report with the summary of the results was generated. This report was made available to the experts in the second round of the research and once again, experts were asked to rate their agreement with a revised version of the guidelines according to the six-point scale. If their rating was on the disagreement part of the scale, the expert was presented with a text box to explain the reasons for disagreeing. Results were compiled and sent to the experts.

Sixteen experts participated in the first round of the study (for a response rate of 35%) and 13 participated in the second round. Each of the rounds of the Delphi study is discussed next.

5.5.1 Characterization of Participants

Characterization of participants was accomplished through the use of three dimensions derived from Boyer's model for scholarship [56]: research, application and teaching. Respondents were asked to identify the number of years they have been involved in each one of these dimensions and also to estimate the number of publications they have authored, application projects they have participated and courses they have taught. Results for this characterization can be seen in Table 5.6 and Table 5.7.

Table 5.6 - Characterization of Delphi study participants in terms of years of experience in research, application and teaching.

	Number of years		
	Conducting research	**Participating in application or consulting projects**	**Teaching**
Does not take part in such action	0 (0.0%)	2 (12.5%)	0 (0.0%)
Less than 2 years	0 (0.0%)	1 (6.3%)	0 (0.0%)
From 2 to 5 years	0 (0.0%)	3 (18.8%)	5 (31.3%)

From 5 to 10 years	7 (43.8%)	2 (12.5%)	1 (6.3%)
Over 10 years	9 (56.3%)	8 (50.0%)	10 (62.5%)

Table 5.7 - Characterization of Delphi study participants in terms of number of works authored, projects and courses.

Number of					
Journal articles and conference papers		**Application or consulting projects (other than research projects)**		**Courses**	
Less than 10	3 (18.8%)	*Less than 5*	3 (21.4%)	*Less than 2*	2 (12.5%)
From 10 to 19	1 (6.3%)	*From 5 to 9*	5 (35.7%)	*From 2 to 4*	6 (37.5%)
From 20 to 49	6 (37.5%)	*From 10 to 19*	3 (21.4%)	*From 5 to 9*	4 (25.0%)
More than 50	6 (37.5%)	*More than 20*	3 (21.4%)	*More than 10*	4 (25.0%)

It can be seen, from these tables, that respondents have a strong background in all three dimensions. There are more than 50% of respondents with over 10 years of experience in each of the dimensions, and, in particular, all respondents have more than 10 years of experience in research. Additionally, more than 50% of respondents have published more than 20 works in journals and conferences and more than 50% of participants have taught more than 5 courses in enterprise engineering. This analysis provides evidence that participants in the Delphi study may be considered experts in the area.

5.5.2 Round 1 Results

Results for the agreement of participating experts with the preliminary set of guidelines are presented in Table 5.8. This table shows the guideline number (#), as referenced in Table 5.4, and the rating for each one of the 16 experts that participated in the first round, labeled A through P. The mean value, standard deviation and inter-rater reliability (IRR) for that guideline, according to the model proposed by James *et al* [57] are also presented.

Table 5.8 – Results for the agreement rating in the first round of the Delphi study.

#	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Mean	Standard deviation	IRR
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6.00	0.00	1.00
2	6	5	5	5	6	5	4	5	5	6	6	6	5	5	3	6	5.19	0.81	0.78
3	6	5	4	5	6	6	5	6	5	4	5	6	6	5	6	5	5.31	0.68	0.84
4	5	5	5	5	6	6	5	6	5	5	6	6	6	6	6	6	5.56	0.50	0.92
5	4	5	4	4	6	4	3	5	4	6	5	5	6	3	3	4	4.44	1.00	0.66
6	4	5	4	5	5	5	5	1	5	5	5	6	5	3	6	6	4.69	1.21	0.50
7	5	5	4	5	4	6	5	1	5	5	5	6	5	5	6	4	4.75	1.15	0.55
8	6	5	4	5	5	6	4	6	5	4	6	6	6	6	6	6	5.38	0.78	0.79
9	5	5	5	6	6	6	5	1	5	5	5	6	5	5	5	5	5.00	1.12	0.57
10	6	5	5	5	6	4	4	6	5	6	5	6	6	6	6	6	5.44	0.70	0.83
11	5	5	6	6	6	5	5	6	5	6	6	4	6	6	6	5	5.50	0.61	0.87
12	5	5	6	5	6	6	5	6	5	5	6	6	6	6	6	5	5.56	0.50	0.92

Note: The rating scale is 1 – strongly disagree, 2 – disagree, 3 – somewhat disagree, 4 – somewhat agree, 5 – agree and 6 – strongly agree.

Most of the guidelines have a high mean agreement score, over 5. The exceptions are guidelines #5, #6 and #7, although the mean still reflects agreement (over 4). Guidelines with an IRR below 0.8 (80% agreement in the mean score) were considered for revision. From lowest to highest IRR, these are guidelines #6 (0.50), #7 (0.55), #9 (0.57), #5 (0.66), #2 (0.78) and #8 (0.79).

- *Guideline #6: Specifications for the interface channels within a process value chain must be defined* – comments related to the disagreement with this guideline are associated with the fact that the wording "process value chain" is confusing, i.e., only process or processes should be used, emphasizing the fact that relationships of processes with external entities related to them must be properly defined. The interface channels of the process might be internal or external entities, such as systems or even other processes.
- *Guideline #7: Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared throughout the organization and its value chain* – it was commented, once again, that the term "value chain" is too vague and confusing and that the phrasing of the guideline could end in the word "sharing". This way, it is assumed that process models and elements are shared with all interested parties.
- *Guideline #9: Process design must address different types of exceptions* – it was commented, for explaining the disagreement with this guideline, that "different" does not allow for the determination of the exceptions that should be handled and that the definition of the guideline should be more precise. It was suggested that all possible exceptions must be handled.
- *Guideline #5: Information structure must be based on open standards to ensure interoperability with different systems* – comments about the disagreement with this guideline are about the fact that information structure does not necessarily need to be open – it may be proprietary. What must be open are the protocols that map the information structure into information that may be exchanged with other systems.

- *Guideline #2: People involved in a process must participate in its design* – it was commented that all parties involved in the process should be involved in its design and that this fact should be made clearer in the guideline.
- *Guideline #8: Processes must explicitly support management/control (e.g. synchronization, decision-making, delegation and coordination) within a process and with other processes* – the IRR for this guideline was 0.79 and no participant disagreed with it. Mean agreement was 5.38, so this guideline was not changed for the second round, but a note about this fact was added to the summary report presented to the experts in the second round.

Another point to be noted is that there were comments that stated that “design” and “execution” should not take part in the guidelines and that “execution” should not be the concern of enterprise engineering – “execution” is what happens after the enterprise engineering process ends. It was argued that “implementation” is the word that should be used, meaning that the enterprise “design” should be “implemented” or “realized”. This is particularly important for guidelines #1 and #10, as both contain “design” and “execution” in the phrasing of their statements, and guideline #9, which contains “design”. However, it was also mentioned that if the guidelines are to be general, they should not specify “design”, “execution”, “implementation” or any other practice in the phrasing of their statements – as general principles, they should be valid for the task they were conceived for. Taking this context into account, guidelines #1, #9 and #10 were also revised so that “design” and “execution” were removed from their respective statements, although “design” and “implementation”, instead of “execution”, remained in the concept map depicting the relationships among guidelines.

A remark about “design”, “execution” and “implementation” must be made about guideline #2. Although the word “design” is part of its statement, the intended notion is clearly about the participation of people in the conception of a process. People who are involved in it are the ones executing it and they are also involved in its implementation when necessary. The concern with this guideline is that people’s experience and opinion are taken into account when the process is designed. Therefore, “design” remains as part of this guideline.

Two other comments are also worth noting. One is about the support of unstructured and ill structured processes and process alternatives and interfaces depending on skill and expertise. No modifications were made to the guidelines as a result of this comment because it is understood that they already support it. In particular, guideline #3 handles this issue by stating that processes must be clearly defined, but not stating the form in which this definition should be done. An unstructured or ill structured process will have at least some information that defines it – its objective, for instance. This information that defines the process is the element that must be clearly defined. In this way, guideline #3 fits all kinds of processes – structured, unstructured and ill-structured.

The other comment worth noting is about the consideration of services, as defined by the information systems community, as elements of the guidelines. Services may be understood as the binding elements between two systems – the way through which interactions between these systems occur. Services, however, are a technological solution to one broader problem, that of integrating systems so that they interoperate. Hence, the explicit consideration of services in the guidelines would associate a technological solution to them. If the technology ever changes, these guidelines are no longer general principles for the design and implementation of enterprises. It is understood, however, that guidelines #5 and #6 address this issue. In first place, if a process has to interact with another process through systems that use services, this should be specified (guidelines #6). And the information that is exchanged through the service must also be specified in order for them to interoperate (guideline #5).

Table 5.9 presents the revised version of the guidelines incorporating the comments from the first round of the Delphi study. Guidelines #2, #6, #7 and #9 were modified according to the comments presented in the previous list. Guideline #5 was split into two different guidelines, also according to these comments and to test whether its component statements should or not be guidelines. Guidelines #1, #9 and #10 had "design" and "execution" left out of their statement. Guidelines #3, #4, #8, #11 and #12 were not modified.

Table 5.9 - Revised version of the guidelines after the first round of the Delphi study.

#	Guideline
1	Processes must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)
2	People involved in a process, including interested parties, must participate in its design
3	Processes must be clearly defined (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces)
4	Capabilities of resources in a process must be aligned with expected process performance
5.1	Information structure must be based on open standards.

#	Guideline
5.2	Information structure must ensure interoperability with different systems.
6	Specifications for the interface channels of a process must be defined.
7	Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared
8	Processes must explicitly support management/control (e.g. synchronization, decision-making, delegation and coordination) within a process and with other processes
9	Processes must address all possible exceptions
10	Processes must incorporate mechanisms for change/improvement detection/management
11	Process semantics must be coherent and consistent throughout all processes
12	Information related to the performance of the process and the organization must be collected

The version of the guidelines seen in Table 5.9 was used in the second round of the Delphi study.

5.5.3 Round 2 results

Results for the agreement rating of participating experts with the proposed guidelines are presented in Table 5.10. This table shows the guideline number (#), as referenced in Table 5.9, and the answer for each one of the 13 experts that participated in the second round, labeled A through M. The mean value, standard deviation and inter-rater reliability (IRR) are also presented. Although guidelines #3, #4, #8, #11 and #12 were not altered, they were kept in this round for completeness.

Table 5.10 - Results for the agreement rating in the second round of the Delphi study.

#	A	B	C	D	E	F	G	H	I	J	K	L	M	Mean	Standard deviation	IRR
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6,00	0,00	1,00
2	5	6	5	5	6	5	6	5	5	6	6	6	5	5,46	0,50	0,91
3	6	5	4	5	6	6	5	6	5	4	5	6	6	5,31	0,72	0,82
4	6	6	5	5	6	5	5	6	5	6	6	6	6	5,62	0,49	0,92
5.1	5	6	3	4	5	2	5	4	4	3	3	4	3	3,92	1,07	0,61
5.2	5	5	6	4	5	6	5	4	5	5	5	5	6	5,08	0,62	0,87
6	5	5	4	5	5	5	5	4	6	5	5	6	5	5,00	0,55	0,89
7	5	5	6	5	4	6	5	5	5	4	5	6	5	5,08	0,62	0,87
8	5	4	5	6	5	6	5	6	6	4	6	5	6	5,31	0,72	0,82
9	5	5	5	6	6	6	5	4	5	5	4	6	5	5,15	0,66	0,85
10	5	5	6	5	6	4	5	6	6	6	5	5	6	5,38	0,62	0,87
11	6	5	6	6	6	5	6	6	5	5	6	4	6	5,54	0,63	0,86
12	6	5	6	5	6	5	5	6	6	5	5	6	6	5,54	0,50	0,91

Note: The rating scale is 1 – strongly disagree, 2 – disagree, 3 – somewhat disagree, 4 – somewhat agree, 5 – agree and 6 – strongly agree.

The only guideline with a mean agreement rating of less than 5 is guideline 5.1. Its IRR is also below 0.8. All other guidelines have a mean agreement rating of over 5 and an IRR of over 0.8. This means that this group of experts, with a high degree of reliability, agrees that the provided statements should be considered enterprise engineering guidelines.

Comments received for disagreements with guideline 5.1 were based on the argument that the information structure of a process or an organization does not need to be open. What needs to be open is the way it interoperates with other systems, fetching and storing information in this proprietary structure – that means, a mapping between what is open and what is in the structure should be defined. This mapping is what defines if the organization is aligned to this guideline or not, which is an important point in later verifying it.

Table 5.11 shows the set of guidelines after the second round of the Delphi study. This set of guidelines is considered the initial model that will have its application further analyzed and verified. The updated concept map showing the relationships among the guidelines is presented in

Table 5.11 - Final version of the guidelines after the second round of the Delphi study.

#	Guideline
1	Processes must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)
2	People involved in a process, including interested parties, must participate in its design
3	Processes must be clearly defined (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces)
4	Capabilities of resources in a process must be aligned with expected process performance
5	Information structure must ensure interoperability with different systems.
6	Specifications for the interface channels of a process must be defined
7	Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared
8	Processes must explicitly support management/control (e.g. synchronization, decision-making, delegation and coordination) within a process and with other processes
9	Processes must address all possible exceptions
10	Processes must incorporate mechanisms for change/improvement detection/management
11	Process semantics must be coherent and consistent throughout all processes
12	Information related to the performance of the process and the organization must be collected

5.6 DISCUSSION

Guidelines will be analyzed here according to their coverage of content and process of enterprise engineering and its research topics, their relationship with performance excellence models, and their value as an initial maturity framework.

