Analysing the Provenance Tracking of Business Process Management in the Quality Domain

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Abstract

Organizations cope with complex, persistently changing environments and have to be reactive if they want to keep their market presence. The quality approach provides a set of methodologies and principles which help organizations to guarantee a long term success. The main concept of this approach is to satisfy customers by developing products and services that satisfy their needs and exceed their expectations. In order to guide organizations to the implementation of the quality approach, the ISO 9001 standard has been created. This standard is composed of different quality principles which provide a framework of best practices. Among them there is the "process approach" principle which underlines the fact that managing activities and related resources as processes enables users to achieve a desired result more efficiently. There is also the "evidence-based decision making" principle which underlines the fact that effective decisions are based on the analysis and evaluation of real data and information.

The Business Process Management (BPM) field defines different steps and tools in order to enable organizations to implement a process approach. The concept of it is to design, analyse, implement and execute business processes in order to clearly see how business entities work and to provide a structure to control and improve the way an organization works. Provenance is another field which provides trustful information by tracking the different events that happen to a digital object. Both fields are relevant to one of the quality principles: BPM to the "process approach" principle and "provenance" to the "evidence-based decision making" principle. From a literature analysis, a few existing works combine BPM and provenance providing benefits for specific aspects in the organization (e.g. to improve the compliance, to improve the process model, to improve the software development, or to improve the realization of innovative ideas). This thesis analyses the combination of the concept of BPM and provenance regarding the two quality principles, by investigating to what extent such a combination can benefit organizations in the quality domain.

This work presents a framework of how Provenance can be combined with BPM. This is achieved through a use case, from the Martine Spécialités enterprise which is using the Agilium BPM system (without the provenance functionality). Using the PROV Data Model, a graphical representation of the provenance tracking of the processes of the enterprise has been done and the functional requirements for combining provenance and BPM have been defined. A survey was submitted to the employees in order to see if adding the provenance functionality is something beneficial for them. The results have shown that provenance is adding value for the decision making during the execution of the processes, and that several benefits can be obtained from this, such as better decision making and time saving.

Dedication & Acknowledgements

This thesis is dedicated to my family.

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Without the support of my parents, who have strongly encouraged me, this work would not be possible. Their happiness and their kindness really helped me during this work.

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Chapter 1 – Introduction

1.1 Introduction

This chapter identifies the subject of interest of this research study and the motivation for carrying out this work, which is related to the analysis of the combination of two concepts: Provenance and Business Process Management (BPM) in the Quality domain. It introduces the context and defines the hypothesis and research questions that will be the focus of this work. As well as these, the research methodology which is the chosen approach to carry out this study is also described. The last part of this chapter is related to the presentation of the structure of the thesis.

1.2 Motivation

In complex and persistently changing environments, it has become crucial for organizations to continuously satisfy their customers in order to maintain their market presence. The role of the quality approach, which can be defined as the ability to satisfy stated or implied needs, is to help organizations to reach this objective (Eszter Tóth and Tamás, 2014). This approach can be considered as a competitive advantage and it delivers real value and benefits to organizations such as the improvement of effectiveness, flexibility and reactivity (Pillet and Duret, 2008). For example, thanks to the implementation of a quality approach, an organization can have a better understanding of customer expectations which should lead to fast responses to market opportunities. To guide organizations to the understanding and the implementation of the quality management approach, the International Organization for Standards (ISO) has created the ISO 9001 standard (International Organization for Standardization, 2008). The objective of this standard is to ensure that customers' requirements are taken into account and that the organizations know how to satisfy them in a way that is sustainable. The standard defines a set of exigencies relative to the implementation of a system of quality management. Today, the quality approach is still a subject of concern as demonstrated by the fact there is a recent version of the standard ISO 9001 to keep helping organizations towards the improvement of their performance (International Organization for Standardization, 2017). The main question remaining is how it is possible to improve customer satisfaction?

The ISO 9001 standard is based on different quality principles which provide a framework of best practices for organizations (International Organization for Standardization, 2015). One of those quality principles deals with the process approach, considered today as a fundamental concept (Club des pilotes de processus, 2016). It defines the importance for an organization to manage their activities and related resources as a process (International Organization for Standardization, 2015). Business Process Management (BPM) is an approach that enables implementations of this process orientation principle in organizations. Indeed it is a methodology that defines the different steps and tools in order to help organizations to be process oriented. In recent years, BPM has become an important research domain that has matured considerably

(Vom Brocke *et al.* 2014). BPM is now considered as one of the major topics in modern information systems (Bucher, Raber and Winter, 2014) and there is a proliferation of BPM modelling languages, standards and software systems (Ko and Wah Lee, 2009). This is illustrated by the BPM software market which is considered as the second fastest-growing middleware (a form of integrative software) market segment. A survey on modelling techniques confirms this proliferation with a list of at least 18 different modelling techniques used by BPM practitioners (Davies *et al*. 2006). The management of the work with processes enables organizations to have a clear vision of the activities realized in order to satisfy customers' requirements. BPM brings a structure and a process of continuous improvement to control efficiently its organization. Because of its multifaceted approach (since it concerns both organizational and technological aspects (Caetano, Pereira and Sousa, 2012) and its positive impact on organizations, such as costs reduction (Kohlbacher, 2010), BPM is a complex field that continues to be investigated (Hammer, 2014).

Another quality principle is focused on the evidence-base for decision making (International Organization for Standardization, 2015). The main objective of this is to obtain effective decisions based on the analysis of data and information. A recent concept in the computer science world called "Provenance" enables the provision of information on the history of a piece of data (or process). Indeed it records the changes that have happened for data produced, starting from its original source (Ram and Liu, 2014). Therefore, it constitutes an audit trail of how a piece of data or information came into being. This is useful in terms of quality as it gives an understanding of the context in which an action was made by ensuring where, when, how, for what purpose and who is using data. Firstly it allows people to trace the source or origin of some element of interest and secondly it finds its use in different areas such as in the scientific domain (for example to determine the veracity and quality of information, in collaborative research) or in the business domain (for example in order to maintain the data quality and avoid costly errors in business forecasting) (Simmhan, Plale and Gannon, 2005).

On one hand, BPM is relevant to quality since it is based on the process approach quality principle. On the other hand Provenance is relevant since it provides a factual approach to decision making. The purpose of this research is to investigate the combination of the BPM approach with Provenance in order to see to what extent such a combination of the two can benefit organizations in the quality domain. It will provide a framework of how Provenance can be combined with BPM in order to facilitate the improvement of quality.

1.3 Research Context

This work is done in the framework of the CRISTAL-ISE project (Shamdasani *et al.* 2014). CRISTAL-ISE is an Industry-Academia Partnerships and Pathways (IAPP) Marie Curie Actions project, funded by the European Union. It consists of three main project partners which are the University of the West of England (UWE, Bristol, England), M1i Sarl (Annecy, France) and ALPHA3i (Rumilly, France). The primary focus of the project is to develop long lasting and beneficial collaborations across the partners using the CRISTAL software ((Branson *et al*. 2014)

as a basis for this. This software had previously been developed at the European Organisation for Nuclear Research (CERN, Switzerland), in collaboration with UWE and the Centre National de la Recherche Scientifique (CNRS, France). At the end of the CRISTAL-ISE project it is foreseen that there will be three final pieces of software developed. These will be:

- A new open source version of CRISTAL (UWE).
- A new version of Agilium (M1i), a BPM system (AGILIUM, 2016) which will be based on this open source version of CRISTAL.
- And CIMAG-RA (Alpha-3i), a resource allocation application, which will be built upon both the work developed by UWE and M1i.

The specificity of the CRISTAL software is that it is a so-called *description driven system* which excels in the area of provenance (Shamdasani *et al.* 2014). It brings the following advantages: users who develop models of systems need only define them once to create a usable application. CRISTAL then orchestrates the execution of the processes defined in that model (with the consequent capture of provenance information). For the Agilium BPM system, which is based on CRISTAL, it provides many benefits: firstly it allows the modification of an on-going process in a graphical form and in real time. Without interrupting the business processes, the user can make modifications directly and graphically to any process parameter (workflow, data definition, roles). Secondly, on the basis of process indicators and/or piloting rules and external events, the system can modify the planned execution of a process without previous modelling. This function guarantees company flexibility by allowing it to react rapidly to external events which have not been modelled, without having to review or complicate the model itself.

Thanks to the CRISTAL software, Agilium BPM system is able to provide modifiable and reconfigurable business process workflows. In this context, this research study concerns the new version of the Agilium BPM system with the involvement of three concepts: BPM, provenance and quality. The main objective being to understand which benefits of the combination of provenance and BPM can be provided in the quality domain.

1.4 Research Hypothesis and Research Questions

The study will be driven by the following hypothesis: *"The gathering and use of provenance information for BPM can positively facilitate the improvement of quality management processes in an organisation"*. In order to evaluate this hypothesis, the following research questions should be answered:

a) What does provenance provide for BPM in the quality domain?

In the quality domain, the raison d'être of an organization is to satisfy the customer. It is an important challenge as the market demand evolves quickly and there is considerable concurrency. It requires an organization to be performant, i.e. both to be able to follow the market demand by offering a product or a service which keeps satisfying the customer, and to manage its organization so as to stay profitable.

BPM is an approach which provides opportunities for an organization to be competitive. Indeed with its process orientation concept, it enables organizations to manage their activities in a transversal way which improves the business-to-business collaboration and offers a better reactivity when organizations are faced with changes. With BPM, organizations know exactly how activities are performed and linked together and are able to ensure that their outcomes satisfy the requirements set. For example, if a problem occurs in the supply of a particular component, it becomes possible to know exactly what will be impacted by the problem component (which activities, which resources) and to react quickly to manage it.

Provenance is a concept that can be used in the quality domain because it provides reliable information and a complete knowledge of the evolution of an object. Indeed by tracking the history of an object it enables the context of the domain to be captured and thus the understanding of why it has evolved. This research question will therefore investigate what are the benefits of combining provenance with BPM in the quality domain. The idea is to analyse whether and what are any advantages of using those two concepts together for an organization.

b) How does one track the provenance of a process?

Provenance can be represented by a graph which describes the relationships among all the elements (sources, processing steps, contextual information and dependencies) (Moreau *et al.* 2011). Graphical representations of processes can vary because there are multiple languages to design a process (Van Der Aalst, 2013). However all processes are composed of these three basic elements:

- *Events*: this is something that influences the flow of a process. For example an event can be a mail that has been received or the start of an activity.
- *Activities*: this is a task executed during a process.
- *Orchestration flows*: this is the sequence flow which links the different concepts in a specific order, thereby, being the edges in a graph or the control flow.

For a process to be provenance-enabled there has to be a study of how to combine provenance with a process. The objective of this research question it is to understand how it is possible to mix the two methods.

c) How can provenance information from BPM be used to improve quality management?