First, if guidelines are categorized according to whether they address the content of enterprise engineering initiatives or the process through which such an initiative is conducted (both the enterprise design process and the design implementation process), it is interesting to note that only guidelines #2 and #7 are associated with the process related aspect. All other guidelines are associated with content, such as the definition of models, roles, capabilities, semantics, mechanisms, exceptions, interface channels, and alignment to context, among others. It may also be argued that guideline #7 is also related to content, as proper ways to share process models and their elements must be designed for it to be fulfilled. Enterprise design implementation may be an area for developing further works and one of the first things to be done is to determine its relationship with (or even its place within) the enterprise transformation field as defined in section 5.3.4. The enterprise transformation field is concerned with changes and how change is implemented.

It is also interesting to note that all except one of the guidelines are associated with processes (the exception is guideline #5). In particular, there are guidelines that are directly associated with modeling (#3, #8, #9 and #10), integration (#1, #4, #, #12), interoperability (#5 and #6), enterprise architecture, virtual enterprises and ontologies. This shows that most of the relevant topics related to enterprise engineering as identified in previous work are covered.

These guidelines could also lead to the development of a maturity model for enterprise engineering. The assessment of the guidelines in a certain scale and their grouping could be used to characterize the level of maturity of an enterprise regarding its design and the implementation of this design. For this to be possible, practices applied for aligning an organizational system to each one of the guidelines would have to be identified and the effectiveness of each practice measured.

Table 5.12. shows the ranking of guidelines by their expert assessment ratings from the second round of the Delphi study. It is noteworthy that the top guidelines are either related to context alignment, terminology, performance, people involvement, and change/improvement. Guidelines related to the definition of process components and mechanisms, information structure and interface channels are considered next.

Table 5.12 – Ranking of guidelines according to their expert assessment rating.

#	Guideline	
1	Processes must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)	6,00
4	Capabilities of resources in a process must be aligned with expected process performance	5,62
11	Process semantics must be coherent and consistent throughout all processes	5,54
12	Information related to the performance of the process and the organization must be collected	5,54
2	People involved in a process, including interested parties, must participate in its design	5,46
10	Processes must incorporate mechanisms for change/improvement detection/management	5,38
3	Processes must be clearly defined (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces)	5,31
8	Processes must explicitly support management/control (e.g. synchronization, decision-	5,31

#	Guideline	
	making, delegation and coordination) within a process and with other processes	
9	Processes must address all possible exceptions	5,15
5	Information structure must ensure interoperability with different systems.	5,08
7	Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared	5,08
6	Specifications for the interface channels of a process must be defined	5,00

Finally, it may also be observed that there is a relationship between these guidelines and performance excellence models. These models, as presented in section 5.3.3 are very comprehensive, dealing with leadership, strategy, planning, customer focus, products and services, society relationships, people, business results, knowledge, information, technology and processes. These guidelines may be thought as principles to guide the design of a part of an organizational system, their processes, structure and interactions. Their actual relationship with these models is also a field for further exploration.

5.7 CONCLUSIONS

The main objective of this work was to identify a set of guidelines that could be used in enterprise engineering initiatives. This set of guidelines should be able to synthesize common patterns among different contributions to the enterprise engineering literature supported by enterprise engineering reference models, performance excellence models, and the enterprise transformation literature. These guidelines are supposed to aid in the problem of formalizing a set of higher-level guiding principles for the diagnosis, design and redesign of organizations. This was accomplished through the presentation and discussion of the development of the 12 guidelines for enterprise engineering in sections 5.4 and 5.5. These guidelines address issues related to the formalization of processes and structure of an organization, the coordination and synchronization of processes, the explicit consideration of process performance, the treatment of exceptions, and the incorporation of change and improvement mechanisms. They do not state how design or improvement should be performed as actions nor guarantee success of an organization, but they establish the foundations for the consistent structuring of an enterprise system so that it may have the potential to achieve its objectives.

Limitations to this work come from the fact that the extraction of recommendations, the statement of the guidelines, and the assessment of the guidelines by the experts in the area, culminating in the initial model, although systematic, are subjective processes. The analysis of the supporting sources is performed in order to adapt the terminology, meaning that other links between the sources and the guidelines that are not presented here may occur. There are also limitations related to the fact that only works from the enterprise engineering research field contained in previous studies [5][6], [9][7] were analyzed for extracting candidate statements. These studies, although embracing a large number of works, have limitations of their own.

The guidelines, although covering different aspects of an enterprise engineering initiative, still need refinement. They cannot be seen as the definitive set of guidelines for enterprise engineering initiatives – they are, rather, one possible set from many others. Case studies will be conducted in organizations of different industries and sizes in order for the guidelines to be tested as an organizational diagnosis tool. This diagnosis must be done through a proper auditing procedure and a protocol for this must be developed, in which different information sources are used to provide evidence for the assessment of the guidelines. The usefulness of the guidelines could then be tested and they could also be improved from the results of these tests.

After this refinement, these guidelines could be used as both a diagnosis, design and redesign tool. As a diagnosis tool, they would be used in the same way as described in the previous paragraph, the only change would be that the main objective would not be the improvement of the guidelines but the assessment of an organization. As a design and redesign tool, they would be applied to generating a new organizational system or improving it.

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6 ARTICLE #4 – EVALUATION OF ENTERPRISE ENGINEERING GUIDELINES APPLICATION

This paper presents the protocol to be used in the case studies and the result of its application as an evaluation tool for the proposed enterprise engineering guidelines. The decomposition of guidelines into analysis points and information requirements, their grouping and the definition of information sources are detailed. The results of the individual cases as well as overall observations from the cases are presented. Table 6.1 presents works whose results contributed to this article.

Table 6.1 – Related works whose results lead to this article.

#	Notes
1	DRP case to be published in the Proceedings of the 22nd International Conference on Production Research, to be held in Foz do Iguaçu, Brazil, from July 31st to August 3rd, 2013.
2	PSP case to be published in the Proceedings of the 6th IFAC International Workshop on Management and Control of Production and Logistics, to be held in Fortaleza, Brazil, from September 11th to 13th, 2013.

Diagnosing organizational systems based on enterprise engineering guidelines: lessons from case studies

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Abstract

The design and implementation of organizational systems is a challenge faced by many organizations. The enterprise engineering research field aims at providing a response to this challenge through the organization of knowledge in different areas such as industrial and systems engineering, information systems and organizational sciences. Several contributions have been developed that address issues in different enterprise engineering topics. In previous work, a set of guidelines has been proposed to direct enterprise engineering initiatives based on review of the enterprise engineering literature and a Delphi study with experts in this field. This work applies these previously-developed enterprise engineering guidelines for the diagnosis of organizational systems. A data collection and analysis procedure that operationalizes this diagnosis is presented and applied to five case studies of different organizational systems – an unstructured process, two business processes and two organizational units. The results of the case studies are presented and the evaluation of the application of the procedure and the guidelines is discussed.

Keywords: enterprise engineering, enterprise engineering guidelines, organizational systems diagnosis.

6.1 INTRODUCTION

The design and implementation of enterprise or organizational systems has been studied in the field that is conventionally called enterprise engineering. Enterprise engineering aggregates knowledge from multiple areas such as industrial and systems engineering, organizational sciences and information technology [1] to the task of designing and implementing an organizational system so that it is able to achieve its goals [2].

There exists a multitude of contributions to the enterprise engineering field, ranging from methods, tools, frameworks, ontologies, reference models and architectures in topics such as modeling and integration [3][8]. Most of these contributions describe very prescriptive and restrictive approaches to the enterprise engineering process and most of them are applicable to only a very narrow set of situations. If the well-known CIMOSA (Computer-Integrated Manufacturing Open Systems Architecture) reference model is taken, for instance, it can be seen that: (i) there are many necessary models from different views to be defined; (ii) the amount of work that has to be invested to define these models is huge, even prohibitive to medium and small organizations. Additionally, most of these reference models are thought to be used to create new designs, not accounting for the fact that, in general, an organizational system that implements partially or fully the required functionality already exists.

A set of enterprise engineering guidelines was created in previous work [4][9] to be applied to enterprise engineering initiatives, encompassing the design and implementation of enterprise systems and addressing the issues discussed in the last paragraph. These guidelines were created based on a review of the enterprise engineering literature and a Delphi study with enterprise engineering experts. These guidelines are shown in Table 5.11 and their inter-relationships are depicted in Figure 6.1.

These guidelines are intended to guide the design process and not prescribe or restrict it. Although they are supposed to be used in design and implementation, they may be applied to the diagnosis of an enterprise system to verify whether its design and implementation are well structured and consistent. Using the guidelines in this manner may result in the evaluation of whether a particular enterprise system is well structured and has the potential to perform well and meet its goals. The use of guidelines for diagnosis also accounts for the fact that a new design is usually created from an existing system, and that its assessment is a good starting point for this new design.

[8] This reference is to the 2012 International Conference on Industrial Engineering and Operations Management paper. Article #2 in this document extends this paper.

[9] This reference is for the preliminary model of the guidelines, published in the 2013 Industrial and Systems Engineering Research Conference. The set of guidelines used here is the initial model updated from the preliminary model and presented in article #3.

Table 6.2 - Final version of the guidelines after the second round of the Delphi study.

#	Guideline
1	Processes must be aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)
2	People involved in a process, including interested parties, must participate in its design
3	Processes must be clearly defined (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces)
4	Capabilities of resources in a process must be aligned with expected process performance
5	Information structure must ensure interoperability with different systems.
6	Specifications for the interface channels of a process must be defined
7	Process models and their elements (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces) must be shared
8	Processes must explicitly support management/control (e.g. synchronization, decision-making, delegation and coordination) within a process and with other processes
9	Processes must address all possible exceptions
10	Processes must incorporate mechanisms for change/improvement detection/management
11	Process semantics must be coherent and consistent throughout all processes
12	Information related to the performance of the process and the organization must be collected

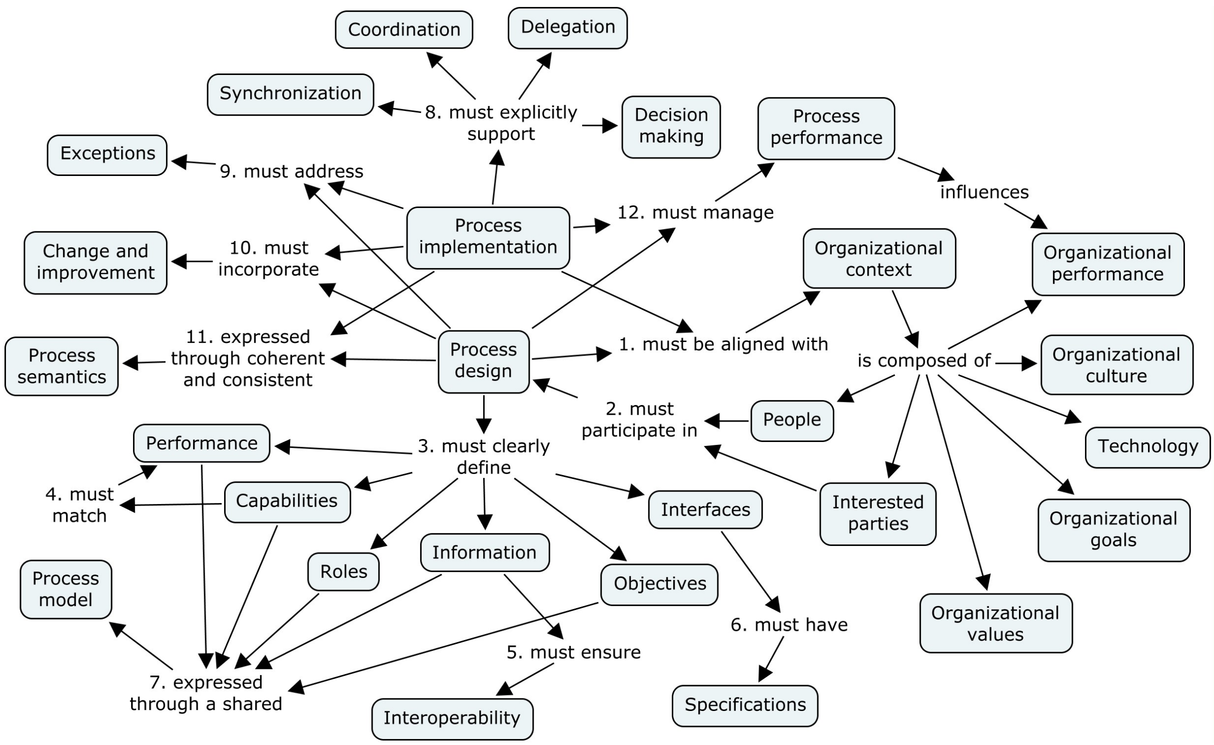

Figure 6.1 – Relationships among the enterprise engineering guidelines.

The main objective of this work, hence, is to apply these guidelines to the diagnosis of an organizational system. To allow for this, first a procedure to be applied to the assessment of an organizational system alignment to the enterprise engineering guidelines is defined in Section 6.2. Next, a set of case studies is conducted and their description, results and cross-case analysis are presented, respectively, in Sections 6.3 and 6.4. Finally, case results, assessment procedure and guidelines are evaluated according to feasibility, usability and utility in Section 6.5. Limitations to this work and perspectives for further research are discussed in Section 6.6.