In order to improve quality management, one principle highlighted by the ISO standard 9001 is evidence-based decision making (International Organization for Standardization, 2015). This is based on the fact that to make effective decisions, an analysis of data and information is required. By applying this principle, the following benefits can be obtained (Eszter Tóth and Tamás, 2014): firstly an understanding of how the decisions have been taken (informed decisions). Secondly an increased ability to demonstrate the effectiveness of past decisions, by looking at the factual record data and thirdly a better ability to review, to challenge and to change opinions and decisions.

Provenance enables the collection of all data and information. It provides concrete facts that happen in the lifetime of an object. Using provenance with BPM means the collection of information of how the processes have been executed and what were the decisions that have been taken during their execution. The purpose of this research question is to define how provenance information from BPM can be used in the organization to improve quality management. An investigation will be made in order to define which provenance information is required for organizations and how it has to be represented. It will be based on a concrete use case provided by an Agilium customer.

1.5 Contribution to Knowledge

An analysis of existing processes of an enterprise (described in chapter 3 "Use Case") will be realized. It will be followed by a study of the implementation of provenance collection points in those processes, in order to determine in which activities of the processes the provenance information could be useful for the enterprise in the quality management domain. Then, a reflection of how the provenance information collected has to be represented will be also realized. Once this work is carried out, an evaluation with the enterprise will be required in order to see if the fact of collecting provenance in the processes has provided improvement in the quality management. It will enable us to see if there are any benefits obtained in the quality domain by combining BPM and provenance

This work will make the following contributions:

- An analysis of what the combination of provenance and BPM provides to the quality domain.
- A framework of how provenance information from BPM can be used in order to improve quality management.

1.6 Research Scope and Limitations

The research scope of this study (illustrated in Figure 1) includes the following key points:

- The analysis of the requirements of the Quality management with the Standard ISO 9001 which provides criteria for the performance of organization.
- The identification of the concepts and methodologies in the BPM domain.
- The analysis of how to model a process in the BPM domain.
- The identification of the concepts and methodologies in the Provenance domain.
- The analysis of the graphical representation of Provenance.
- The analysis of the combination of the two domains BPM and Provenance and its effect in the quality domain.

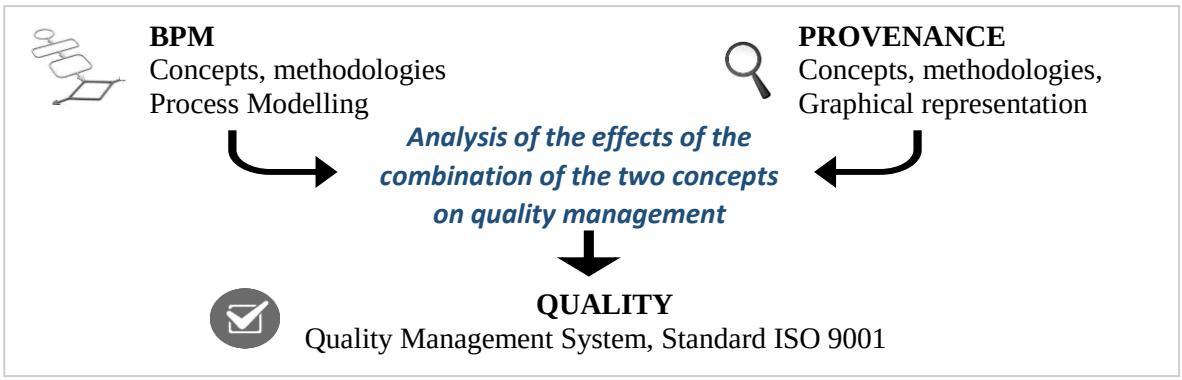


Figure 1: Research Scope

These different points are analysed in a limited environment since the study is based on specific business processes within a single organisation: the Martine Spécialités enterprise (introduced in chapter 3).

1.7 Research Methodology

In order to test the hypothesis and to answer the associated research questions, a qualitative research methodology has been adopted, combined with the guidelines and principles of an action research methodology (developed in chapter 3). The framework of action research has been chosen since it particularly applies in the context of this work, namely a collaborative project with a specific situation (the use of the Agilium BPM system). The concepts and justification regarding research methodology are highlighted in section 3.2. It is important to specify that although action research is normally considered as an iterative cycle of action and reflection (Townsend, 2013), this work is only presented as a first iteration of this methodology, due to constraints of time and availability of staff from Martine Spécialités. It can be regarded as a starting point for a deeper action research analysis, which will emerge from future work (described in chapter 7). Thereby the action research methodology has been adapted for this work with a single iteration of four distinct steps illustrated in Figure 2.

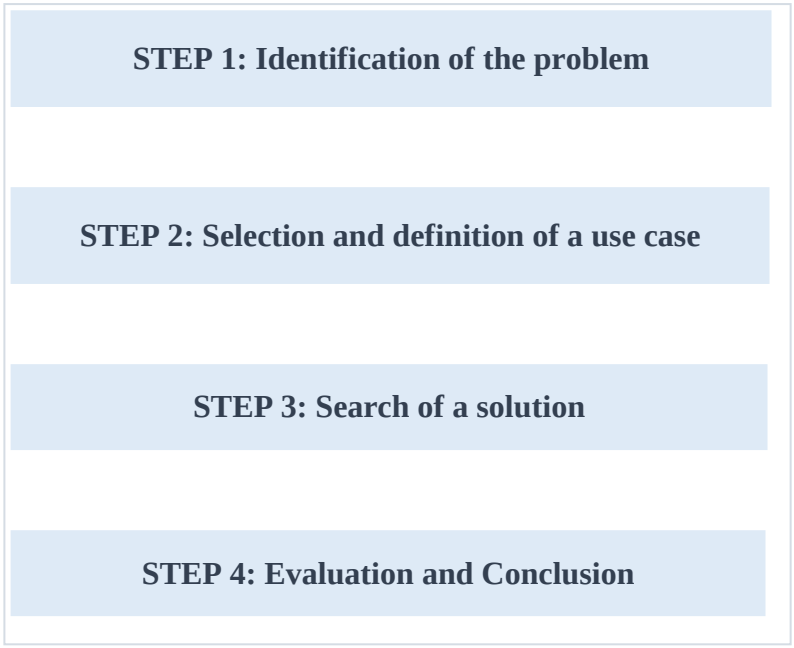


Figure 2: Research Steps

The first step concerns the identification of the problem. This is informed by a literature review leading to the formation of the hypothesis and research questions. Based on the identified hypothesis and questions, an analysis of the state of the art (regarding the quality, the BPM and the provenance domains) has been performed and also the related work that have been carried out (chapter 2), in order to gather relevant information related to the problem.

The second step concerns the study of a real-life example with the selection and definition of a concrete use case, which is the Martine Spécialités enterprise (introduced in chapter 3). The use case methodology (Fowler, 2004) has been selected in this phase in order to fit with one of the objectives of the CRISTAL-ISE project: the capture of the requirements of users of the Agilium BPM system regarding a future new version. The important point of this study being the understanding of the needs of the users, a human-based use-case approach has been adopted. The selection process of the use-case has been established with the Director of Agilium who chose the Martine Specialities enterprise because the processes they manage are complex and involve several actors. The outcomes of this second step are the specifications of the concrete environment in which the hypothesis of this work can be evaluated.

The third step is related to the search for a solution regarding the subject of concern of this research study. The outcome of this phase is a proposed description (presented in chapter 4) of the solution with the functional requirements from the combination of provenance and BPM, a graphical representation of how provenance can track the Martine Spécialités processes and a list of benefits that can be obtained from this combination.

The fourth step is related to the evaluation of the proposal description with the realization of a survey (described in chapter 5) that has been submitted to the employees of Martine Spécialités.

The results generated from this evaluation have been analysed (results presented in chapter 6) and this provides conclusions and future work regarding this thesis.

1.8 Thesis Structure

Chapter 2: Related Work

This chapter will provide an introduction to quality management, BPM and the provenance domain. This will define the basis for understanding the quality requirements and the concepts of BPM and provenance, and it will cover the current state of the art which is relevant to this thesis. This chapter will also cover the related work regarding the use of provenance (traceability) in the BPM field in order to outline the different reasons to combine both concepts. It will be structured as follows: section 2.2 will cover the area of quality management, section 2.3 will focus on the area of the BPM, section 2.4 will be related to the area of provenance and section 2.5 will provide the related work regarding this research study.

Chapter 3: Use Case Definition

Chapter 3 will outline the environment of this research study and will be divided into two main sections. The first section will describe the methodology used in this research study by explaining what is a use case, why it is important to have one and how it will be represented. The second section will provide a description of the concrete environment in which the combination of provenance and BPM will be demonstrated, by introducing the Martine Spécialités enterprise and their different processes. It will describe the actual state of the enterprise.

Chapter 4: Proposal Description

This chapter will firstly determine the requirements for combining provenance with the processes of Martine Spécialités (such as explaining which information is required to be retrieved in order to improve the quality management of processes and how it will be represented). It will also describe the future state of the enterprise by providing the potential contributions that might be obtained for the enterprise with the combination of the provenance and BPM approaches.

Chapter 5: Evaluation Methodology

An evaluation of the work will be carried out to analyse the effect of the combination of provenance and BPM. Chapter 5 will explain which methodology has been chosen in order to evaluate the work of this research study. It will describe why this methodology has been chosen and how it has been implemented in order to obtain various feedbacks.

Chapter 6: Results and Analysis

This chapter will present the results obtained from the evaluation of the work. This will provide a discussion regarding the pros and cons of the combination of provenance and BPM and it will investigate whether there are any benefits obtained in the quality domain regarding the combination of the two approaches.

Chapter 7: Conclusion

Chapter 7 will discuss the contribution this work will make in the BPM, quality and provenance fields. It will highlight how the research questions have been answered and will present the key findings of this research study. A discussion regarding the relevance of this research study will be also provided and an introduction to the future work that can be carried out to extend this study will be highlighted.

1.9 Research Publications

The following publications are related to this work:

- Requirements for Provenance Tracking of S-BPM Workflows. C. Blanc, J. Shamdasani, R. McClatchey & the CRISTAL-ISE Consortium. Proc of the 6th International Conference, S-BPM ONE 2014, Eichstätt, Germany, April 22-23, 2014. Lecture Notes in Business Information Pro-cessing LNBIP Vol 170. Springer 2014 ISBN: 978-3-319-06064-4.

- CRISTAL-ISE: Provenance Applied in Industry. J Shamdasani, A. Branson, R McClatchey, C Blanc, F Martin, P Bornand, S Massonnat, O Gattaz & P Emin. Proceedings of the 16th International Conference on Enterprise Information Systems (ICEIS14) Vol 3 Lisbon, Portugal. April 2014. DOI 10.5220/0004953004530458 ISBN: 978-989-758-029-1 pp 453-458 SCITEPRESS 2014

- Analysing the Provenance tracking of Business Process Management in the Quality Domain. C. Blanc, Doctoral Consortium of the 13th conference of the Business Process Management (BPM15), Innsbruck Austria, August 31 – September 5, 2015.

Chapter 2 – Related Work

2.1 Introduction

The previous chapter described the subject of research of this thesis and the motivation to carry out this work. This chapter provides an introduction to the quality management, the BPM and the provenance domains. This will define the basis for understanding the quality requirements and the concepts of BPM and provenance, and it will cover the current state of the art, which is relevant for this thesis. This chapter also covers the related work regarding the use of provenance (traceability) in the BPM field in order to outline the different reasons to combine these concepts. It will be structured as follows: section 2.2 will cover the area of quality management, section 2.3 will focus on the area of the BPM, section 2.4 will be related to the area of provenance and section 2.5 will discuss the related work regarding this research study.

2.2 Quality Management

2.2.1 The Quality Management approach

Definition and Evolution

As explained by Watson and Howarth (2011), there is no one singular, universally accepted definition of quality. The concept of quality differs according to the subject and its context and it can be seen in various ways. For example, if it is viewed from a conventional definition, quality describes a quality item as something that it is well constructed and that will last a long time. If it is viewed from a strategic definition, quality is defined as the meeting of the needs/requirements of the customers. The common element of the different views is that quality is a perceptual, conditional and somewhat subjective attribute (Eszter Tóth and Tamás, 2014).

The concept of quality management has appeared with the advent of mass production and has grown from the nuclear and space industries (Pillet and Duret, 2008). In the beginning, quality management referred to the management of product conformity. The objective was to detect defects through measurements and standardization (quality inspection). It then evolved with statistical quality control (statistical theory applied to quality). The principle of it was to obtain enough information on few pieces of product instead of controlling all products (which means reduced inspection). After that, quality assurance was introduced with a management focus not only on the product but on the entire organization (all departments and functions involved). It is characterized by the fact that the customer needs must be taken into account, with for example the implementation of surveys to obtain the feedback of customers and to react according to it. Finally, with the growth of the competitiveness and the importance to survive in a complex and changing environment, the notion of Total Quality Management (TQM) was established in the quality world. It includes the importance of being aware of the market and it takes into account a strategic view for the organisation. In order to implement a quality management approach, organizations have to develop their Quality Management System (QMS).

A QMS is a framework for the implementation of quality management. It can be defined as the management chosen for reaching quality policy and quality objectives (Pillet and Duret, 2008). It enables managers to orientate and control the organization in terms of quality.

The reasons to implement a quality management approach

Within the last few years, different studies have demonstrated the benefits of implementing a quality management approach. Dale, Bamford and van der Wiele (2016) and Jimenez (2015) identify that quality has an impact in the sustainability of an organisation:

- The quality approach provides different tools and methods (such as quality inspection, process improvement and customer focus) that will guarantee the conformity of products or services. It will guarantee a shorter lead-time with the increase in certainty of achieving contract requirements and deadlines. This leads to customer satisfaction and to customer loyalty that are key factors to ensure the sustainability of organizations.
- The quality approach promotes supplier partnerships; the advantage of this is that it increases market share to both parties and thereby improved sustainability is reached.
- With its continuous improvement principle, quality guarantees the fact that organizations provide an ongoing effort to search for new progress and to identify opportunities. This directly increases the ability of organizations to survive in aggressive markets by maintaining a competitive edge over their rivals.

Borut (2010) and Dale Bamford and van der Wiele (2016) underline that quality has an impact in organizational effectiveness. The quality approach indeed enhances the effectiveness of the work by providing:

- Improved documentation: This includes but is not limited to procedures, standards, regulations, work instructions. These support clarity and guarantee that employees know how to perform their tasks. The quality approach ensures an accessible knowledge of the way of working along with the appropriate means for doing it. This enables a common approach and language for all business and avoids confusion.
- Organizational consistency: This provides a clear focus on the organization’s goals and priorities and a guarantee that those are aligned with operational activities. The quality approach supports an open and active commitment to quality at all levels.
- Improved working conditions: This concerns increased coordination between the different functional or departmental areas. The quality approach promotes a positive working atmosphere with increased job satisfaction and morale and commitment to the organization.
- Reactivity in the case of problems: With the implementation of operational and management control and supervisory mechanisms including internal and external audits. The quality approach enables users to detect, prevent and correct failures with prompt, appropriate, and sensitive managerial action to redress problems.
- Improved processes: This is a focus on operations with added value and the elimination of waste. The quality approach provides higher productivity with increased capability of processes and higher production quantities.

Different works (Oakland, 2010; Zhang, 2000; Dale, 2016; Borut, 2010) demonstrate that quality has an impact on organizational costs:

- The quality approach enables a reduction of operating costs thanks to the identification and elimination of waste with less scrap, rework, and failure. As an example, the study of Zhang (2000) demonstrates that 10 companies had reduced quality costs by approximatively 7.6% since the implementation of the total quality management approach.
- With improved processes, quality ensures increased income. The performance and the efficiency are higher from continuous improvement and this leads to improved profitability and better return on investment.
- As explained previously, the quality approach guarantees the conformity of products or services. This leads to a decrease in customer complaints with fewer non-conformities of delivered goods. This directly impacts customer loyalty; it has been demonstrated that customers cost less to retain than acquire. This way the longer the relationship with the customer remains, the higher is the profitability (Oakland, 2014).
- Since quality contributes to reducing the rate of staff turnover with improved working conditions, the associated costs of recruitment, selection and training activities are also decreased.

These different studies confirm that quality makes a positive contribution toward the performance of organizations. However other works (Mohammad Mosadeghrad, 2014; Jaeger, 2016; Belekoukias, 2014) demonstrate that there are many difficulties and obstacles in the implementation of such a system. This can be justified by the models, the methods and the tools chosen that are not adequate and/or are poorly deployed or by the fact that quality management systems are not aligned with strategic quality planning and business strategies during the implementation. The objective of this research study is to understand what the quality requirements are and analyse whether the combination of BPM and provenance can improve quality management. In order to obtain the quality requirements, this research will focus on the standard ISO 9001 which will be presented in the following section.

2.2.2 The Standard ISO 9001

Introduction to ISO and the ISO 9000 family

ISO is an independent, non-governmental membership organization composed of 163 member countries. The objective of this international organization is to facilitate trade, spread knowledge, and share technological advances and good management practices (International Organization for Standardization, 2011). It provides transparent procedures (standards) for every sector of business. Those standards are considered as strategic tools and guidelines to help companies to achieve benefits such as cost savings, enhanced customer satisfaction and environmental benefits (International Organization for Standardization, 2017).

The ISO 9000 standards family deals with quality management aspects. The objective of this category is to provide guidance and tools in the quality domain in order to help organizations guarantee that their products and services consistently meet customers' requirements, and that quality is consistently improved (International Organization for Standardization, 2017). This family is composed of four different standards:

- **ISO 9000**: this standard covers the basic concepts and language.
- **ISO 9001**: this standard sets out the requirements of a quality management system.
- **ISO 9004**: this standard focuses on how to make a quality management system more efficient and effective.
- **ISO 19011**: this standard sets out guidance on internal and external audits of quality management systems.

For this research study, the focus will be on the standard ISO 9001 as it is the most implemented in organizations (over 1 million implementations across the world) (International Organization for Standardization, 2017).

ISO 9001 Requirements

The standard ISO 9001 defines a set of exigencies regarding the implementation of a quality management system. It has been designed for any type of organization (small or large) and any type of products or services. It is the only standard of the ISO 9000 family which enables organizations to certify their quality management system by an external entity (International Organization for Standardization, 2017). This standard has recently been revised in a new version (ISO 9001:2015 instead of the ISO 9001:2008) in order to keep it current and relevant for the marketplace.

The objective of ISO 9001 is to ensure that customers' requirements are taken into account and that organizations know how to satisfy them in a sustainable way. It is built around seven quality principles that guide organizations towards improved performance (International Organization for Standardization, 2015):

- **Principle 1 – Customer Focus**: this principle underlines the importance of understanding current and future customer needs, with the objective to strive to exceed customer expectations.
- **Principle 2 – Leadership**: this principle defines the importance of having leaders which establish the organization's goals and objectives, and to maintain an environment where people can operate effectively.
- **Principle 3 – Engagement of People**: this principle exposes the necessary full involvement of people as their commitment enables their abilities to be used for the organization's benefit.
- **Principle 4 – Process Approach**: this principle underlines the fact that managing activities and related resources as a process enables users to achieve a desired result more efficiently. It describes the importance of identifying, understanding and managing

interrelated processes as a system as it helps the organization's effectiveness and efficiency in achieving its objectives.

- **Principle 5 – Improvement**: this principle explains that improvement has to be a permanent objective as it ensures that the performance of the organization will be maintained and it will enable to react to future challenges and create new opportunities.
- **Principle 6 – Evidence-based Decision Making**: this principle defines the fact that effective decisions are based on the analysis and evaluation of real data and information.
- **Principle 7 – Relationship Management**: this principle exposes the importance of a mutual beneficial supplier relationship as it improves the ability of both to create value.

Based on those seven principles, the ISO 9001 standard is structured in different chapters which provide a framework to implement a quality management system in organizations. The principle 4 "Process Approach" and the principle 6 "Evidence-based Decision Making" are the main centres of interest of this research study since BPM and provenance enable respectively to answer these principles. In the next section, the BPM approach will be presented (definition and benefits of this methodology) with the state of the art of this domain.

2.3 Business Process Management

2.3.1 The Concept of BPM

Business Process Management (BPM) deals with different tools and methods to design, analyse, implement and execute a business process. It is defined by Jeston and Nelis (2008) as "a management discipline focused on using business processes as a significant contributor to achieving an organization's objectives through the improvement, ongoing performance management and governance of essential business processes". A business process is a set of activities that helps in realizing a business goal and that is performed in coordination (Weske, 2012). The activities are correlated or interactive, and transform input elements (for example a request for an estimate) into output elements (e.g. the estimation made). To illustrate it,

Figure ***3*** shows an example of the different activities that form a simple ordering process. The goal of this process is to complete an order from customers. It starts when there is a customer order that has been sent (the input). It ends when the activities (process order, send invoice, receive payment and ship product) are executed and as a result there is a completed order (the output).