6.2 DATA COLLECTION AND ANALYSIS PROCEDURE

The data collection and assessment procedure used in the case studies is comprised of six steps: the decomposition of guidelines into information requirements; the creation of worksheets to aid in the data collection process; data collection using the worksheets through multiple information sources; the assessment of information requirements evidence quality; the alignment assessment to the guidelines; and the analysis of main issues and identification of improvement opportunities. Figure 6.2 summarizes these steps and their outputs. This procedure is based on the Cambridge process approach initially developed to audit manufacturing strategy formulation procedures [5], [6], [7], [8]. In particular, four main aspects must be observed:

- **Procedure:** there must exist a well-defined process for analyzing information, collecting data and identifying improvement opportunities, as well as clear documentation of all of these tasks.
- **Participation:** the necessary people in all of the steps of the procedure must be involved and invited to participate.
- **Project management:** there must be a clear division of responsibilities among people participating in the intervention and the use of adequate resources.
- **Point of entry:** expectations of the intervention must be clearly defined and there must be commitment from managers for the intervention to be successful.

The six steps of the procedure used in this work are discussed next.

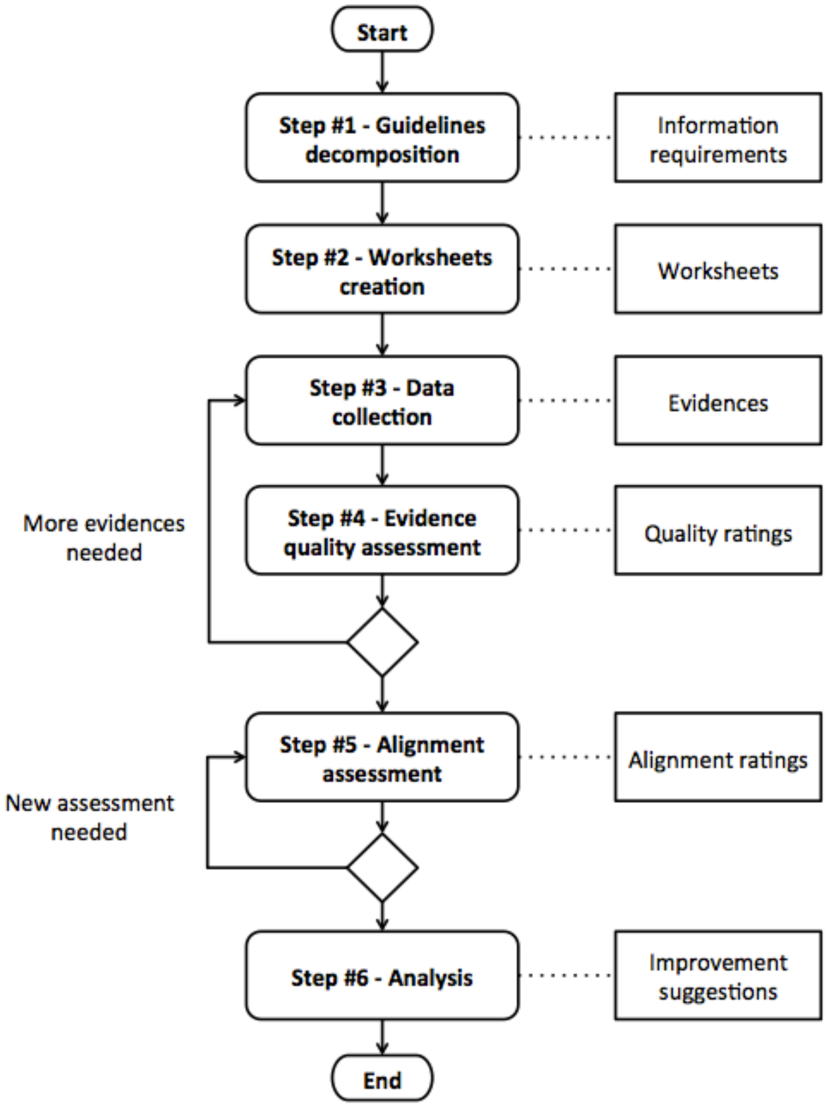

Figure 6.2 – Data collection and analysis procedure.

6.2.1 Step #1: Guidelines decomposition

In order to allow for the assessment of an organization's alignment to the guidelines, the gathering of evidence showing how the organizational system under study is structured and works is necessary. For the appropriate evidence to be collected, information requirements for each one of the guidelines have to be defined. This was accomplished through a decomposition approach in which collectable pieces of information were identified in accordance to the literature in which they were based. First, guidelines were divided into analysis points based on their accompanying concept map that illustrates the relationships among their elements, so that all of their different aspects are considered. Next, these analysis points were divided into a set of information requirements that provide the necessary evidence for their assessment. Table 6.3 lists the analysis points and information requirements resulting from this decomposition.

Table 6.3 – Guidelines decomposition into analysis points and information requirements.

ID	Analysis point	Information requirements
1	To what extent are processes aligned with organizational context (e.g. organizational goals, organizational values, organizational culture, organizational performance, technology and people)	Process objectives
		Organizational objectives related to the process
		Process performance measures
		Organizational performance measures related to the process
		Process performance goals
		Organizational performance goals related to the process
		Technology used in the organization
		Technology used in the process
2	To what extent people involved in the process, including interested parties, play any kind of role (i.e. suggesting/being consulted/being responsible for) in process design (i.e. from its creation to any changes made to the process)	Organizational structure
		Positions in the organizational structure involved in the process
		Positions in the organizational structure involved in process design
		Other interested parties involved in process design
		How people are involved in process design
		How processes evolved
3	To what extent processes are clearly defined (e.g. objectives, roles, responsibilities, capabilities, performance, information and interfaces)	Process objectives
		Process roles
		Positions in the organizational structure involved in each role
		Process tasks/activities
		Responsibilities of each role
		Capabilities necessary for each role
		Capabilities necessary for each task/activity
		Process performance measures
		Process performance goals
		Information needed in the process
		Process interfaces
		Interface specifications
4	To what degree/extent the capabilities of resources in the process are aligned with expected process performance	Process performance goals
		Process roles
		Positions in the organizational structure involved in each role
		Capabilities necessary for each role
		Capabilities necessary for each position
5	Whether information structure ensures interoperability with different systems	Information needed in the process
		Systems with which information is exchanged
		Information mapping to other systems
6	Whether specifications for the interfaces	Process interfaces

ID	Analysis point	Information requirements
	of a process are defined	Interface specifications
7	Whether process models and their elements are shared	Positions in the organizational structure with access to process information
		Other interested parties with access to process information
		How process information is shared
8	Whether process design supports management/control within a process and other processes	Synchronization mechanisms present in process design
		Decision-making mechanisms present in process design
		Delegation mechanisms present in process design
		Coordination mechanisms present in process design
		Other management/control mechanisms present in process design
	Whether process implementation supports management/control with other processes	Synchronization mechanisms used in the process
		Decision-making mechanisms used in the process
		Delegation mechanisms used in the process
		Coordination mechanisms used in the process
		Other management/control mechanisms used in the process
9	Whether processes address all possible exceptions	Exceptions that may occur during process execution
		Exceptions addressed in process design
		Exceptions addressed in process implementation
10	Whether process design incorporates mechanisms for change/improvement detection/management	Change/improvement detection mechanisms incorporated in process design
		Change/improvement management mechanisms incorporated in process design
	Whether process implementation incorporates mechanisms for change/improvement detection/management	Change/improvement detection mechanisms used in the process
		Change/improvement management mechanisms used in the process
11	Whether process semantics is consistent and coherent throughout all processes	Consistency of process semantics
		Coherence of process semantics
12	Whether information related to the performance of the process is collected	Process performance information collecting procedure
		Process performance information

Note: ID refers to the guideline ID in Table 5.11.

6.2.2 Step #2: Creation of worksheets

It can be noted from Table 6.3 that some information requirements appear in the decomposition of more than one guideline, such as “process performance goals” and “capabilities necessary for each role”, which appear in the decomposition of guidelines #3 and #4. To have a better understanding of the necessary information requirements, to better organize them according to the category of information they provide, and to avoid duplicate effort in the gathering of evidence, these were grouped in five categories:

- *creation, evolution and sharing:* information related to how the process was created, how it evolved, and the participating people and how the process is shared;
- *structure, capabilities and roles:* information related to structural aspects of the process, such as tasks, activities, roles, capabilities, responsibilities and their relationships;
- *management and control mechanisms:* information related to how coordination, synchronization, decision-making, delegation, exception handling and other management and control mechanisms are implemented in the process;
- *performance:* information related to organizational and process objectives, performance measures, performance goals, their alignment and assessment procedures; and
- *systems, information and technology:* information related to the structure of information, the systems and the technology needed and used in the process.

For each one of the information requirements in these categories, primary and secondary information sources were defined. Different sources were used so that evidence from different perspectives could be gathered and triangulated, and data analysis reliability improved [9], [10]. The sources of information used were:

- Standards, norms and documents (D): existing documentation that describes the organizational system, its elements, and their relationships (e.g., people, resources, technology, tasks and roles).
- Logs and records (R): existing documentation that describe the results of actions performed in the context of the organizational system such as meeting notes, reports and completed forms.
- Interviews (I): conducted individually with people that work in the process, with a pre-defined set of guiding questions and topics.
- Observation (O): observation of the organizational system operation and its environment in order to document how tasks are executed in practice.

- Survey (S): people working in the organizational system answered a survey composed of a set of questions related to their perception about aspects related to the information requirements.

Table 6.4 shows the sources for the information requirements defined in Table 6.3.

Table 6.4: Information Requirements and Sources

ID	Information requirements	Source				
		D	**R**	**I**	**S**	**O**
1	*Creation, evolution and sharing*					
1.1	How processes evolved		2	1	2	
1.2	Positions in the organizational structure involved in process design	1		1	2	
1.3	Other interested parties involved in process design	1		1	2	
1.4	How people are involved in process design		2	1	2	
1.5	Change/improvement detection mechanisms incorporated in process design	1		1		
1.6	Change/improvement detection mechanisms used in the process		1	1	2	2
1.7	Change/improvement management mechanisms incorporated in process design	1		1		
1.8	Change/improvement management mechanisms used in the process		1	1	2	2
1.9	Positions in the organizational structure with access to process information	1	2	1	2	
1.10	Other interested parties with access to process information	1		1		
1.11	How process information is shared	1		1	2	2
2	*Structure, capabilities and roles*					
2.1	Process tasks/activities	1		1		2
2.2	Process roles	1		1		2
2.3	Responsibilities of each role	1		1		2
2.4	Organizational structure	1		2		
2.5	Positions in the organizational structure involved in the process	1		1	2	
2.6	Positions in the organizational structure involved in each role	1		1		
2.8	Capabilities necessary for each task/activity	1		1		2
2.9	Capabilities necessary for each position	1		1	2	
2.10	Capabilities necessary for each role	1		1		2
3	*Management and control mechanisms*					
3.1	Coordination mechanisms present in process design	1				
3.2	Coordination mechanisms used in the process	1	2	1		2
3.3	Decision-making mechanisms present in process design	1				
3.4	Decision-making mechanisms used in the process	1	2	1		2
3.5	Delegation mechanisms present in process design	1				
3.6	Delegation mechanisms used in the process	1	2	1		2
3.7	Synchronization mechanisms present in process design	1				
3.8	Synchronization mechanisms used in the process	1	2	1		2
3.9	Other management/control mechanisms present in process design	1				
3.10	Other management/control mechanisms used in the process	1	2	1		2
3.11	Exceptions addressed in process design	1				

ID	Information requirements	Source				
		D	R	I	S	O
3.12	Exceptions addressed in process implementation	1	2	1	2	2
3.13	Exceptions that may occur during process execution	1	2	1	2	2
4	*Performance*					
4.2	Organizational objectives related to the process	1		1	2	
4.4	Organizational performance measures related to the process	1		1	2	
4.6	Organizational performance goals related to the process	1	2	1	2	
4.9	Process objectives	1		1	2	
4.10	Process performance measures	1		1	2	
4.11	Process performance goals	1	2	1	2	
4.12	Process performance information		1	2		
4.13	Process performance information collecting procedure	1		1		2
5	*Systems, information and technology*					
5.1	Information needed in the process	1	2	1		2
5.2	Systems with which information is exchanged	1		1		
5.3	Information mapping to other systems	1		1		
5.4	Process interfaces	1	2	1		2
5.5	Interface specifications	1		1		
5.6	Coherence of process semantics	1	2	2	2	2
5.7	Consistency of process semantics	1	2	2	2	2
5.10	Technology used in the organization		2	1	2	1
5.11	Technology used in the process		2	1	2	1

Note: 1 indicates primary source, 2 indicates secondary source, D indicates documents, standards and norms, R indicates records and logs, I indicates interviews, S indicates surveys, and O indicates observation.

Worksheets were created for each one of the sources in order to facilitate the data collection process. These worksheets grouped all information requirements from one source and were completed by the person responsible for collecting the data.

6.2.3 Step #3: Data collection

The data collection procedure was structured in four main phases:

- **Phase #0:** the scope of the intervention is defined, management support is obtained and the intervention is communicated to all involved people.
- **Phase #1:** preliminary interviews with the organizational system manager, supervisors and workers are conducted alongside the analysis of documents with the objective of discovering information about the process.
- **Phase #2:** the work in the process is systematically observed and surveys with supervisors and workers are conducted to deepen the understanding of the process.

- **Phase #3:** final interviews with supervisors and workers are conducted alongside the analysis of documents and records with the objective of gaining detailed knowledge about the process.

Figure 6.3 presents the suggested sequence of data collection tasks for each intervention.