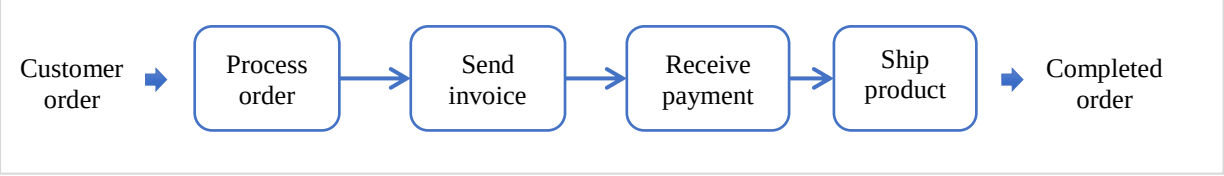


Figure 3: A simple order process

A business process can be enacted manually (by the organization's personnel). Or it can be enacted automatically thanks to a BPM System (called BPMS). A BPMS is a piece of software that enables the representation (modelling) and the execution of business processes. Thanks to this tool, it is possible to automate completely certain activities; the BPMS provides coordination for the realization of the successive activities (i.e. a graphical view on a process).

The reason to use processes in businesses is that they allow organizations to clearly see how business entities work. They provide a structure to control and improve the way of working with the objective of satisfying the customers' needs. The concept of focusing on business processes is not new. Hammer (2014) explains that BPM has two primary intellectual antecedents.

- The first one is related to the quality domain with the works of Shewhart (1986) and *Deming* (1953) which demonstrated the importance of managing processes, to limit their variation, to evaluate and continually improve it.
- The second one is related to the business process reengineering domain which brought the idea of focussing on high-leverage aspects of the organization's operations and dealing with cross functional business processes (Aguilar-Saven, 2004). It also introduced the importance of focussing on process design since the process execution performance depends on the process design. Indeed if the process model is not well designed, there is no possibility that the execution will be improved. The rule is the following: what is modelled is what is run.

As a result, BPM is a combination of these different approaches. It is a continuous improvement methodology that manages end-to-end business processes.

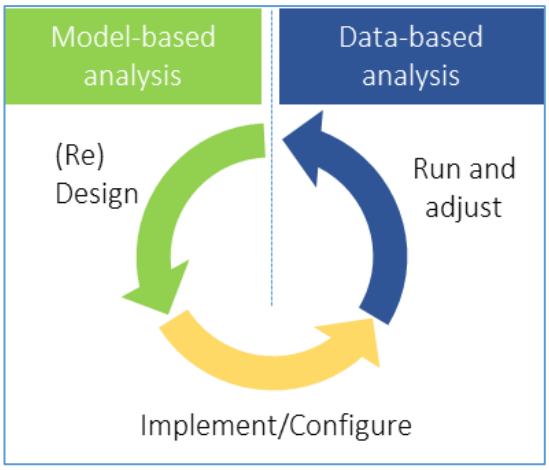


Figure 4: The BPM life cycle (Van Der Aalst, 2013)

The methodology of managing business processes is called the BPM life cycle (Van Der Aalst, 2013). It is composed of three steps: (1) the (Re) design, (2) the implementation and configuration and (3) the execution and improvement (Figure 4 illustrates the BPM life cycle). Those steps which are used in practice to implement a BPM approach have their own particularities:

- **(Re) design phase**: process models are designed during this phase. This is an important step as the model enables a common understanding and an analysis of the process (called model-based analysis) (Hammer, 1990). To express the ordering of the activities, graphical notations are used to design the process. Today a plethora of notations exist (for example BPMN (BPMN, 2017), UML (Fowler, 2004) for modelling business processes (Van Der Aalst, 2013); all those notations have the same objective which is to provide a language that facilitates the collaboration between people concerned with BPM. It brings a unique and understandable way to communicate about processes.
- **Implement/Configure phase**: in this phase, process models are transformed into a running system. For example if the model is informal it will be necessary to hardcode it in conventional software if the organization uses a BPMS.
- **Run and adjust phase**: this is the execution of the processes. During this phase the process can be adjusted. It is also an important step as it enables a data-based analysis. This allows the detection of waste or deviation from design and it gives the possibility to implement key performance indicators. Several methodologies and techniques have been developed to analyse the data of the process execution. For example Business Activity Monitoring (BAM) refers to the real time monitoring of business process. It is a concept which provides the information needed to control processes and enables the creation of a business process dashboard.

2.3.2 The Benefits of BPM

Segatto *et al.* (2014) describe the actual organizational environments as becoming increasingly complex. They explain that the interaction between organizations and the market globalization has entailed new strategic implications for business entities. Organizations have to be reactive and constantly implement changes in their structures and processes, in order to be more efficient. There is today a competitive pressure that obliges organizations to be focussed on activities that will generate high performance (L. Sanders Jones and Linderman, 2014). This turbulent and complex environment leads to new managerial approaches with the objective of providing organizations with a greater capacity for value creation and to help them to grow and increase their competitiveness (Segatto *et al.* 2014). BPM is one of these new managerial approaches and business entities can expect many benefits from it (Rudden, 2007).

Several studies have been done to demonstrate the different benefits possible thanks to the adoption of a BPM approach. It is possible to differentiate the benefits coming from the BPM methodology (process orientation with continuous improvement) and the benefits coming from the BPM technology (implementation of a BPMS).

Kohlbacher (2013, 2010) has analysed the effects of being process-oriented for an organization. Their survey shows that process orientation has a positive influence on organizational performance. The main positive effects reported are the following:

- Speed improvement in terms of cycle time reductions;

- Increase of customer satisfaction;
- Improvement of quality (most often in terms of product quality);
- Reduction of cost.

Hammer (2014) proves that process management provides a variety of strategic benefits such as a better response to periods of rapid change and a reduction of the inventory. A concrete example has been given to illustrate the decrease of inventory: it concerns a consumer goods manufacturer which redesigned its product deployment process. A new process which consists of manufacturing goods and delivering them to distribution centres has been implemented. This enabled a reduction of the inventory by 25%.

The study of Reijers (2006) gives the positive effects of using a BPM system. It demonstrates that thanks to a BPMS, it is possible to (1) reduce lead times, (2) have fewer hand-off errors and (3) have more flexibility to change the structure of supported business processes. Melenevosky and Sinur (2006) indicates that a BPMS allows collecting real-time data from a production environment which is an important benefit for an organization since it can then be more reactive.

Some conditions however are required to obtain the different benefits of BPM. Many surveys have been done to determine the critical success factors of a BPM approach (Melenevosky, 2006; Mutschler, 2008; Trkman, 2010). A recent one realized by vom Brocke *et al.* (2014), identifies ten principles to be successful:

1) Principle of context awareness (organizations must be concerned by the context in which it applies a BPM approach, as for example the strategy alignment);
2) Principle of continuity (BPM has to be seen as a permanent practise with continuous efforts);
3) Principle of enablement (it is necessary to develop the skills needed in BPM);
4) Principle of holism (BPM should be a global approach, not focus only on a specific area);
5) Principle of institutionalization (it is imperative to distribute roles with responsibilities to employees as process owners);
6) Principle of involvement (everybody in the organization has to be involved in a BPM approach);
7) Principle of joint understanding (a BPM common language is needed such as the use of process models);
8) Principle of purpose (the BPM approach has to be associated with goals to create value);
9) Principle of simplicity (organizations should focus on simple solutions);
10) Principle of technology appropriation (a fit between technology and business process must be established and maintained).

The process approach has been highlighted in the new version of the standard ISO 9001 in order to demonstrate the importance of understanding and managing activities as interrelated processes that function as a coherent system (International Organization for Standardization, 2017). By implementing a BPM approach, the organization answers to the quality principle "Process approach" and will be more efficient to increase the customer satisfaction with the respect of their exigencies (International Organization for Standardization, 2015). Now that the BPM domain has been introduced, the following section will present the provenance approach.

2.4 Provenance

2.4.1 The Concept of Provenance

Provenance is a term used to describe the lineage, history, or origin of an object (Ram and Liu, 2012). It was firstly used in the art domain to know what happened in the life of a work of art (the history of its ownership) from the time of its creation to its current state and to be sure of the work's authenticity (West, 1996). Then it has been used in digital libraries where provenance refers to the documentation of processes in a digital object's life cycle (Moreau *et al.* 2011). As explained by Ram and Liu (2012), it is now growing in the computer science domain as provenance is also applicable on digital objects such as generated data. Indeed they demonstrate that in the scientific world, there is more and more collaboration which leads to a proliferation of shared data.

Provenance in this domain allows ensuring where, for what and who is using this data (Ram and Liu, 2012). It is applicable in the life sciences as well, for example in neuroscience (Anjum *et al*. 2011) or bioinformatics (Goble, 2002) and a recent domain where provenance has been applied is in industry (Shamdasani *et al.* 2014). Moreau and Groth (2013) recap five actual use cases of provenance. The first one is called "Food Provenance" and it is used by food suppliers in order to guarantee the quality of all foods products, to facilitate the realization of audits and to guarantee the respect of the public and regulatory authorities' requirements. The second one is the use of provenance for open data and data journalism in order to guarantee the validity of data and to contribute to a more transparent and accountable environment by providing the primary source of the data and the transformational steps performed. The fourth use case is tracing of information in the social web which enables once again to guarantee the veracity of the information in the web domain and to understand how it has been created. The fifth use of provenance is the reproducibility in science by providing the possibility of replaying the execution of an experiment that led to a certain result. And the last one is the "accountability, transparency, compliances in business applications" where provenance enables to perform policy checks and make the systems accountable.

By recording the different events that happen to a digital object, provenance enables a high characterization of the object. It gives a clear identity to an object by answering seven W's (What, When Who, (W)How, Where, Which and Why) (Goble, 2002). The 'What' allows knowing the

event that happens to the object and the others W's allow specifying the details of the event (Moreau et al. 2011):

- **WHEN**: the time at which event occurs
- **WHO**: the agent responsible for the event
- **HOW**: the mechanism or actions that caused the event to occur
- **WHERE**: the place where the event occurs
- **WHICH**: the instrument that makes event happen
- **WHY**: the reason the event occurs

Visually, provenance refers to a graph describing the relationships among all its elements (sources, processing steps, contextual information and dependencies) (Carata, 2014). The Open Provenance Model (OPM) (Moreau *et al*. 2011) was a first core representation of provenance. It has been replaced by the PROV DATA MODEL (PROV-DM), which is defined as "a generic data model for provenance that allows domain and application specific representations of provenance to be translated into such a data model and interchanged between systems" (World Wide Web Consortium, 2013). It has now become a W3C (World Wide Web Consortium) standard.

2.4.2 The Benefits of Provenance

Provenance brings the following benefits:

- **Useful knowledge**: thanks to provenance, it is possible to interpret and understand a result. As explained by Simmhan, Plale and Gannon (2005), by analysing the sequence of steps that led to a result, it is possible to gain insights into the chain of reasoning used in its production. For example, in each run of a scientific experiment (with different configurations parameters) there will be specific results. Provenance can help to make the link between results and the corresponding configurations parameters. It therefore provides the context and thus the possible explanation of the result. It adds meaning to the result and can thereby turn the result data into information/knowledge.
- **Replication**: provenance enables reproducibility. As it captures the characterization of an object, it is possible to re-obtain exactly the same object.
- **Reliability**: according to Cheney *et al*.(2009), the motivation of using provenance is that it enables assessing authenticity and integrity because provenance provides knowledge of its origin. In terms of quality this could be very useful since it enables tracking back sources of errors. Provenance can be used for the purpose of creating an audit trail to evaluate if any errors were made in processing the object.

In a world with a great deal of data, and actors, with fast execution and transformation of complex processes, provenance provides a truthful knowledge and it is an approach which enables to answer to the quality principle "Evidence-based Decision Making". Now that this domain has

been introduced, the next section is looking at the related work that has been done in the context of this research study.

2.5 Related Work

One thing which is similar to a business process is a scientific workflow. Indeed although a scientific workflow is executed in order to accomplish a scientific objective and a business process is executed in order to realize a business goal, both are structured with activities which are coordinated together. Since these two concepts are similar, this section will introduce the related work of this thesis regarding scientific workflows and provenance, and then regarding business processes and provenance.

2.5.1 Scientific Workflows

Provenance has become popular is the scientific workflow domain (Davidson and Freire, 2008). A scientific workflow can be defined as a formal description of a process for accomplishing a scientific objective, typically expressed in terms of tasks and data dependencies among them. Usually those tasks are complex (for example it can be the analysis of human brain images, the analyses of physics particles or weather forecasting) and provide a large amount of data. Provenance in this field enables systems to provide important documentation that is key to preserving the data, to guarantee the quality of it and to reproduce the validated results. It enables users also to simplify exploratory processes by giving the possibility to re-use workflows or workflow fragments (Freire *et al*. 2006). Several studies have been made in this context to define the capture mechanism, the data model for representing provenance information and the infrastructure for storing, accessing, and querying provenance (Davidson and Freire, 2008). Regarding the state of the art, the provenance information collected for a workflow can be divided into three categories:

- The first one is Prospective Provenance which captures the description of an experiment (i.e. the steps that must be followed to obtain a data product) (Lim *et al*. 2010). It corresponds to a statement about how to produce the data.
- The second one is the Retrospective Provenance which captures the steps taken during the execution of the workflow (Freire *et al*. 2008). It includes information collected at runtime such as activities invoked and parameter values used, intermediate data produced, the execution start and end times etc.
- The third one is Workflow evolution which captures all the changes applied to a workflow during its lifetime (Freire *et al*. 2014). It corresponds to the tracking of the evolution history of the workflow structure itself.

To illustrate the combination of scientific workflows with provenance, this section introduces one scientific workflow management system which collects provenance information and that is described in the work of *Carata et al.* (2014). VisTrails is an open-source scientific workflow and provenance management system that provides support for simulations, data exploration and visualization. It enables users to track provenance for the execution of various workflows and for

the evolution of the workflows themselves and it is possible to express provenance queries about three different aspects of the workflow: the execution log, the abstract workflow representation, and the evolution of the workflow in time. The benefits of such a system is that it is possible to work collaboratively, to return to a previous version in an intuitive way, to undo bad changes, to reuse workflows and workflow fragments, to compare different workflows and their results, and to be reminded of the actions that led to a particular result.

Scientific Workflow Provenance is a field that is interesting as it is linked with this subject of research. Provenance, here is applied to a particular domain which is that of scientific workflows. In this research study, the idea is to combine provenance in the business domain. The similarity is that in both cases the objective is to apply provenance with processes. The difference is that in this research study, the focus in on what provenance can provide for the business processes according to the quality domain regarding the standard ISO 9001. The next section looks at the related work regarding the use of provenance in the BPM field.

2.5.2 Business Processes and Provenance

BPM and Provenance

In the literature, there is one work which combines the concept of provenance with the BPM approach. This is the work of Cubera *et al*. (2008) called Business Provenance, which introduces a technology which uses provenance for the business environment. It is a generic data model and middleware infrastructure which provides a traceability of end-to-end operations. This technology allows the automatic discovery of what has happened during any business process execution. In their study, the authors demonstrated the use of provenance in the BPM domain with a main argument based around compliance. They explain that business processes rely on human activities and that business operations often differ from their original design, which can lead to business integrity lapses and compliance failures. To avoid supplementary work and costs due to those failures, they propose a compliance solution which tracks business operations. The principle of the Business Provenance technology is to extract the relevant information to address a specific compliance goal. Provenance in this case enables the tracking of end-to-end operations for assuring compliance. Others studies have used this Business Provenance technology to go further in compliance monitoring with the work of Doganata *et al.* (2011) and to enable advanced case management with the work of Martens *et al.* (2012). This work is limited to a single use of provenance in the BPM domain which is compliance.

As explained in chapter 1, the combination of provenance and the BPM approach is not new since the Agilium BPM system is built around the CRISTAL software which provides provenance (Shamdasani *et al.* 2014). In this case, the objective of applying provenance with a BPM system was to provide modifiable and reconfigurable business process workflows, even during the execution of the processes. This work demonstrates the usefulness of provenance in the BPM domain as it brings flexibility by allowing businesses to react rapidly to external events.

This research study is based on this work but will be focused on a new aspect which is the benefits of provenance and BPM in the quality domain.

BPM and Traceability

Since there are few if any works which have used provenance methodology with BPM, this part investigates the combination of traceability (which is the main functionality of provenance) with BPM. In the literature there are different works which combine traceability and BPM.

One important field which extracts what happens in a process is the Process Mining approach (Van Der Aalst, 2012). This technique focuses on the analysis of processes using event data in order to discover process, control, data, organizational, and social structures. Process Mining establishes links between the actual processes and their data and the actual processes and the process models. This is used firstly to discover a process model (i.e. to produce a model based on event logs without using any *a priori* information). Secondly Process Mining is used to guarantee the compliance of the process designed and the process executed (i.e. conformance checking which guarantees the alignment between model and reality). And thirdly this technique is used to improve an existing process model (i.e. by enhancement, by changing or by extending the model). The objective of tracking the processes with this technique is to improve the (re)design, control, and support of operational business processes. This is focused on the improvement of the process model.

A recent investigation done by Uronkarn and Senivongse (2014), provides arguments for using the traceability concept in business processes. They propose a methodology which is using traceability in order to manage business process change. In this study, the traceability is used for improving software development. Indeed it provides a technology which tracks changes which happen by comparing the current business process model with the newly designed model. This enables users to identify exactly where a development or a modification of the software is required, to implement the changes. The benefit of this approach is for the software project leader and the system analyst that are able to plan the effort in order to change the artefacts, including the software itself, accordingly.

The work of Beyl, Berg and Giese (2013), demonstrates the required use of traceability for the innovation processes. It presents how traceability can improve the successful realization of innovative ideas. Indeed, according to this study, innovative ideas have to be feasible and viable in practice. It means engineers need a handover by the designer that must be as detailed and explicit as possible in order to create the desirable product or service. Traceability in this case helps to obtain all the required information and to prevent information loss between engineers and non-engineers.

With those different works, it is clear that there are different reasons for using provenance (traceability) in the BPM domain. Most of the time the benefits found are for a specific aspect in

the organization (e.g. to improve the compliance, to improve the flexibility, to improve the process model, to improve the software development, or to improve the realization of innovative ideas). The objective of this research study is to analyse the combination of provenance and BPM in the context of the quality approach. The combination of BPM, provenance and quality will be demonstrated by a real use case which focuses on the use of these technologies in businesses.

2.6 Conclusion

This chapter introduced the quality, the BPM and the provenance domains. It enabled us to define the requirements of the quality field with a description of the different quality principles. For this thesis, the principles which are the centre of interest are the "process approach principle" and "evidence-based decision making" since the BPM and provenance enable respectively to answer to those principles. This chapter provided the state of the art of the BPM domain and showed that by implementing this approach, organizations are more efficient to increase customer satisfaction with the respect of their exigencies. The state of the art of Provenance has been described as well and this demonstrated that provenance provides a truthful knowledge.

The related work of this thesis has been also described in this chapter. This showed that provenance is currently used in scientific workflow domains to provide important documentation that is key to preserving the data, to guarantee the quality of it and to reproduce the validated results. It also demonstrated that there are few studies which combine BPM and provenance. Existing studies have proved that provenance brings flexibility and compliance in the BPM field and that it can improve process models, software development and the realization of new ideas. The benefits quoted in this section enable us to provide some answers of the first research question which is "what does provenance provides for BPM in the quality domain?"

The interesting aspect regarding the analysis of the related work is the fact that to the best knowledge of the author, the provenance has not been analysed in the BPM field according to the two quality principles which are the process approach and the evidence-based decision making. Now that the relevant information regarding the subject of concern of this thesis has been outlined, the next chapter will define the environment by describing the use case chosen for this work, by which the hypothesis will be tested.

Chapter 3 – Use Case Definition

3.1 Introduction

Chapter 2 enabled the identification of the state of the art regarding the BPM and the provenance fields. It demonstrated the fact there are few, if any, studies that have been done regarding the combination of those two concepts in the quality domain. This chapter outlines the scenarios of this research study and is divided into two main sections. The first one describes the methodology used in this research study by explaining what is a use case, why it is important to have one and how it will be applied. The second one provides a description of the concrete environment in which the combination of Provenance and BPM will be demonstrated, by introducing the Martine Spécialités enterprise and their different processes. It will analyse the actual state of process management with the Agilium BPM system in order to understand the context in which this research study was carried out and which methodology was used.

3.2 Use Case Methodology

Considering the fact this work was done in the frame of the CRISTAL-ISE project (Shamdasani *et al.* 2014) which fostered collaboration between academic and industrial partners, the methodology chosen for this thesis was oriented toward an action research methodology. Action research is a holistic approach that takes place in real situations with the aim of reaching a mutually desirable direction (O'Brien, 2013). In the CRISTAL-ISE context, the desirable direction of this work study is to enable the transfer of new and future academic research into the Agilium commercial domain. Regarding the specific time duration of this project and the collaboration aspects between academia and industry, an action research methodology is the most appropriate approach to reaching the objective of the project. Indeed it is a collaborative approach which enables users to study a system and concurrently collaborate with members of the system in changing it into what is defined as the objective (O'Brien, 2013).. The framework of action research is structured into three stages (Stringer, 2013):

- **LOOK**: this stage enables us to gather relevant information and to define the actual situation.
- **THINK**: this stage is related to an analysis and the search for a solution.
- **ACT**: this stage concerns the implementation of the solution and the evaluation of its effectiveness.

Those three stages have to be considered as a continually recycling set of activities until the desirable direction is reached. Since the time of this project is limited, this thesis will focus on the functional aspects of Agilium with an analysis of what provenance can provide in a BPM system regarding the quality domain. In order to analyse a concrete situation, the use case methodology will be used to specify scenarios and to evaluate the work. The next sections will explain what is a use case and why this approach is used in this research thesis.