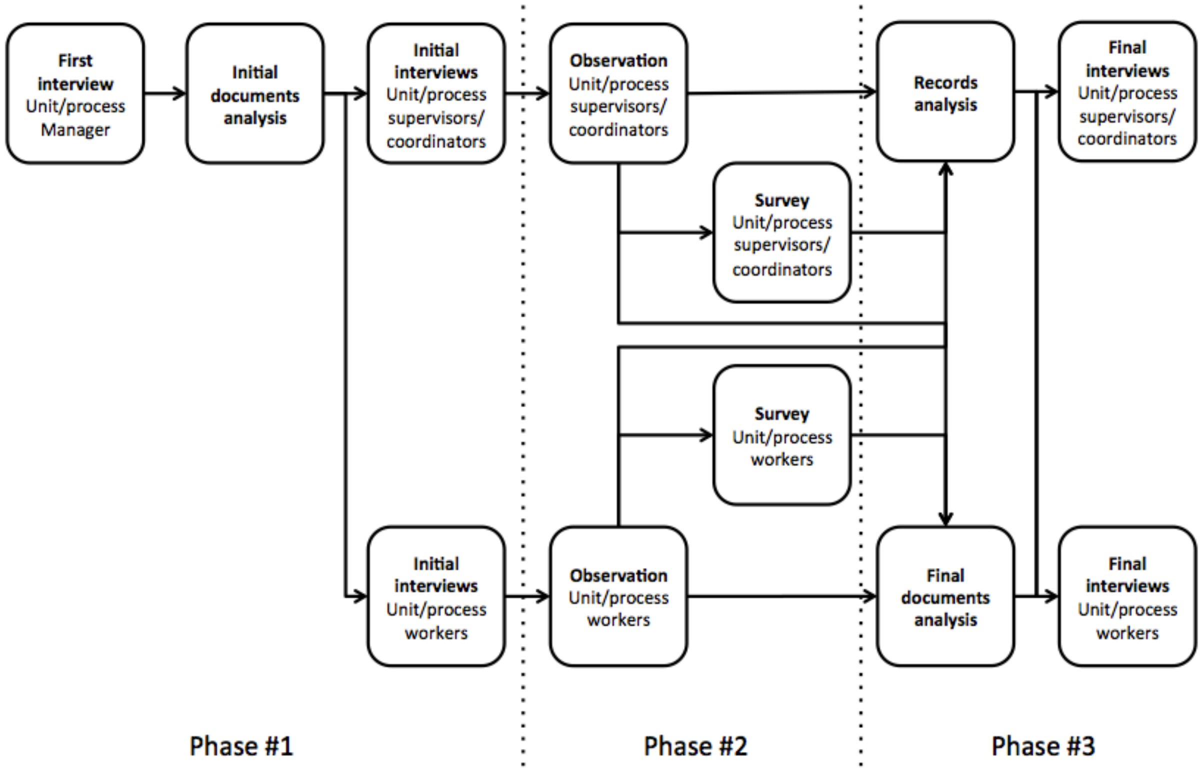

Figure 6.3 - Suggested sequence of data collection tasks for an intervention.

For each case, a data collection group must be defined. This group is composed of people that are trained in methods for obtaining information from different sources (documents analysis, records analysis, observation, interviews or surveys application and analysis) and responsible for executing the data collection tasks in Figure 6.3.

Additionally, as the amount of data collected is large and relationships among guidelines, analysis points, information requirements, information sources and evidence are numerous, an information system was used for organizing data and preparing it for analysis.

6.2.4 Step #4: Evidence quality assessment

After the collected data were organized, the quality of the evidence for each one of the information requirements is assessed. This is done through two criteria: existence and consistency.

- *Existence:* extent to which the collected data provide evidence about an information requirement that could help in the assessment of the organizational system alignment to the enterprise engineering guidelines. A four-point Likert scale is used to assess existence: 1 - no evidence, 2 - some evidence, 3 - moderate evidence, and 4 - strong evidence.
- *Consistency:* extent to which the collected data from different information sources provide non-conflicting evidence about the information requirement. A four-point Likert scale is also used to assess consistency: 1 - not at all consistent, 2 - somewhat consistent, 3 - moderately consistent, and 4 - strongly consistent.

For each case, a data rating group must be defined. This group is composed of people who are capable of reviewing the evidence and assessing its existence and consistency. These people do not need to be the same people that performed data collection. The objective is that multiple raters are presented with all the evidence from the different data sources for each information requirement and perform the assessment of each of the criteria. Inter-rater reliability for each information requirement is calculated according to the procedure described by James *et al* [11]. If there is a low IRR (below 0.80) in any of the criteria, the participants of the rating group analyze its causes and decide to proceed to the next step, review their ratings, or collect new data.

6.2.5 Step #5: Alignment assessment

Participants of the rating group defined in the previous step were presented with the evidences and complete assessment results for the information requirements of each one of the analysis points and assessed the extent to which the organizational system is aligned to them using a four-point Likert scale: 1 - not at all aligned, 2 - somewhat aligned, 3 - moderately aligned, 4 - strongly aligned. Inter-rater reliability is also calculated the same manner as in the previous step for each analysis point. If there is a low IRR (below 0.80) for the alignment assessment, the participants of the rating group analyze its causes and decide to proceed to the next step or review their ratings. The average of the analysis point ratings for each guideline was calculated.

6.2.6 Step #6: Analysis

With the results of the alignment assessment available, a ranking of the guidelines according to this alignment was produced. Suggestions for the improvement of the organizational system were defined, prioritizing the least aligned guidelines. Evidence that support these suggestions are presented to trace them back to the main causes of misalignment, identifying the root of the problem.

6.3 CASE STUDY DESCRIPTIONS

This section presents a description of the five case studies conducted to evaluate the application of the enterprise engineering guidelines: the disaster response process of a healthcare organization (an unstructured process), the adult benefit programs unit of a city administration (an organizational system), the information systems infrastructure support unit of an oil and gas company (an organizational system), the production scheduling process of a cosmetics manufacturer (a business process), and the product development process of a household utilities manufacturer (a business process).

It must be mentioned that the first two cases were conducted before finalizing the initial model for the guidelines shown in Table 5.11. These cases were used to evaluate the data collection and analysis procedure as described in Section 6.2. In both of these cases, surveys were not used. After the initial model was finalized, information requirements were updated and a new assessment was performed.

6.3.1 Disaster response process

The healthcare organization that had its disaster response process (DRP) analyzed is a major hospital in its region in the USA. It has approximately 700 beds and is a certified level I trauma center, meaning it has the capability to provide the highest level of care to trauma patients with a full range of specialists, operating 24/7.

The DRP is responsibility of the Incident Command Team (ICT), which was deployed in 2005, and since then, has handled approximately 2 incidents per year. The ICT started with 10 members and presently has 19 members from different hospital areas. Areas with members in the ICT include the Police Department, Emergency

Department, Public/Media Relations Department, Practice Clinics and Administration, among others. To be a part of the ICT, a person from the hospital has to be invited by the ICT and complete a number of Federal Emergency Management Agency (FEMA) courses.

The DRP is executed on a per-incident basis, meaning that each incident will have a specific set of tasks that are put in place according to its context. This makes the DRP an unstructured process. Generally speaking, the first person of the ICT to arrive at the Incident Operations Center (IOC) during an incident is the Incident Commander (IC). The next persons to arrive are responsible for one of the four sections of the Incident Command System (ICS) structure: logistics, operations, planning or finance/administration. Tasks are defined, executed and coordinated according to the situation – e.g., a patient surge due to a virus epidemic or a major power outage in the region. The ICT is demobilized as soon as the organization is put back to normal operation. After the incident, the ICT meets to evaluate its performance and deliberate over any necessary improvements to its structure and functioning.

Summary of findings from data collection

There were three different information sources used in this case: documents, records and interviews.

The main documents analyzed were the Emergency Operations Plan and its annexes, FEMA course materials, the HICS (Hospital Incident Command System) job action sheets, the HICS guidebook and some exercise plans. The following was found during the analysis of these documents:

- Although none of the documents provide a detailed process to be followed in case of a disaster, there is a clear description of the different roles necessary for responding to it and the responsibilities of the people in these roles. This is shown in the job action sheets and in the training materials, which also lay out the basic structure of an ICT and the general steps needed for disaster response.

- Most of the documents are written in general terms, meaning that they are not specific to how actions should be executed according to the context of the hospital. The Emergency Operations Plan, for instance, describes a set of responsibilities and requirements for ICT members and people involved in a disaster, but does not provide guidance on how some of the main tasks for dealing with a disaster should be executed in the given hospital environment – e.g., what tools, systems or techniques to use.

- The Emergency Operations Plan also provides guidelines to be followed in case of some more specific disasters, which is an initial exception handling mechanism.
- A major focus is given to the training of ICT members according to FEMA standards.

There was only one type of record available for analysis, the analysis of emergency event form. This form completed each time an actual disaster happens or an exercise is performed. This record shows a concern with the improvement of the process and some performance measures associated with it, although these measures can be modified according to the disaster or exercise under analysis. Nevertheless, lessons from each disaster and exercise are acknowledged and addressed.

There were four interviews conducted in this study: the DRP owner and ICT members from the Police Department, the Dental Practice Clinic, and Public Media Relations. The following was found from the analysis of the interviews:

- All interviewees received the required training and are aware of the main documents supporting the disaster response process, especially the Emergency Operations Plan and the job action sheets.
- Interfaces of the DRP with other processes within the organization and with outside organizations are not standardized. Most of these interfaces rely on an already-established relationship between people. Some areas of the hospital do not know that the ICT exists.
- There is a clear focus on process improvement and the necessity to perform better each time a disaster occurs. The ICT has regular monthly meetings and conducts tabletop exercises twice a year.
- Coordination mechanisms and information flow seem to be a major difficulty in the process, particularly because of the lack of definition of process interfaces.
- Most of the people feel that experience plays a major role in disaster response, meaning that performance of the process is greatly impacted by it.

- Objectives of the ICT are not explicitly defined. There is general understanding about what the objectives are, but no consensus.

Observation of the DRP in execution or a DRP tabletop exercise could not be conducted. What was observed for the purposes of this study was the structure available for ICT members, mainly the Emergency Operation Center (EOC), including its communication infrastructure.

6.3.2 Benefit programs unit

The benefit programs unit (BPU) of a city administration in the USA was analyzed. This unit is responsible for processing requests for benefits such as Medicare (healthcare assistance for people over 65 years old), Medicaid (healthcare assistance for people with low income), Supplemental Nutrition Assistance Program (SNAP, for people with low income) and Temporary Assistance to Needy Families (TANF, for families with children, aiming at aiding parents to be able to provide for their own families without any government help). All of these are federal programs administered by the states and the difference between them is that TANF is for families or adults with dependent children. The BPU is thus divided in two sections: one that oversees benefits for families or adults with no dependent children, with around 20 people, and other that oversees benefits for families or adults with dependent children, TANF, with around 25 people. The BPU has one manager, who is also responsible for the employment unit, and 7 supervisors, who oversee the activities of a number of workers.

TANF workers are more specialized than other workers because restrictions on the TANF program are stricter and a TANF request usually also involves requesting other benefits such as Medicaid and SNAP.

Activities that are performed by the BPU are processing benefit requests, monitoring approved benefits and renewing benefits. The processing of benefit requests starts with the interaction with the intake unit that also serves other units. The processing of a request involves analysis of the documentation provided, interview with the requester (referred to as client), confirmation of provided documentation with third parties such as an employer or landlord, asking for additional documentation, the input of information for the benefit in information systems, the determination of eligibility and of the actual benefit to be received, and communication of the analysis result to the client. The monitoring of approved benefits involves periodically determining whether the eligibility criteria still hold and whether there is a change in the actual benefit to be received by the client. Renewing benefits involves the same tasks as processing of a request, but triggered by the benefit deadline.

Summary of findings from data collection

There were four different information sources used in this case: documents, records, interviews, surveys and observations.

Several documents were provided for analysis. Among these documents were instructional manuals, forms, procedures, regulations, norms, standards and operational instructions for specific tasks. The following was found during the analysis of these documents:

- There is a large number of documents specifying how the work should be performed in the context of the BPU, from how a voice mail message should be recorded to how documents should be stored in the BPU archive. However, there is a lack of a document consolidating all of these documents and providing an overall guide to all these of these procedures and instructions.
- Information in the forms to be completed for each benefit is standardized.
- Eligibility criteria for all benefits are in the regulations and norms for each individual benefit.
- Updated versions of all documents are accessible to everyone involved in the process through the BPU intranet.

Among the records analyzed were communication broadcasts from the managers of the unit and case records from benefit requests. The following was found during the analysis of these records:

- Communication broadcasts usually inform workers about the modification in an important document, such as a norm or regulation that establishes eligibility criteria or an instruction or procedure.
- Case records are standardized through the use of forms. All information and documentation for a case is kept with its record.

Six people were interviewed – a supervisor and case worker for the family and children section, a supervisor and a case worker for the adults with no dependents section, a member of the information technology unit staff and the supervisor of the intake unit. These last two interviewees were chosen because these are the units that most closely interact with the BPU. The following was found during the interviews:

- Experience is a determining factor in the work of the unit. The standard exception handling procedure is to escalate – if the case worker has any kind of doubt regarding a case, he/she consults with his/her supervisor. If the supervisor has a doubt, he/she consults with the BPU manager. If the BPU manager has a doubt, they consult with the state administration office responsible for the benefit and wait for an answer.
- Case workers have some autonomy in the way they perform their work. Some of them develop checklists, personalized schedules, or reports to help in the execution of particular tasks.
- The operation of a team lead by a supervisor also varies. In general, supervisors ask for performance data and conduct periodical meetings to share information that can be related to policy changes or recommendations about how to do work.
- There are many different information systems that have to be used by the case worker. Each different benefit program has its own systems in which information must be input and in some cases information is duplicated.

Four observations were conducted: two of the processing of a request and two of the renewal of a request. Each observation had an approximate duration of 15 minutes. These observations confirmed the findings of the interviews.