3.2.1 Definition of a Use Case

According to Fowler (2004), a use case is a technique which enables developers to capture, to understand and to communicate about the functional requirements of a system, by describing the typical interactions between the users of a system and the system itself. Precisely, a use case is a collection of possible sequences of interactions between the system under consideration and its actors (that is external entities who interact with the system), relating to a particular goal. An actor will have a particular goal(s) in mind which requires the assistance of a system. Use cases provide a narrative of how the system is used in order to satisfy that goal(s). Although there are different ways to write a use case (Adolph, Cockburn and Bramble, 2002), the common elements that are required are the following:

- The description of the goal to be achieved by the use case.
- The list of actors involved in the use case.
- The conditions that must be true for the use case to terminate successfully and the interactions between the actors and the system that are necessary to achieve the goal.

Thus, the use case captures who (actors) does what (interactions) with the system, and for what purpose (goal) (Malan, 2009).

3.2.2 Application of the Use Case Methodology

This research study is oriented toward the functional aspects of the Agilium BPM system, by analysing if the use of provenance in this system can improve the management of processes in the quality domain. The use case methodology is particularly interesting in this context since it helps in capturing the requirements of a system from the user's point of view. The fact that the use case is focused on the goal of the user is related to one quality principle which, in this research, is the "Customer Focus". This takes into account the user's needs as recommended by the ISO 9001 standard. Thus the use case methodology fits into this work since the subject of research is related to the quality domain. Another benefit of using the use case methodology is that it is easy to understand and it provides an excellent means for communicating with users. Indeed, the use case consists mainly of narrative text which holds functional requirements in an easy-to-read format. Finally, the objective of this research study is limited to the intended behaviour (without dealing with the internal structure) of the Agilium BPM system which is exactly what the use case methodology provides.

The use case methodology will be applied in the Martine Spécialités enterprise which is using the Agilium BPM system to manage its processes. The choice of this enterprise is justified by firstly the fact that Martine Spécialités works closely with Agilium to manage the development of their process models in the BPM system. Secondly, by the fact that Agilium has access to all the data managed in the processes of Martine Spécialités. And thirdly, by the fact that the

processes managed by Martine Spécialités are complex and involve several actors. Figure 5 illustrates the structure of the work of this thesis regarding the use case methodology, which is separated into two main parts. The first part will be described in this chapter and is related to the actual environment of the Martine Spécialités enterprise. It includes a description of the processes (using the Agilium BPM notation) and an analysis of the actual state regarding the processes and the BPM system. The second part will be presented in chapter 4 and concerns the proposed description of the combination of provenance with the processes of Martine Spécialités. It takes into account the functional requirements of the Agilium BPM system with provenance, and the potential contribution that might be obtained for the enterprise with the combination of the provenance and BPM approaches.

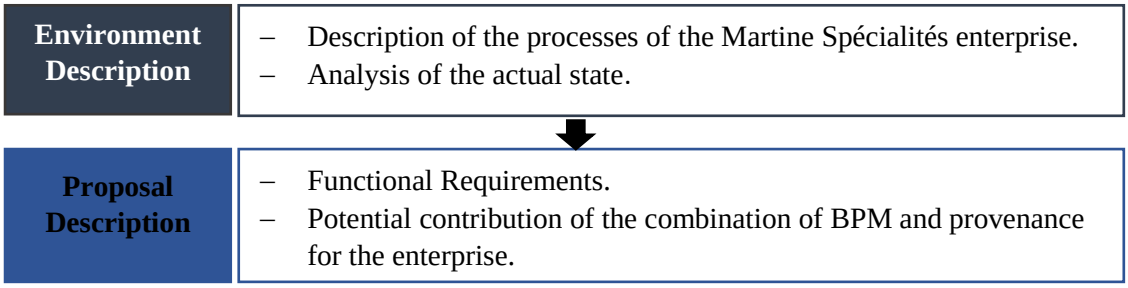


Figure 5: Work structure regarding the Use Case Methodology

3.3 Martine Spécialités Use Cases

3.3.1 Description of the Enterprise and the Agilium BPM system

Martine Spécialités, which is specialized in the manufacturing of pastry-based goods to both food retail outlets and the catering industry, has been certified ISO 9001 until 2006 and has implemented a process management approach in order to apply the requirements of the company and to obtain the benefits of the BPM methodology (developed in chapter 2). The enterprise is today certified to the IFS (International Food Standard) and by the BRC (British Retail Consortium). IFS certification ensures a common standard with a uniform evaluation system, and transparency throughout the entire supply chain. BRC certification ensures a documented and effective Quality Management System and a safety control system. Both certifications require the control of production processes. The enterprise counts 460 employees for more than 28,000 tons of goods produced every year (pastry cases, sweet cream tarts, cooked and uncooked tarts) with 13 production lines (including eight used exclusively for the production of large and small tarts). Innovation is an important consideration at Martine Spécialités since 100 new products are created every year. Martine Spécialités is composed of different departments. The list below introduces the main departments which are involved in the different processes (i.e. the actors):

– **The Sales and Marketing department**: this is in charge of sales of the different products to customers and to guarantee the needs of the customers. At the head of this department there is the Marketing Director and the Sales Manager, who manages the salespersons.

- **The Production department**: from the operators to the Production Line Manager, this department is in charge of manufacturing the different products.
- **The Research and Development (R&D) department**: composed of different employees (R&D employees, laboratory technicians, methods manager, industrial manager, R&D Project Manager), this department is in charge of innovation in the development of new products.
- **The Quality and Security department**: as the name suggests, this department is divided into two sections: one which is in charge of the quality in the enterprise (in order to guarantee the application of the standards) and the other which is in charge of the security.
- **The Accounting department**: this department is in charge of the accounts of the enterprise. The responsible of it is the Financial Director.
- **The Purchasing department**: composed of different purchasers and the Purchase Manager, this department guarantees the purchase of components and raw materials required to manufacture the product at the best price.
- **The Logistics department**: this department is in charge of optimizing the flows of the different components, raw materials and final products.
- **The Committee of Direction** (known as CODIR): this committee is composed of the different managers of each department (Financial Director, Logistic Director, Plant Director, Industrial Director…) in order to take the decisions regarding the strategy of the enterprise. The person above the department is the President who is at the head of the enterprise.

In order to manage efficiently its processes, Martine Spécialités has implemented the Agilium BPM system. The enterprise has chosen this BPM system since it enables them to model processes in a simple way, and it provides the ability to connect the system with different applications (such as Enterprise Resources Planning) in order to avoid data redundancy. The architecture of Agilium is composed of one server and three user interfaces:

- The server is based on CRISTAL (Branson *et al*. 2014) and deals with the process execution.
- The Agilium factory is a user interface which deals with modelling and integration (graphical representation of process (flows, rules, indicators) and connection to others applications). The indicators can be implemented thanks to a "control point" which retrieves information required by the user on the processes.
- The Agilium supervision is another user interface which deals with the management and the monitoring of the processes
- The Agilium web is a web application where the different instances of the business processes are.

In order to manage the processes in Agilium, the methodology is the following:

- Model the processes = model the activities and associate them to the actors with the managing rules and indicators, through a graphic tool.
- Integrate the processes = Agilium Factory connects the existing application, and supplies the specific application screen for manual activities. It makes far easier browsing between vertical applications, the priority system and web applications.
- Execute the processes = it is possible to describe the system behaviour in case of drift, non-response of one of the components requested by the business process. The probe put during the establishment of the model captures permanently the data necessary for the creation of indicators.
- Monitor the processes = supervision of the processes through a simple and accessible tool without complex settings. It is possible to analyse the statistics and to control the behaviour directly on the process.

Martine Spécialités has modelled two important processes in this system, one concerning financial aspects and the other one concerning research and development aspects.

The next section will describe those two processes. The description of the processes will be realized in a simplified version of the Agilium BPM notation. Figure 6 provides an illustration of the different elements of this notation.

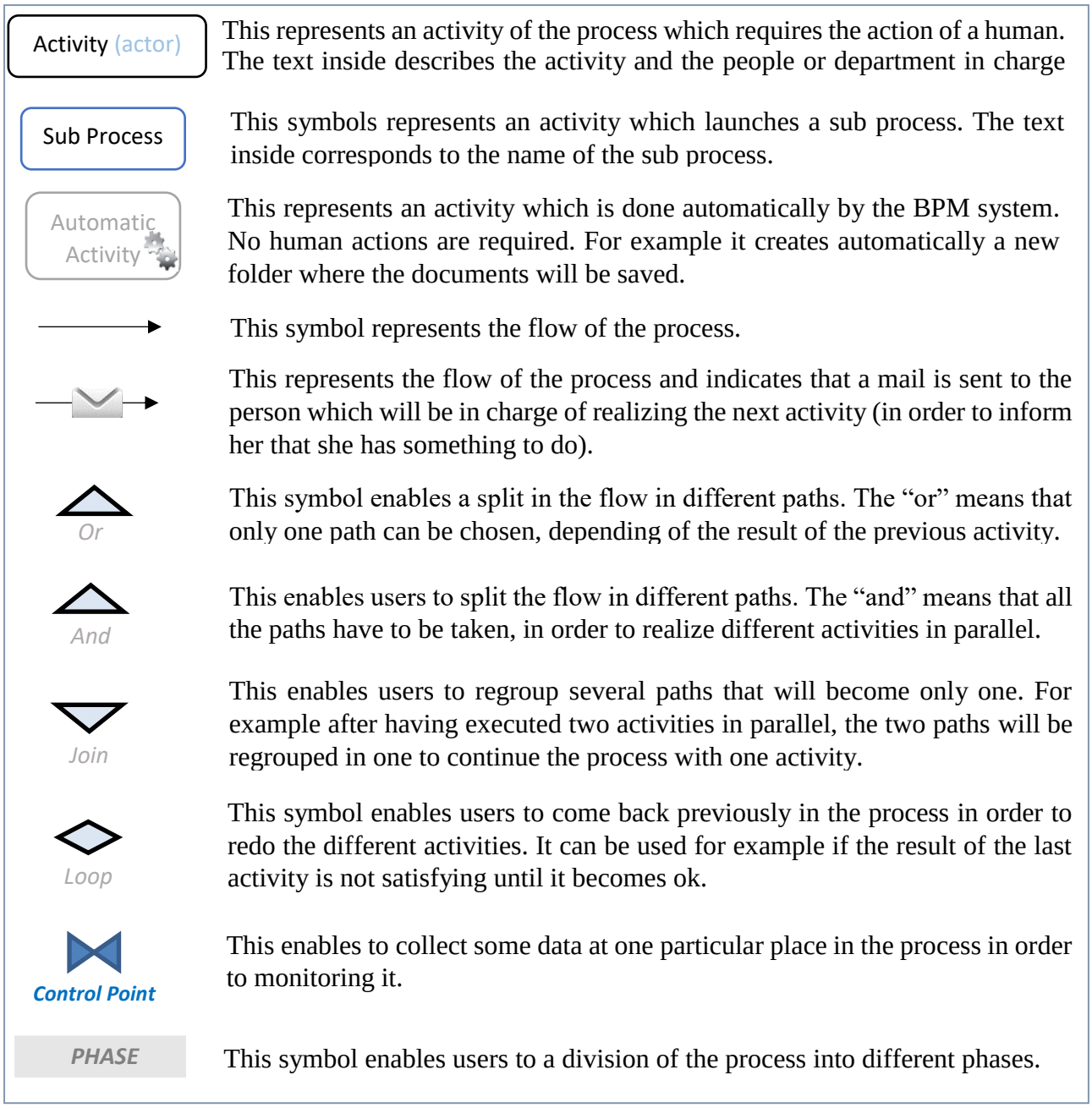


Figure 6: Simplified Notation of the Agilium BPM system

3.3.2 Description of the Processes of Martine Spécialités

In this section a description of the two processes (the Financial Process and the Research and Development process) will be provided in order to understand the environment of this subject of research. This description will demonstrate that there are an important number of actors involved and, particularly for the Research and Development process where an important numbers of activities have to be realized in order to complete the process.