6.3.3 Information systems infrastructure support unit (ISISU)

The information systems infrastructure support unit of an oil and gas company business unit was assessed. This support unit is responsible for maintaining the information infrastructure of this business unit operational, so that all of its processes can be executed and interact with the rest of the company. There are approximately 41 people working in the ISISU: 1 unit manager, 5 unit supervisors, and 35 technicians and analysts. The unit is composed of one basic support division and a systems division. The basic support division is responsible for maintaining software and hardware – installing, uninstalling, updating and solving problems related to them. The systems division is responsible for customizing information systems to the need of operational divisions and, eventually, processing large amounts of data by request. The basic support division interacts with software and hardware vendors, whereas the systems division interacts with third party systems development organizations and the corporate systems development unit.

Generally speaking, anyone who needs the service of the ISISU can issue a ticket in an information system and provide details about the call, choosing the nature of the service. New tickets are analyzed by any of the technicians or analysts and are prioritized according to existing demand and urgency. Requests for giving a higher priority to a ticket are treated by the supervisors and ISISU manager and must be justified. The person who issued the ticket can monitor its status through the ticketing system.

Usually, basic support tickets are handled quickly. Systems tickets depend on the scope of the modification and are treated on a per-ticket basis.

When there is a corporate systems update, for either software or hardware, several tickets are issued by one of the supervisors or the ISISU manager. These tickets are used to determine the impact of the update, plan for the update and execute the update, much in the form of a project with several phases.

Summary of findings from data collection

There were five different information sources used in this case: documents, records, interviews, surveys and observations.

Among the analyzed documents were policy manuals and basic procedures to respond to a ticket. The following was found during the analysis of these documents:

- The process is defined through a flowchart and a responsibility matrix. Certain situations are detailed in specific procedures – for instance, the procedure on how to update a specific system. For the analysts, however, there is no template for collecting requirements for system customization.
- All documentation is readily available in the ISISU intranet.

Among the analyzed records were ticket data stored in the ticketing system. Through the analysis of this information, it can be seen that most of the basic support division tickets are closed within two days. Most system customization tickets take from two to six days.

Seven people were interviewed – the ISISU manager, two supervisors, two technicians and two analysts. The following was found during the interviews:

- Experience for executing the different activities of the ISISU is important, and new people are trained directly in the process.
- The interaction with other units is through the ticketing system, phone calls are used only to clarify information.
- Performance is measured by the time taken to respond to a ticket and the amount of tickets open each day.
- Tickets may be forwarded from one analyst to the other. There is an informal structure for doing this so that the unit can respond more effectively to each request and everyone in the unit having a good performance.
- Basic support involves the knowledge and there is pressure for solving the issue quickly.
- Systems customization involves primarily the definition of what the user wants. There is no standardized way of performing this task and each analyst uses the tool he/she finds best. This documentation is not stored in the ticketing system, but rather, in the division's own system.

One survey was distributed to all of the ISISU members, with fifteen answers collected, for a response rate of 12%. The main perception collected with this survey is that there is little understanding of the importance of the ISISU activities to the organization.

Four observations were conducted, two with people from the basic support division and two with people from the systems division. Each observation had an approximate duration of 30 minutes. Observations confirmed the findings of the interviews.

6.3.4 Production scheduling process

The production scheduling process of a large manufacturer of cosmetic products in Brazil was assessed. This organization has three production units: one for hydro-alcoholic products (perfumes and deodorants), one for make-up related products (powders) and one for creams and lotions. Its product portfolio is comprised of approximately 3,000 different items and there is constant development of new products due to market demands.

The organization has a Logistics Planning (LP) unit responsible for production planning, including materials requirements planning, maintenance planning, new product production planning and production scheduling. There are twelve Production Schedulers (PS): three for each one of the production lines (each working one shift), and three for third-party products – products that are produced by third-party suppliers and distributed and sold with one of the organization’s brand labels. This work focuses only on the production scheduling process for the production lines inside the organization.

In brief, the process is executed as follows: a Master Production Plan (MPS) is created by production planners taking into account expected demand, existing orders, maintenance schedule, the need to test a production process for a new product, and other production restrictions like available personnel and machine capacity. This plan is generated every three months and is revised monthly. The PS is responsible, each week, for obtaining the production plan for the next month from the Enterprise Resource Planning (ERP) system, checking its validity and adapting it to current order priorities, delayed orders, available personnel and materials, and other restrictions. The adaptation of the plan generates a preliminary detailed schedule for the next week in the form of an electronic spreadsheet and is done three days before the start of the production week. Two days before the start of the production week, the PS meets with other members of the LP staff to discuss the schedule and guarantee that available resources, especially materials, will be in place when needed. One day before the production week, the PS meets with the LP staff and the factory staff that will execute the schedule to discuss it and resolve any issue that may affect it, generating a final detailed schedule.

After the production schedule is approved in this meeting, the PS has the responsibility to issue the production orders for the products in the schedule and to monitor their execution. Whenever a problem occurs that impacts the schedule, the PS is responsible for solving it – suspending production, reallocating personnel, equipment, and materials or through other actions that maximize throughput and are most adherent to the schedule. The LP unit is evaluated according to the Production Planning Alignment (PPA) indicator, which measures the percentage of the production that was completed according to the plan. The goal for each of the lines is different, ranging from 50% to 80%.

Summary of findings from data collection

There were five different information sources used in this case: documents, records, interviews, surveys, and observations.

Among the analyzed documents were the production planning process flowchart, production planning process activities description including scheduling activities, and responsibility and organizational charts of the LP unit. The following was found during the analysis of these documents:

- Although specifying the tasks that the production scheduler has to perform in order to create a production schedule, the production planning process flowchart does not reflect how the process currently works.
- The production planning process activities description is also comprehensive but does not include description for all the interfaces that the production scheduling process has with the different organizational areas.
- Organizational charts are up-to-date.

Among the analyzed records were previous MPS and production schedules related to the MPS. Through the analysis of these records it was found that what is planned in the MPS is, in some cases, very different from what is scheduled. There is a clear difference in each one of the lines, the most efficient being the hydro-alcoholic line and the least efficient being the make-up and powder line.

Six people were interviewed – one manager from the LP unit, two production planners and three PS. Interviews showed:

- The production scheduler is a problem solver. He/she has to guarantee that all items of the production plan are produced. Any problems have to be solved by him/her. If there are materials missing, the production scheduler is responsible for making sure the material arrives in time. If a machine is broken, the production scheduler is responsible for arranging repair.

- There are many details of the work of the production scheduler that are not documented, for instance, the way that shift changes are implemented and the interfaces with other organizational areas such as process engineering and maintenance.

One survey was distributed to the PS, with nine responses received, for a response rate of 57%. The main perception collected from this survey were that process improvement suggestions are taken into account.

Two observations were conducted, one with a hydro-alcoholic production line PS and another with a creams and lotions production line PS. Each observation had an approximate duration of two hours. Findings of the observations confirmed the ones obtained through the interviews.

6.3.5 Product development process

The product development process (PDP) of a home appliance manufacturer was assessed. This process includes all activities necessary to create an initial product concept, evaluate project feasibility, specify and verify a product, and start up a production process and is executed by the engineering department. There are four divisions in this department that are involved with this process: air conditioning, refrigerators, microwaves, and ovens and cooktops. Overall, there are approximately 120 people in these divisions, among division managers, project leaders, and project team members. The process has interfaces with many other organizational units such as marketing, quality, purchasing, intellectual property, manufacturing and aftermarket sales and services.

The process is executed in several phases, and for it to progress from one phase to the other it has to pass a series of checkpoints. Each checkpoint establishes reviews that have to be performed and requirements that have to be met, ensuring that a particular instance of the process is mature enough to proceed. Besides the initial phase, in which the project is started by request of the marketing team that requests a product to be developed, other phases and checkpoints involve: product feasibility, in which an initial concept for the product is developed and its requirements are evaluated to determine its technical and business feasibility; product concept definition and validation, in which the product concept is detailed and validated through research with potential customers; engineering solution, in which all technical issues with the product are addressed and the product final design is approved; process engineering, in which process for producing the product is designed, taking into account available resources; product reliability and process verification, in which samples of the product using the specified process are built to verify the process and determine product reliability; production start-up, in which production is started and, eventually, adjusted; and project evaluation, in which experiences and lessons learned are documented and shared.

Summary of findings from data collection

There were four different information sources used in this case: documents, records, interviews and surveys.

Among the analyzed documents were the PDP flowchart, the corporate PDP manual and in-software documentation explaining specific steps of the PDP process. The following was found during the analysis of these documents:

- Documents are very detailed and establish not only the process and its activities but also all interfaces with other organizational areas, the information that needs to be exchanged, the information that needs to be recorded and performance goals for each one of the phases.
- The in-software documentation is also very detailed and provides a very good guide to how specific activities should be executed.
- There is no link between paper documents and the in-software documentation, that is, one does not reference the other – if someone only reads the paper documentation, he/she will not know about the existing software used.

Among the analyzed records was the documentation of previous projects. Documentation of the analyzed records is very complete. There are meeting notes with different groups, reports (marketing, requirements, customer tests), specifications and many other documents related to a product development project.

Seven people were interviewed – one division manager, three project leaders and three project team members. The following was found during the interviews:

- Only division managers and project leaders have a clear understanding of how the whole process works according to the process documentation.
- There is a product development project system that supports the execution of the product development process. The system is very straightforward to use and all necessary documents for a project are stored in it.

A survey was distributed to division managers, project leaders and project team members, with 30 answers collected, for a response rate of 43%. Perceptions collected from this survey are that here is a lack of understanding of how performance of the process is measured.

6.4 CASE RESULTS

Case results will be presented in this section. Results of the alignment assessment are presented in Table 6.5.

Table 6.5 – Alignment to guidelines assessment results.

ID	Case										A
	DRP		BPU		ISISU		PSP		PDP		
	A	IRR	A	IRR	A	IRR	A	IRR	A	IRR	
1	3.0	1.00	1.7	0.83	1.3	0.83	2.7	0.83	3.0	1.0	**2.34**
2	3.3	0.83	2.3	0.83	1.3	0.83	2.3	0.83	2.3	0.83	**2.30**
3	3.0	0.47	1.7	0.83	2.3	0.83	1.7	0.83	2.7	0.83	**2.28**
4	1.7	0.83	2.7	0.83	1.7	0.83	2.3	0.83	2.7	0.83	**2.22**
5	2.0	0.47	2.3	0.83	2.3	0.83	1.7	0.83	2.3	0.83	**2.12**
6	1.0	0.83	2.7	0.83	1.7	0.83	1.3	0.83	3.0	1.00	**1.94**
7	3.3	0.83	2.7	0.83	3.3	0.83	2.3	0.83	3.3	0.83	**2.98**
8	1.7	0.83	1.7	0.83	3.3	0.83	2.3	0.83	3.3	0.83	**2.46**
9	1.7	0.83	3.0	1.0	2.3	0.83	2.3	0.83	2.3	0.83	**2.32**
10	2.3	0.83	2.3	0.83	1.3	0.83	2.7	0.83	2.7	0.83	**2.26**
11	2.7	0.83	3.3	0.83	2.8	0.83	2.7	0.83	3.3	0.83	**2.96**
12	3.3	0.83	3.3	0.83	2	0.83	3	1.0	3.3	0.83	**2.98**
A	**2.42**		**2.48**		**2.13**		**2.28**		**2.85**		**2.43**

Note: ID is the guideline ID, A is the average for the ratings and IRR is the inter-rater reliability. The righmost column is the average for the guidelines and the bottom row is the average of the ratings for each case.

Next, the three guidelines to which each organizational system is least aligned are analyzed and improvements are suggested. The following are suggested improvement actions for the DRP case:

- *Guideline #4:* The problem with the assessment of guideline #4 in the DRP case is that process performance is difficult to determine – it depends on the specific incident under study. When process performance is better defined, capabilities of resources in each process role may automatically be better defined and aligned to it. This being said, it is suggested that for at least the most common or frequent incidents, clear performance measures are defined.
- *Guideline #6:* Although interface channels are identified, they are not formalized and the interfaces with these channels are not standardized. Interfaces with outside organizations, particularly, are based on personal relationships. Interfaces with other hospital areas should also be better defined, as some of these, as commented in the interviews, do not know that the DRP exists. A major improvement would be to formalize these interface channels and train people to use them.
- *Guideline #8:* Most of the management and control mechanisms in place are related to interactions within the process and not with outside organizations involved in it. The establishment and training of ICT members in the use of these mechanisms, especially for coordination, delegation and decision-making should help improve process results.

The following are suggested improvement actions for the BPU case:

- *Guideline #1:* Although there are many different documents that determine how specific parts of the processes should be executed, there is no higher-level document of the process explaining it in general terms, linking all of these other documents and providing an overview of the integration of the BPU processes with other units – for instance, the employment services unit. It is suggested that such a document is constructed and shared with everyone involved in the process.
- *Guideline #3:* There is no clear definition of the BPU processes, but a set of documents determining how specific parts of it should be executed. There is a large dependence on experience for the processes of the BPU to be executed and workers have some autonomy on how to process requests. In order to reduce this variability and reduce the necessary experience to process requests, it is suggested that the processes are better documented and standardized.

- *Guideline #8:* There are many interactions with inside and outside agents in the processes of the BPU. Coordination and synchronization mechanisms are not formally defined and standardized – each worker uses his/her own. It is suggested, for better performance of the BPU processes, that these interactions are better documented and standardized.

The following are suggested improvement actions for the ISISU case:

- *Guideline #1:* Especially because of the nature of the work executed in the ISISU, it is difficult to see a close alignment between its processes and organizational context. This is particularly perceived in survey results and interviews. Although there is a clear objective for the ISISU and performance measures associated with its activities in documents, it is suggested that the role of the ISISU be strengthened among people working in the process to improve its performance.
- *Guideline #2:* The involvement of people working in ISISU processes in its design is marginal and done mainly through informal channels. Changes are gradual and whenever a major change occurs, it is usually associated with restructuring of the unit and its activities due to management decision.
- *Guideline #10:* There are little mechanisms incorporated both in process design and process implementation that are related to the detection of improvement opportunities and the management of change related to the implementation of an improvement. As mentioned, as the nature of the work is not seen as strategic, and people are only marginally involved in the design of the process, most of the improvement is done informally. When formal changes and improvements are executed, they are usually performed by managers or supervisors, or are the result of a major restructuring initiative.

The following are suggested improvement actions for the PSP case:

- *Guideline #3:* A PS functions mainly as a specialized problem-solver – a person in this role must balance lots of demands and restrictions to keep a production line in operation. Documents defining what activities and responsibilities are attributed to a PS do so at a high abstract level. When one talks to the PS and other people involved in the process, it becomes evident that some schedulers do things how they consider best. This lack of standardization and proper definition of the several elements of the process may cause an additional operational overhead for the scheduler and the factory staff. It is suggested that a more detailed view of the scheduling process be developed. This detailed view should focus on a low abstraction level, including details about systems, resources, interactions and information needed in the process.

- *Guideline #6:* Additionally to the unclear definition of the process, the unclear specification of interface channels also creates an operational overhead. The PS has to understand to what other organizational units it must interface, especially to solve a scheduling issue during the execution of a production order. This may be clear for the most experienced scheduler, but not for all of them. Occasionally, a situation will arise that even experienced schedulers do not know how to handle or with whom to interface with. Although exceptions are treated in another guideline, if a scheduler possesses a list of the interfaces, a solution for the problem could be more promptly encountered. It is suggested that interface channels are documented, specifying the exchanged information, and that the points of contact of the scheduling process are not specific people, but rather positions in the organizational structure that are aware of their responsibilities in the process.
- *Guideline #5:* The only structured information used in the scheduling process is the schedule itself. Even though it is structured, if one ever tries to integrate this schedule with another information system, chances are that this process will not be executed smoothly. It can be observed that the scheduler takes the schedule from the ERP system and makes extensive use of electronic spreadsheets. These spreadsheets are usually adapted to the scheduler’s needs, which eventually makes their reuse even harder. It is suggested that a standardized information structure for the schedule, available resources and production system restrictions be developed. It would be desirable that this information structure be created in the form of a meta-model that could be used to derive different instances of it for each one of the systems used.

The following are suggested improvement actions for the PDP case:

- *Guideline #2:* The product development process has a corporate nature and is executed the same way across other units. The process is well structured and most of the involvement of people in changes is informal, suggesting modifications or improvements to specific tasks, particularly in the context of the unit it is executed in. There is no structured procedure to review the process and incorporate improvements to it by taking into account the opinion of involved people and other interested parties.

- *Guideline #5:* There are many different types of information and documents used in a project, e.g., product and process specifications and supplier information. Sometimes, information that is structured for one system is reformatted to be input in another system – one example is the bill of materials for a product, which is in one format in the design information system and in another format in the production information system. It is suggested that automatic mappings are developed in order for this information to be more easily exchanged.
- *Guideline #9:* There is no explicit exception handling mechanisms in this process. Whenever something out of the ordinary occurs, the project leader is consulted or the manager of the division is consulted in order to determine what needs to be done. The team involved in a project must always find a solution to any exception that occurs. It is suggested that this situations start to be separately documented and explained in the learned lessons documentation generated at the end of the process and that this documentation is consulted when exceptions occur.

Table 6.6 lists some of the implemented identified practices that are responsible for making each one of the organizational systems analyzed more aligned to each one of the guidelines.

Table 6.6 – Identified practices for fulfilling the alignment to each guideline.

ID	DRP	BPU	ISISU	PSP	PDP
1	Emergency Operations Plan	Several documents, but a stronger relationship is missing	Some documents state the area	Process documentation	Product Development Methodology Brochure
2	Regular meetings and performance evaluation meetings	Team meetings and informal relationships	Only through informal relationships	Only through informal relationships	Only through informal relationships
3	No strict model, but course materials define the overall process	Several documents, but a stronger relationship is missing	Flowcharts and activity descriptions	Flowcharts and activity descriptions	Stage-gate process, activity descriptions and in-software documentation
4	-	-	Responsibility matrix	Documentation of roles in the process	-
5	-	-	-	-	-
6	-	-	-	-	Templates in the product

					development system
7	Shared folder in the intranet	Intranet accessible to all members	Intranet accessible to all members	Intranet accessible to all members	Product development system consolidates all information
8	Emergency Operations Center	Different information systems and informal contact among people	Ticketing system coordinates activities	Many different systems exist to coordinate and synchronize activities and sometimes are bypassed	Product development system coordinates activities
9	Emergency Operations Plan specify some exceptions	Escalation	Escalation, but team is responsible to solve problem	-	Escalation until a certain point and lessons learned
10	Performance evaluation meetings	Team meetings	-	-	-
11	-	Consistency is guaranteed because of the norms and regulations used	-	-	Product Development Methodology Brochure specifies terminology
12	Performance evaluation form filled out after an incident or exercise	Individual appraisals and number of processed cases per worker and unit	Number of tickets processed and average time a ticket remains open	Adherence to Production Plan (APP) of the production schedule	Monitoring of schedule and budget during a project and meeting of requirements and scope

Finally, some overall observations about the analyzed cases are presented:

- Specifications of process interfaces were usually poor, if at all existent. It seems that most of the definitions of a process are about its sequence, not about its interfaces and what information is exchanged through the interface.
- Interoperability was not systematically treated in any of the cases. Most of the interoperability in the cases was achieved through the use of common documents and databases and not the exchange of standardized information.
- People involvement was usually informal and third parties involved in processes were usually not consulted to design, redesign or improve the process.
- There is a focus in representing activities and their sequences in process models, but roles and responsibilities are usually not defined, what makes the assessment of the matching of process performance to capabilities extremely difficult.

- Process documentation should be hierarchically developed, meaning that there should be an overall document explaining the process and its alignment to the objectives of the organization and other documents detailing specific parts of this process.
- In most cases, exceptions are handled through escalating the problem to a higher managerial level. This, however, does not solve the problem, but rather delays its solution. Better exception handling mechanisms are needed in these cases.

6.5 DISCUSSION

A discussion of the usability and utility of the enterprise engineering guidelines and the assessment procedure follows. This discussion is based on the conduction of the case studies.

6.5.1 Enterprise engineering guidelines

Usability – Could guidelines be used to diagnosis an organizational system?

It can be seen in Section 6.2 that guidelines could be decomposed and generate an analysis framework that is usable, although there are many information requirements, and a lot of work is involved in collecting data in search for information evidencing them. It must be noted, however, that this is not the only possible decomposition. Particularly, guideline #4 was difficult to assess and its information requirements need better definition.

Utility – Do guidelines help in the diagnosis of organizational systems?

The enterprise engineering guidelines used addressed some of the difficulties of the organizational systems. Although general in nature, these guidelines were constructed in a way that relevant aspects of the context, structure and process of an enterprise engineering initiative are revealed. Using the guidelines as the basis for process diagnosis comes from the understanding that an existing process is the result of its implementation, which is an enterprise engineering initiative.

6.5.2 Guidelines alignment assessment procedure

Usability – Could the procedure be used in the assessment of alignment to the guidelines?

The procedure could be used, although it involves many steps, information sources and reviews. It is extremely difficult not to use the procedure without the help of an information system that organizes and manipulates data and helps in data analysis. The rating stage is very demanding – raters have a large amount of information to review and the rating process takes a long time.

Utility – Does the procedure help in assessing alignment to guidelines?

The analysis framework systematically treated a variety of evidence gathered from different sources, organizing it and helping its analysis. The decomposition of the guidelines into analysis points and information requirements and the grouping of information requirements in worksheets by source of information helped direct the evidence gathering efforts and focus on the needed data. The assessment procedures guided analysis by organizing data and providing raters with the necessary evidence for evaluating information requirements and analysis points. The use of more than one rater helped increase the reliability of the analysis.

The guidelines also provide a direction for improving the process. However, they do not prescribe a clear path for how improvements should be implemented nor prescribe the exact practices that should be used in the process. This still is dependent upon experience with the process and knowledge of its context.

6.6 CONCLUSIONS

A good design and a good implementation of a design are by no means guarantees for good performance – one cannot even say that they are necessary conditions. However, good designs and implementations ensure that resources – e.g., processes, information, interfaces, people and knowledge – are structured and deployed in such a way that one may expect good results from their application and use. Enterprise engineering, in particular, advocates that in order for an effective performance to be achieved, an organization must be well designed, and the design must be well implemented.

This work analyzed the application of enterprise engineering guidelines to the diagnosis of organizational systems by proposing and evaluating a data collection and analysis procedure. Guidelines helped accomplish the objective of finding improvement suggestions to the organizational system under study by prioritizing the analysis of the least aligned ones.

The objective was not to determine whether an organizational system is or is not performing well, but rather to determine whether it may have the potential to perform well. This is a very relevant question. On the one hand, if an organizational system is not performing well, but has the potential to perform well, the problem lays on the execution; if it does not have the condition to perform well, the problem lays on its design. On the other hand, if it is performing well, but does not have the potential to perform well, this is an unsustainable situation that has to be addressed if the organizational system is to survive; if it does have the potential to perform well, this is the sought condition.

Both enterprise engineering guidelines and the assessment procedure could also be applied to the analysis of organizational units or processes from different areas. This could lead to the refinement of the guidelines model and the assessment procedure. Results of the analysis are, however, limited by the knowledge that raters have about the application area under consideration and knowledge that the analyst has about the process to elaborate improvement suggestions. Other types of guidelines, for specific knowledge areas or domains such as quality systems could be developed and benefit from the same assessment approach detailed in this work.

Guidelines could also be extended if a set of practices related to it could be taken into account when analyzing them. Through this set of practices, suggestions about what should be implemented to improve the process could be done more systematically. They would also benefit the analysis framework, directing raters to what to look for in the provided evidence. The set of practices could be identified through the consistent application and further deeper screening of the results of the analysis framework in a series of assessment cases. A maturity framework could also be created as a result of the analysis of such cases.

Guidelines provide a framework from which to explore the relationships among variables of a process and organizational performance. For instance, what is the impact of interoperability and exception handling in process performance, given all other variables are held constant?

Guidelines could also be applied in conjunction with other methods and frameworks. For instance, an enterprise architecture framework could benefit from the application of the guidelines for its use as a means of generating an enterprise design that is well structured.

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7 ARTICLE #5 – PROCESS-AWARE PROJECT MANAGEMENT SYSTEM

This paper proposes a Process-Aware Project Management (PAPM) system for enterprise engineering initiatives such as enterprise engineering diagnosis projects. Foundations for this system are presented, as well as the main implementation aspects. The relevance of this paper to this research project is that each one of the cases in the project is treated as an enterprise engineering initiative and an information system that aids in the manipulation of collected data facilitates data analysis. The system is, thus, part of the procedure and project management dimensions of the process approach used to define the case study protocol described in Article #4. Table 7.1 presents works that contribute to this article.

Table 7.1 – Works related to the development of the PAPM system whose contributions lead to this article.

#	Notes
1	Technical report on the implementation of the PAPM system
2	First version submitted to the 2nd Adaptive Case Management Workshop (ACM) of the On The Move Federated Conferences and Workshops (OTM) 2013 to be held in Graz, Austria, on September 11th, 2013.

A Process-Aware Project Management System for Non-Structured Processes

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Abstract

Enterprise engineering initiatives may be used to diagnose, design, improve and deploy enterprise systems. They involve the integration of a large number of different techniques and have a scope that evolves with its execution, as more information becomes available. These initiatives are performed in different conditions for each new project, which requires a flexible information system. This work presents and discusses a process-aware project management (PAPM) system for planning and executing enterprise engineering initiatives. This system is based on project management, process management, enterprise transformation and systems engineering practices. It organizes a project as an iterative set of phases composed of steps that implement different enterprise engineering techniques. However, phases and steps are driven by user decisions rather than system decision, because it is considered that each project has specific characteristics and demands. The implementation of the PAPM system using open-source BPMS and DBMS is presented and an example of its application to a production scheduling process scheduling project is discussed.

Keywords: enterprise engineering, project management, process management

7.1 INTRODUCTION

During their existence, enterprises face a constant need for change in the way they operate. This need comes from a very diverse set of demands, usually associated with adding more value to their product and service portfolio by means of cost reduction, quality improvement and development of new technologies. These demands press enterprises for immediate action in the reorganization of their structure, processes and systems – initiatives that due to their inherent complexity are managed very differently according to scope, context and available resources. These initiatives may be called a broad range of names, including: process reengineering; kaizen events; compliance auditing; restructuring projects; or continuous improvement projects [1]. All of these initiatives may also be referred to as enterprise engineering (EE) projects [2] and are generically described by one or more actions executed in a set of domains over a set of objects, with some of the possible combinations shown in Table 6.2. Examples of EE projects are: (i) the diagnosis of a quality assurance system conceived to comply with the ISO 9000 series of standards in order to identify improvement points [3]; (ii) the redesign of processes and organizational structure of a production planning department so that a new enterprise software system for production programming may be used [4]; and (iii) the design of a performance measurement system able to collect information necessary to assess whether the organization is achieving its goals [5].