The Financial Process

The objective of the Financial Process is to manage the requests of investment made by the different departments of the enterprise. It provides a structure which guarantees that the requests have been validated by all the required persons.

This process can be divided into five phases (illustrated in Figure 9):

– **Phase 1: Definition of the request for investment**

The department which needs an investment fills a form (illustrated in Figure 7) in order to describe the request. The information of the form is the name of the enterprise, the person who is asking an investment, the project, the type of project (informatics, innovation…), the cost and the currency. An automatic activity carried out by the Agilium BPM system then creates a specific number of requests to monitor it.

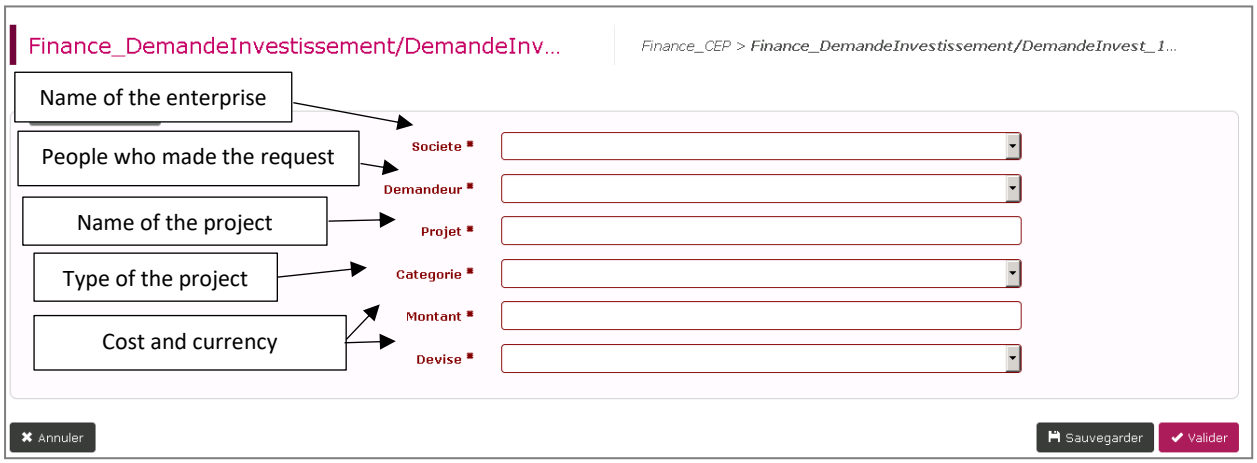


Figure 7: Form for a request of investment

– **Phase 2: Completion of the request by the Management Accountant**

The accountant analyses the form and provides a quote to answer to the request.

– **Phase 3: Validation of the request by the factory director and the logistic director**

The Factory Director studies the request and gives his opinion. The Logistic Director then can validate the request, refuse it or ask to modify it (for example he can request to do another quote with the use of a different product). If the request is validated the process continues in phase 4. If the request is refused the process continues in phase 5 and if the request needs to be modified the process returns to phase 2 (with the comments of the Logistic Director).

– **Phase 4: Validation of the request by others directors and the president**

This phase is done only if the request has been validated by the Logistic Director. It is the Industrial Director who gives his opinion of the request, and then the Financial Director (who writes a comment on the request). After that the President analyses the request and the feedback of the different Directors, and validates or refuses it. In each case a mail is

send to all the people concerned by the request in order to know the status of the request, and the process continues in phase 5.

– **Phase 5: Request saving**

In this phase the request is saved automatically in the Electronic Document Management, (folder where all the documents of the project are saved). This is an automated activity done by the Agilium BPM system.

Between each activity there is an automatic mail sent to the people involved in the process in order to inform them that they have something to do. For example, once the department has created a request, the Management Accountant received a mail that informs him there is a new request and that he has to add a quote. Once the President has made his decision regarding the request, there is also a final mail intended for the person who made the request, the Purchase Department and the Factory Director in order to inform them of the decision.

Martine Spécialités has decided to implement monitoring of the process with three control points (as illustrated also in Figure 9). The objective of this is to inform the enterprise of the number of requests for investment in progress and it informs Martine Spécialités in which step of the process the requests are being handled. The control points are the following:

✓ **The control point n°1** is between the phase 1 "definition of the request for investment" and the phase 2 "completion of the request by the Management Accountant". It enables to inform that a request has been made and it retrieves the information of the request.

✓ **The control point n°2** is between the phase 3 "validation of the request by the Factory Director and the Logistic Director" and the phase 4 "validation of the request by other Directors and the President" or the phase 5 "request saving". It enables users to retrieve the information regarding the decision of the Directors and it informs that the request is now in phase 4 or 5.

✓ **The control point n°3** is at the end of the phase 4 "validation of the request by other Directors and the President". It enables users to retrieve the decision of the President and it informs that the request is now in phase 5 "request saving".

This information is presented in a monitoring dashboard which recaps the requests for investment in progress and the different status of the requests (illustrated in Figure 8).

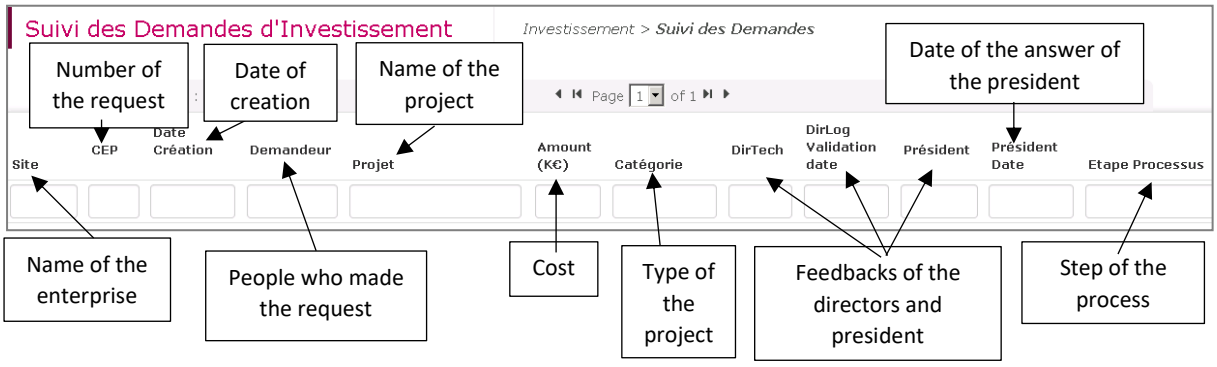


Figure 8: Monitoring Board of the Financial Process

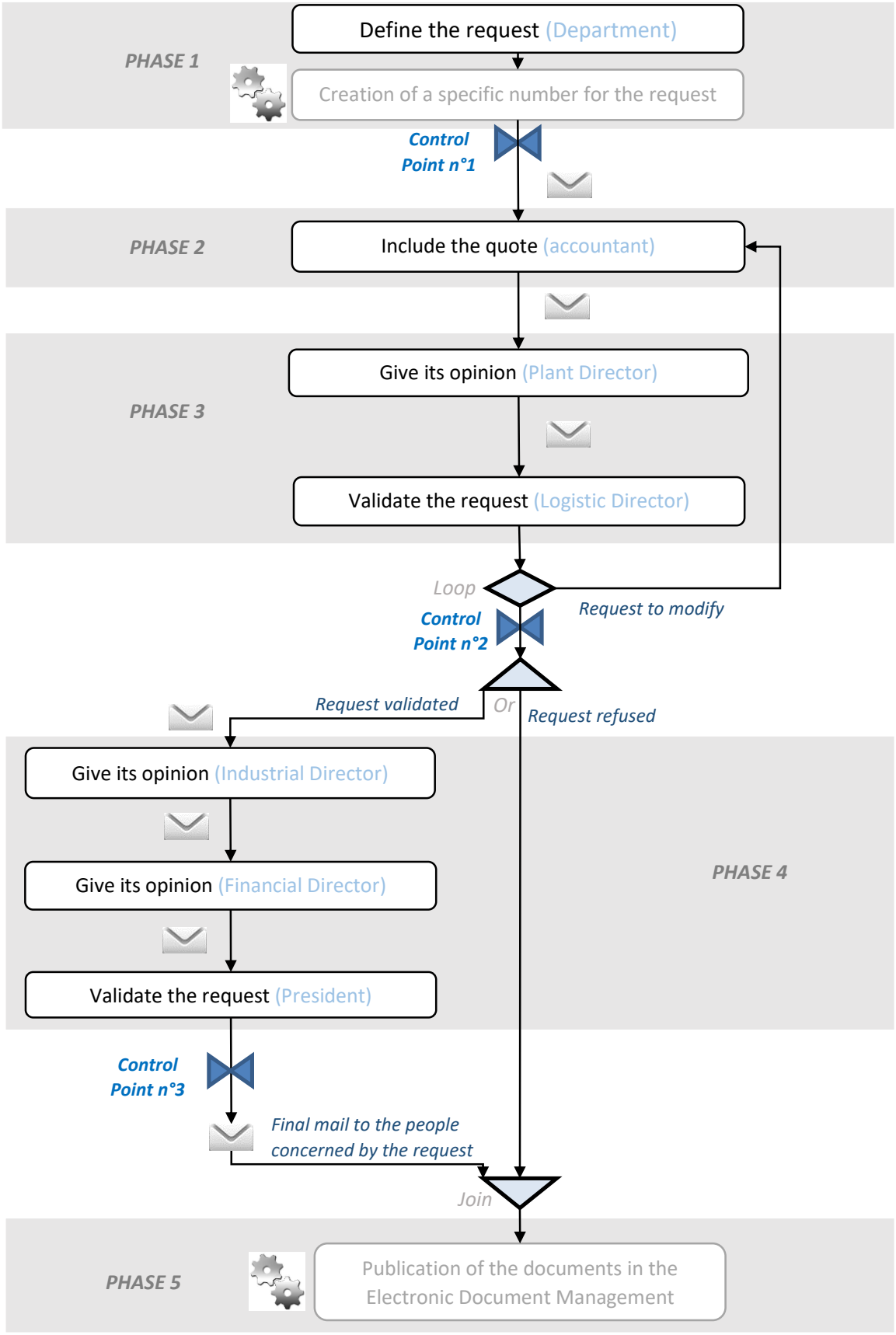


Figure 9: Description of the Financial Process

The Research and Development Process

The objective of the Research and Development (R&D) process is to manage the new requirement from the customers (for example, a requirement of a customer can be the request for a new recipe for a fruit tart). The principle is that the salesperson defines the need of the customer and there is a set of activities to validate the request. If the request is validated, the enterprise will manage a project which will be composed of different activities in order to answer this request. This Research and Development project enables users to involve the different actors regarding the customers' requests; it monitors how this request is taken into consideration in the enterprise.