In essence, despite their differences, all these projects deal with the transformation of an enterprise in an orderly manner. The main problem is that it is very difficult to know in advance all the necessary steps of an EE project, the techniques that will be applied, the necessary information and how this information will be manipulated. Information available in the beginning of the project is limited and as the project advances and more information becomes available, steps may be added, adjusted or even eliminated to better suit this information, according to the assessment of a project manager or a team member. The planning of next actions becomes an iterative and user-driven task. This situation can be better understood by taking the example of the quality assurance system diagnosis in detail. People participating in the project must first understand the boundaries of the system in order to determine who should be selected for interviewing, and what processes and standards should be analyzed. Manuals, forms, reports, process records and other documents used in the system may not be listed in the official system standards and are identified only after interviewing some of the people. As the diagnosis progresses and information becomes available, the need for additional interviews and observations to cross-examine some of the evidence that was found proves necessary. These additional forms of data collection are planned according to the specific context of the organization. Data from different sources must be properly organized and the opinion of multiple people is necessary in order to remove analysis bias. Sometimes, additional analysis must be performed because opinions about a rating are positioned on the opposite extremes of a scale. This is clearly a non-structured type of situation in which the discretion of the project manager and project team members about what to do plays a significant role.

Table 7.2 - Examples of possible enterprise engineering projects.

Actions	Domains	Objects
Auditing/diagnosis Design/redesign Documentation Standardization Implementation	Quality management Production planning Performance measurement Finance/accounting Supply chain management Maintenance Product development	Processes Organizational structure Information structure Enterprise architecture Systems

Although these situations have characteristics of a project (temporary, progressive and generating an exclusive result) and a process case (with a set of pre-determined steps using an organized set of resources), approaches based solely on project management or process management techniques do not conform well to them. Project management approaches usually fail because they overemphasize the planning stages, with replanning becoming a common task and adding a considerable overhead of work. Process management approaches usually fail because of the uniqueness of the case. The sequence of steps is not well defined in the beginning and has to be determined during execution.

This work addresses these issues by proposing a more flexible approach for managing EE projects as adaptive process cases, focusing on the fact that these projects are driven by user decisions. This approach combines practices of the process management, project management, systems engineering and enterprise transformation areas to deal with the characteristics of such projects as explained in the previous paragraph. The approach is implemented in the form of a Process-Aware Project Management (PAPM) system deployed on a combination of Business Process Management System (BPMS) and Database Management System (DBMS).

The next section will discuss the components of process management, project management, enterprise transformation and systems engineering that underlie the PAPM system. Section 3 presents the PAPM system by showing its main models and discusses its implementation. Section 4 details an application of this system to the auditing of a production scheduling process and Section 5 presents conclusions about this work and perspectives for its further development.

7.2 FOUNDATIONS

There are three main concepts in understanding the foundations for the PAPM system: project management, process management and EE project.

Project management is the area concerned with the managing of temporary and progressive initiatives that generate an exclusive result by application of tools and techniques to the initiating, planning, executing, controlling and closing stages of their life cycle [6]. These initiatives are called projects. Projects are unique in their context and their planning is a complex task, involving the extensive use of expert knowledge. Project execution and controlling is usually preceded by a long planning stage, although there are iterative project management methodologies that reduce its duration.

Process management, on the other hand, is the area concerned with managing actions that occur repeatedly in the context of an organization, processing inputs into outputs and using a set of resources [7]. These actions are called processes and they are organized in a sequence of activities. Process management is usually implemented through a planning, implementation, enactment and evaluation life cycle, but once processes are deployed it is expected that they help performing routine work [8]. Each time a process is executed a process case is generated and this case is a unique situation of transforming inputs into outputs.

An EE project was already defined in the introduction. It must be noted, however, that EE projects are considered to be enterprise transformation projects and are studied in the systems engineering area [9], [10]. Systems engineering studies the design and implementation of complex, highly coupled systems [11]. Requirements for such projects are usually stated as an overall objective – and project actions iteratively try to achieve this objective by means of a set of steps in which expert knowledge is one of the main assets.

Given these definitions, Table 6.3 presents the main EE project characteristics and how project management and process management are related to them. It can be seen from this table that neither approach, by itself, is able to address all of the characteristics of an EE project.

Table 7.3 - EE project characteristics and how project management and process management address them.

EE project characteristics	Project management (PjM)	Process management (PcM)
Temporary	Projects are temporary actions	Processes are not temporary, but a process case is
Generates an exclusive result	PjM actions are directed at generating an exclusive result	Processes do not aim at generating an exclusive result, but a process case does
Organized in phases	PjM defines a set of stages as part of the life cycle of a project	PcM defines a life cycle for the management of a process, not for process or process case by itself
Executed through a set of steps	PjM defines steps for managing a project, not for executing it	A process is executed through a series of steps
Each step processes inputs into outputs	PjM defines inputs/outputs for managing a project, not for executing it	Inputs and outputs are formally treated
May have loose rules associated to its execution	PjM makes use of rules	PcM makes extensive use of rules for sequencing activities and processing inputs into outputs
Makes use of expert knowledge to drive its execution	PjM makes extensive use of expert knowledge	PcM makes use of expert knowledge only in the planning stage of a process

7.3 PAPM SYSTEM

This section describes the PAPM system by introducing its conceptual and implementation models. These models are presented by using the Systems Modeling Language (SysML) [12]. Three different types of models were used: block description diagrams, state machine diagrams, and activity diagrams.

7.3.1 Modeling

In the context of the PAPM system, a case or project is composed of phases, which, in their turn, are composed of steps. Phases and steps are derived from phase templates and step templates, respectively. Phase and step templates generically describe the elements necessary for an instance of a phase or a step. A step template must have two processes – a configuration process and an execution process. A step may be performed by any of a set of project users. Projects are to be configured by creating phases from a set of phase templates, by adding steps from a set of step templates, by configuring steps through their configuration processes, by sequencing steps and by selecting step users. Projects are executed through the execution process associated to their steps, starting with the set of initial steps and following the steps sequence. In a formal way a project P is described as $P = (F, S, S_0, p, s, t, u)$, where:

- F is the set of phases in a project;
- $f: F \rightarrow F_t$ is the function that associates each phase in a project to a phase template;
- F_t is the set of phase templates;
- S is the set of steps in a project;
- $S_0 \subseteq S$ is the set of initial steps;
- $s: S \rightarrow S_t$ is the function that associates each step in a project to a step template;
- S_t is the set of step templates;
- $t: S \rightarrow S$ is the transition relation, associating each step in a project to a set of next steps;
- $u: S \rightarrow U$ is the user relation, associating each step in a project to a set of users; and
- U is the set of users in a project.

All of these components can be seen in Figure 6.1 in the form of a SysML block definition diagram.

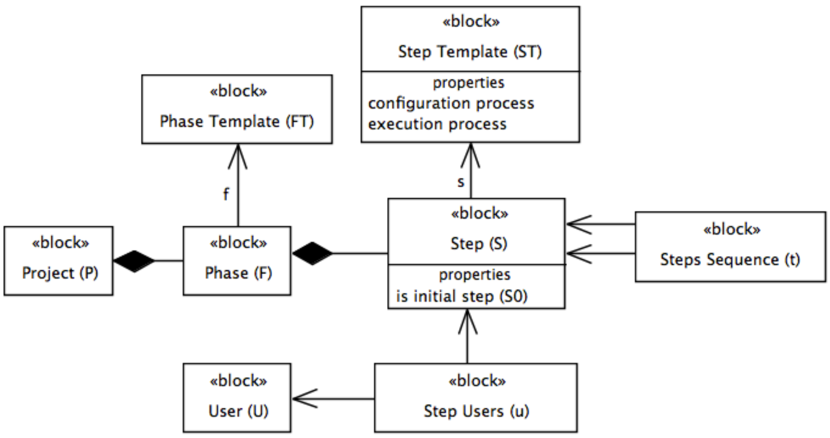


Figure 7.1 - SysML block definition diagram of the main components of the PAPM system.

The set of phases, steps, step sequences and step users in a project may change over time. After a project is created, it must be configured. As soon as an initial configuration is ready, the project can be executed. After some of the necessary steps in the project are finished, project execution may be suspended and the project can be further configured – additional phases and steps may be added and existing phases and steps may be configured or deleted. After this configuration is done, the project can be resumed. This suspend/resume cycle can be performed as many times as necessary. Figure 6.2 presents the SysML state machine diagram representing the life-cycle of a project in the PAPM system as described in this paragraph.

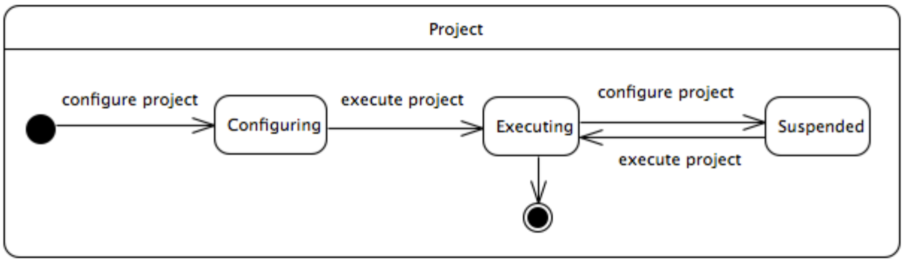
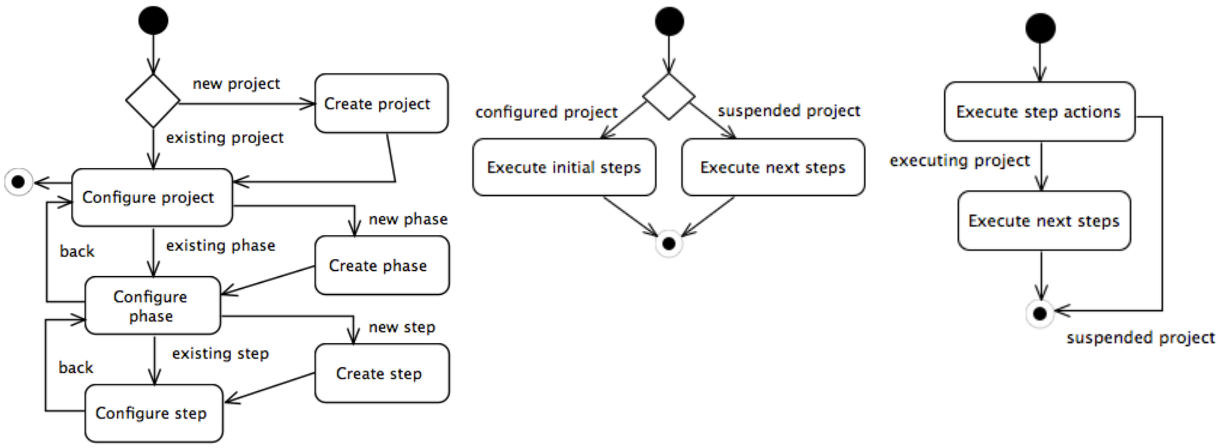


Figure 7.2 - SysML state machine diagram of a PAPM system project.

From this diagram it can be noted that state transitions are triggered by two activities: configure project and execute project. These activities are processes associated to the PAPM system. The configure project process actions were already explained in the first paragraph of this section. The execute project process has to either start or resume project execution from initial or next project steps, enabling their execute step process. Activity diagrams presenting the configure project, execute project and execute step processes are presented in Figure 6.3.



(a) Configure project *(b) Execute project* *(c) Execute step*

Figure 7.3 - SysML activity diagrams of the configure project, execute project and execute step processes.

Lastly, once a step is under execution or finished it cannot be changed, but as long as its execution has not started, it can have the step sequences in which it is involved and its users modified. Figure 6.4 shows the SysML state machine diagram associated with a step in the PAPM system. State transitions are triggered by the configure step process and by the execute step process. This last process is presented in Figure 6.3.

7.3.2 Implementation

The PAPM system described in the previous subsection was implemented through the combination of a Business Process Management System (BPMS) and a Database Management System (DBMS). The chosen BPMS was Bonita Open Solution (BOS) version 5.10 and the chosen DBMS was MySQL version 5.5. Reasons for choosing them were: (i) they fulfill the necessary requirements for implementing the PAPM system; and (ii) they are open-source systems and have a community edition that is free of charge, enabling others to replicate results. The main elements used in the implementation of the PAPM system are shown in Figure 6.5 and are, besides the previously mentioned BPMS and DBMS, the PAPM Base System, PAPM Extensions and external applications. External applications may extend the system by providing other functionalities such as content management or statistical analysis. External applications and the DBMS are accessed by the BPMS.

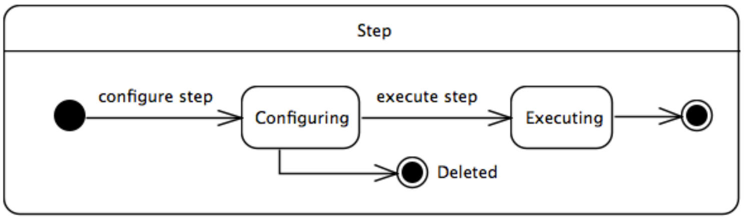


Figure 7.4 - SysML state machine diagram representing the life-cycle of a step in the PAPM system.

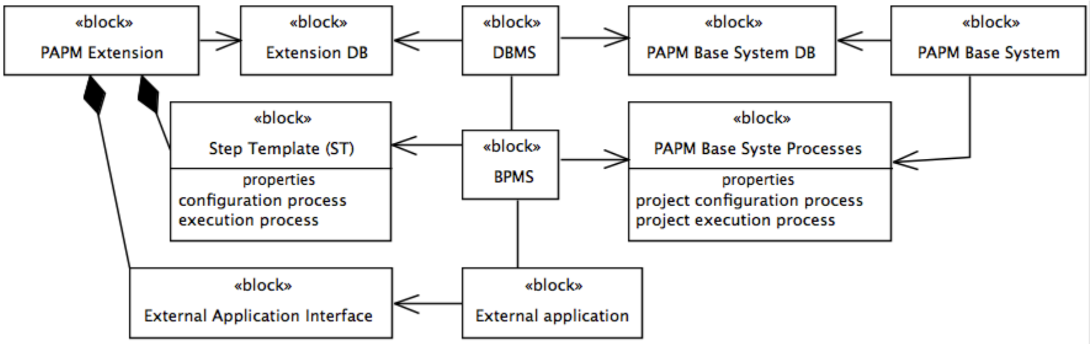


Figure 7.5 - SysML block definition diagram representing the elements necessary for implementing the PAPM system.

The PAPM Base System is composed of a database and a set of configuration and execution processes. The PAPM Base System DB structure is derived from the block definition diagram in Figure 6.1 and implemented in the DBMS. The PAPM Base System Processes are the processes used to configure and execute a project and are implemented according to the activity diagrams in Figure 6.3 and the state machine diagrams in Figure 6.4 and are implemented in the BPMS using Business Process Modeling Notation (BPMN) models.

For a project to be executed, step templates from the steps to be used in the project have to be added to the BPMS by means of a PAPM Extension. Extensions must comprise a set of step templates, a database and interfaces to external applications. The configuration and execution processes of the step template are also implemented in the BPMS using BPMN models. The database and interfaces to any external applications, if necessary, are deployed in the DBMS and in the external applications, respectively.

7.4 APPLICATION

The PAPM system was applied to the production scheduling process auditing project of a cosmetics manufacturer. In this project, information requirements were collected from multiple sources in order to provide evidence for rating the alignment of the process to a set of enterprise engineering guidelines [13]. The project was conducted according to the Cambridge process-approach [14, 15], taking its four main perspectives into account:

- **Point of entry:** A person in the organization was responsible for communicating the importance of the project to people involved in the process, for scheduling interviews and for providing access to the necessary information (manuals, forms, process records and other relevant organizational documents).
- **Procedure:** It was defined that the project would have three phases – an initiation phase, an information collecting phase and an evaluation phase. Each of the phases would have steps related to collecting information requirements, rating the information requirements and rating the guidelines. These steps were defined in general terms, with their specificities detailed in the moment of their execution.
- **Participation:** Besides the person serving as the point of contact, three other people participated in the process. Two of them were responsible for collecting the data and all three of them were responsible for rating the information requirements and the alignment of the process to the guidelines.
- **Project management:** The project manager was in charge of the organization of all the collected evidence for the information requirements and the results of the

analysis. The project manager was the person who defined the necessary steps according to the collected evidence.

As it would not be possible to define all the project steps from the beginning, a more flexible approach for managing the project was necessary – that is, next steps would be planned according to the result of previous steps, justifying the application of the PAPM system described in the previous section. The PAPM system was used to support two of the mentioned perspectives from the process approach: procedure, associated to structuring the phases and steps and project management, associated to organizing the sequence of steps and the collected information requirements.

Table 6.4 shows the phase and step templates for this project according to the procedure perspective and Figure 6.6 shows the overall sequence of phases and steps of the project derived from the phase and step templates. These are the phases and steps that were actually executed and created in the PAPM system.

Table 7.4 - Phase templates and step templates for the production scheduling process auditing project.

Phase templates	Step templates
Initiation phase: definition of project boundaries and gathering of the necessary information about the process and organizational unit to plan the first collect information requirements steps.	*Collect information requirements (CR):* evidences for a list of information requirements is collected from one of five possible sources (organizational documents, process records, interviews, observation and survey application).
Information collecting: gathering all the evidence from multiple information sources from a series of collect information requirements steps.	*Rate information requirements (RR):* each one of the information requirements are rated for their quality (existence and consistency) according to the collected evidence from the different sources.
Evaluation: with all the evidence for the information requirements collected, information requirements are rated and guidelines are rated in order to assess the process.	*Rate guidelines (RG):* the alignment of the process to each guideline is rated according to the evidence collected for the information requirements and their assessment.

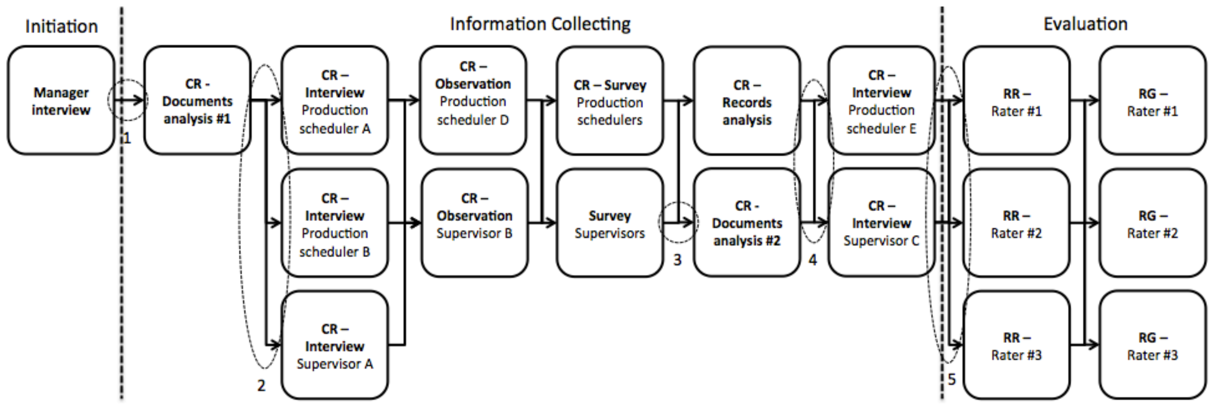


Figure 7.6 - Overall structure of the project or process case after its full execution.

In order to exemplify how user decisions impacted the project, five situations are identified in Figure 6.6. These situations are explained below:

- Situation #1 is the definition of the outlook of the information collecting phase based on the results of the manager interview. This resulted in the project manager defining that before any other action, documents used in the process would be analyzed to determine the proper data collection approaches.
- Situation #2 is the definition of the information requirements sources based on the analysis of the documents. It was defined that two production schedulers, along with a supervisor, would be interviewed first. After these interviews, observations would be conducted and a survey would be applied to all production schedulers, and another survey would be applied to all supervisors. Only after these steps, process records would be analyzed.
- Situation #3 is the perception that further document analysis is needed after analysis of interviews, observations and surveys results. The objective was to review some of the documents and clarify points mentioned in the interviews and surveys and noticed during observations.
- Situation #4 is the definition that interviews were necessary to cross-examine some of the collected evidences, especially after the second documents analysis step. These interviews confirmed some of the diverging evidence collected.
- Situation #5 is the definition of the evaluation phase based on the results of the data collection phase. In this project, evaluation was straightforward, that is, three raters were used to first rate the quality of evidence for the information requirements and then rate the alignment to the guidelines. If ratings have a high standard deviation, more rating steps can be used.

7.5 CONCLUSIONS

This paper presented the PAPM system to help manage EE projects as process cases, addressing the fact that such projects are usually iterative and user-driven, with most of the traditional project and process management techniques not suiting them well. The fact that some of the next steps are defined based on previous project information, and that a more flexible and adaptive reconfiguration of steps is necessary are taken into account in this implementation. The project manager or project team member has discretion over the definition of next actions and their configuration. The system can be implemented over any combination of BPMS and

DBMS by using the presented models. The application to the auditing of a production scheduling process is presented.

One of the main features of the PAPM system is its extensibility. The general models allow for any type of technique necessary in an EE project to be implemented. The application described in this paper implemented three step templates that may be used in any EE project, implementing data collection and rating techniques. Other techniques such as process modeling, organizational modeling, process mining, organizational mining, to name a few, may be implemented in the same way.

Sometimes, a very large amount of data is processed in the steps of an EE project. The PAPM system still does not take into account these data and their processing as system components. Inputs and outputs of process steps and the linking of the output from a process step to the input of a subsequent step are the responsibility of the step, not the system. If inputs and outputs become system components, definition of data types and linking of inputs and outputs would facilitate data manipulation and the handling of information present in the project steps as overall project (or process case) information. This is also true for the implementation of rules.

Lastly, testing and validating the system in other EE projects is necessary in order to determine its ability to handle different situations.

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8 CONCLUSIONS

The objective of this work was to propose and test the application of a possible systematization of contributions to the enterprise engineering research field. Chapters 3 through 7 present papers proposing the results of this research. The content of these chapters will be revised and submitted to scientific journals. Several contributions resulted from this dissertation and are summarized in Chapter 8. These results are, in brief, the systematization of contributions, the system for data manipulation, the data collection procedure and the data collection instruments. These results, besides their application in this project, have the potential to be applied to a series of different enterprise engineering initiatives.

This work is innovative and provides original research in two fronts: its content and its method. Content is original, as the systematization proposed in this work, in the form of general statements applicable to enterprise engineering projects has not been found in the enterprise engineering literature to date. The literature of this field usually contains contributions in the form of prescriptive models applicable to some situation in a developmental fashion. The exploratory nature of this work, hence, makes it unique in trying to organize common aspects of these contributions so that this organization is applicable to a larger number of situations. The adopted method is innovative as it combines three different methodological approaches – systematic literature review, Delphi method, and case study method – using the advantages of each approach to address the limitations of the other approaches. It also fills a gap shown in the maturity assessment of the enterprise engineering field – the need for more empirical research. Considering its limitations, the results of the systematic literature review in Chapters 3 and 4 confirm both the originality and innovativeness of this research.

There are, however, some limitations to the results of this project. These limitations are associated to each one of the methods used and are discussed next.

The systematic literature review method is limited by the works found, by the works selected, by the moment in which it was concluded, and by the person performing it. The use of other reference databases or the search in other sources may result in a different set of works that could change analysis and results. Additionally, as soon as the review is concluded, other works related to the subject may have been published, also changing analysis and results. Finally, although this approach tries to remove as much bias and subjectivity as possible by using a structured approach and well-defined techniques, such as author co-citation analysis, it is the interpretation of a researcher that generates the results. A different researcher could come up with different results – in this case, a different preliminary set of enterprise engineering guidelines as the starting point for the Delphi study. Although the Delphi study is used to reduce bias and subjectivity, a different preliminary set of guidelines could be used to generate a different initial set of guidelines. It is expected that these sets of guidelines would be similar, but they would be, nevertheless, different. Systematic literature reviews, although comprehensive, are not complete and definitive representations of a subject.

The Delphi study is also limited by two factors: the participating experts and the researcher performing the analysis between each one of the rounds. Participating experts were chosen as the main authors identified in the systematic literature review. Although selecting experts in this manner should result in the participation of people with the most relevant contributions, limitations discussed in the previous paragraph also apply here. Even though this approach reduces the probability of bias and subjectivity, one cannot assure that this will happen – participating experts may be influenced by recent experiences that may have a more negative or positive impact on their judgments. If this systematically happens with a large number of the participating experts, results may be biased.

Bias from the researcher performing the analysis between each one of the rounds is also possible. The researcher has to be careful to present only factual information from previous rounds to the participating experts and avoid any kind of judgment. Information should be compiled as is – nothing should be interpreted. Interpretation is required only in the final analysis stage of the Delphi study in order for the initial set of guidelines to be generated.

The number of rounds of the Delphi study also play a role regarding limiting the results of the work. As a general rule, the more rounds the Delphi study has, the stronger the consensus that is achieved. Nevertheless, repeating a large number of similar surveys to participating experts over a short period of time, requiring a considerable amount of their time does not result in a high participation rate. There must be a balance between the number of rounds and rate of participation – and some works, as shown in Hasson and Keeney (2011) argue that in three rounds or less it is possible to achieve strong consensus.

The case study approach is limited by the cases selected for analysis. Variables were defined in order to keep variability of cases within a certain range. Even though the nature of research in this project is exploratory and cases were selected for their diversity, more cases, from different application areas (e.g., quality management, inventory management, finance) may create better results. It must be noted that this project does not aim at generalizing ideas. Generalization in case study research is also a delicate issue. The more cases are analyzed, the better position a researcher has to generalize findings. The strength of generalization will be greater whenever selected cases exhibit a common behavior or characteristic. In this project, though, generalization is secondary. Even if results cannot be generalized, it is expected that situations that prevent the proper application of the systematization for diagnosis are identified and that these situations help in revising the model and the procedure used for analyzing it.

One other limitation common to any case study based research must also be addressed here: researcher bias in both the data collection mechanisms and the data analysis techniques. Researcher bias is reduced through the use: (i) of a structured approach for data collection – the Cambridge process approach and the system for organizing the data; and (ii) of inter-rater reliability evaluation in the analysis of results of the organizational systems alignment to the proposed systematization. Although reduced, it must be noted that it is still present – and the same argument used for the systematic literature review is valid here: different researchers would arrive at different results, but it is expected that this results would be similar.

For future research, the systematization could be applied to different situations, not only the diagnosis of organizational systems. As presented in Chapter 7, enterprise engineering projects can be described by an *action* over an *object* in a *domain* – and the consideration of different actions, objects and domains for the application of the systematization can benefit both the model (for it to be extended in the same way that is proposed to be done through the case studies) and the practical world, for the consideration of the elements of the systematization may result in better implemented initiatives and organizational systems.

Guidelines could be applied together with specific enterprise engineering methods or tools. For instance, an organizational system could be designed according to the guidelines through the use of an enterprise architecture framework such as the Zachman framework or TOGAF (The Open Group Architecture Framework). The relationship between the application of guidelines with different methods and tools could be investigated.

Guidelines could be explored as variables from which to determine the success of an enterprise engineering initiative. For instance, how do organizations that are aligned to context and share their process models and elements compare to organizations that do not?

The collection of practices evidencing alignment to the guidelines could be extended. The inclusion of more practices to the list would lead to a better understanding of how guidelines are implemented and could be used in enterprise engineering design, redesign and implementation projects. This, together with new assessments and discussions, could lead to the development of a maturity framework for enterprise engineering.

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APPENDIX A

LIST OF WORKS USED IN THE ANALYSIS OF CHAPTER 3

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