This process is complex since it is composed of one macro process and different sub processes depending on the results of various activities, and there are several actors involved in it. In order to explain it clearly, a global description of the process will firstly be done and there will, subsequently, be a more detailed description of each sub process.

Global description of the R&D Process

Basically the R&D Process can be divided into three main phases:

- **The first "Project Definition and Validation" phase** is related to the definition of the customer request and the validation of doing a project in order to answer to this request.

- **The second "Project Specification" phase** concerns the description and the validation of the way to realize the project.

- **The third and last "Pre-Production" phase** is related to the realization of production tests of the new product in order to verify the fact that it satisfies the customer request.

The structure of the R&D Process is the following: it is composed of one macro process and different sub processes. The macro process named "*Product Development*" enables users to define the request and according to the result, to continue or to stop the R&D Process. There are two sub processes inside, the "*Project Definition"* process (related to the phase 1 of the R&D Process; this enables users to define the request and to validate it), and the "*Creation of version"* process (related to the phase 2 of the R&D Process; this concerns the specification of the project and its validation). The "*creation of version"* is a sub process which is realized only if the customer request is validated. Inside it, there are also two sub processes. The first one is the "*project specification*" process and the second one is the "*pre-production*" process (related to phase 3 of the R&D Process; this concerns the realization of some manufacturing tests) which is done only if phase 2 has been validated. Inside the "project specification" process there is a sub process called "*Cost Price Estimation*" that can be realized only if it has been required by the request, and there is another sub process called "Feasibility study". Inside the "Pre-production" process there is a sub process called "Industrial Test" which is done only if it has been requested. Figure 10 illustrates the structure of the R&D Process with different sub processes.

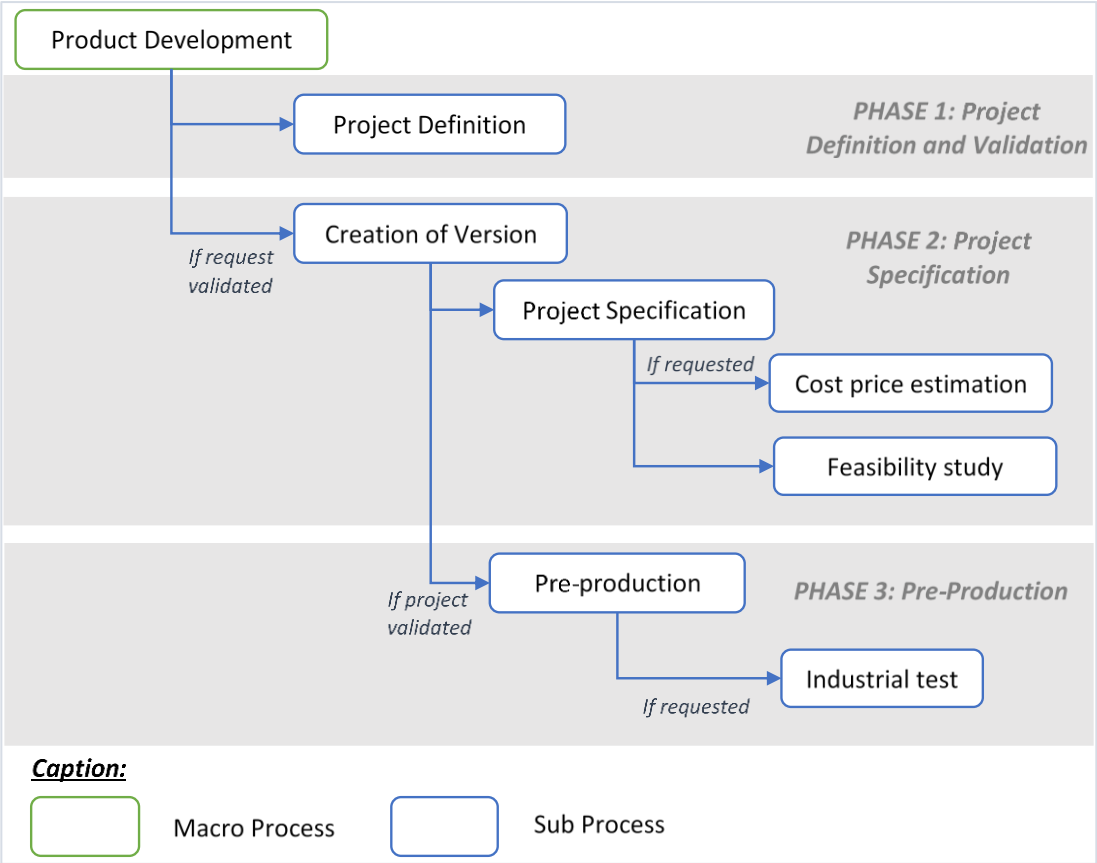


Figure 10: Description of the Structure of the R&D Process

Detailed description of the R&D macro process and each sub process

Product Development Process

The "Product Development" Process is the macro process which enables users to start a new development of a product and to end the global process. As illustrated in Figure 11, the first step is the sub process "*Project Definition*" which enables to define the request. If the request is validated, the next step is the sub process "*Creation of version*" which will provide the specifications of the project. If the request is refused, the next step is the end of the project definition (done automatically by the Agilium BPM system). The last activity of this process is an automatic activity which enables users to end the product development process.

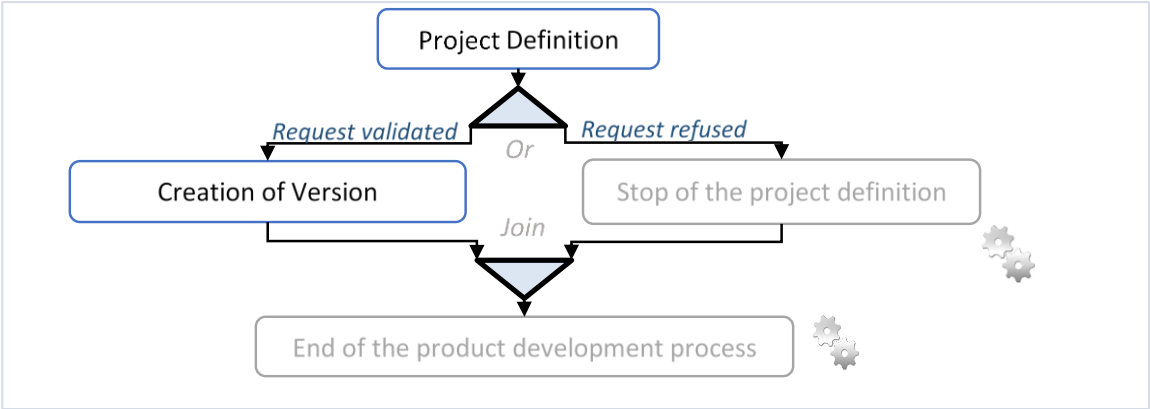


Figure 11: Description of the Product Development Process

Project Definition Process

The project definition is an important step in the R&D Process as it enables users to obtain the details of the customer request and the decisions of the enterprise regarding this request. It can be divided into 4 phases as illustrated in Figure 12:

Phase 1: Customer request definition
The salesperson fills a form regarding the customer request (data: name of customer, recipe, cost price etc.). An automatic Agilium activity updates the date of the request and creates a word document which describes the request.

Phase 2: Feedback of the President
The President studies the request, validates priorities and if he chooses to accept the request, designates a plant which will be responsible for it. There are then several automatic Agilium activities which enable users:

- To inform the salesperson of the feedbacks of the President.
- To create a field in the electronic document management (EDM: where all the documents of the project will be saved).
- To publish the request in the EDM.

If the President refuses the request, it is the end of the project, and if he accepts the process continues into phase 3.

Phase 3: Feedback of the Production and the Purchase departments
After receiving the mail regarding the President's feedback (done automatically by the Agilium BPM system), the production and purchase departments provide their feedbacks regarding the risks of doing the project (in answer to customer requests). It is also possible to add a comment on the project. According to the feedbacks there are three possibilities:

- No risk and no comment = the process continues in phase 4.

- No risk but comments = a mail is sent to recap the comment to everybody and the process continues in phase 4.
- One or several risk = a mail is sent to the President and the committee of direction (CODIR) regarding the risk identified. A decisional meeting is organized. If the risk is too important the process stops. If not the process continues in phase 4.

Phase 4: Definition of the number of versions required

Depending on what the salesperson wrote on the form in phase 1, a technical data file may be required. If it is, then a mail is sent to the R&D Project Manager. If not, the process continues in the next activity which is the definition of the number of versions required. In this last activity, the R&D Project Manager defines the number of development steps required to answer the customer request. If the project definition process ends with a positive answer of all the actors, then the process continues with the sub process "Creation of Version".

Martine Spécialités has also decided to monitor the process with three control points (illustrated also in Figure 12). The objective of this is to inform the enterprise of the number of customer requests in progress and it enables users to know in which step of the process the project is. The control points are the following:

- ✓ **The control point n°1** is between the phase 2 "Feedback of the President" and the phase 3 "Feedback of the Production and the Purchase departments". It enables users to be informed that a project has been validated.

- ✓ **The control point n°2** is after the activities regarding the feedbacks of the Purchase and the Production departments. It enables users to follow the validation or not of the project.

- ✓ **The control point n°3** is after the activities regarding the identification of the risks of the project. It enables users to follow if there are risks on the project and to know what is the decision regarding those risks according to the CODIR.

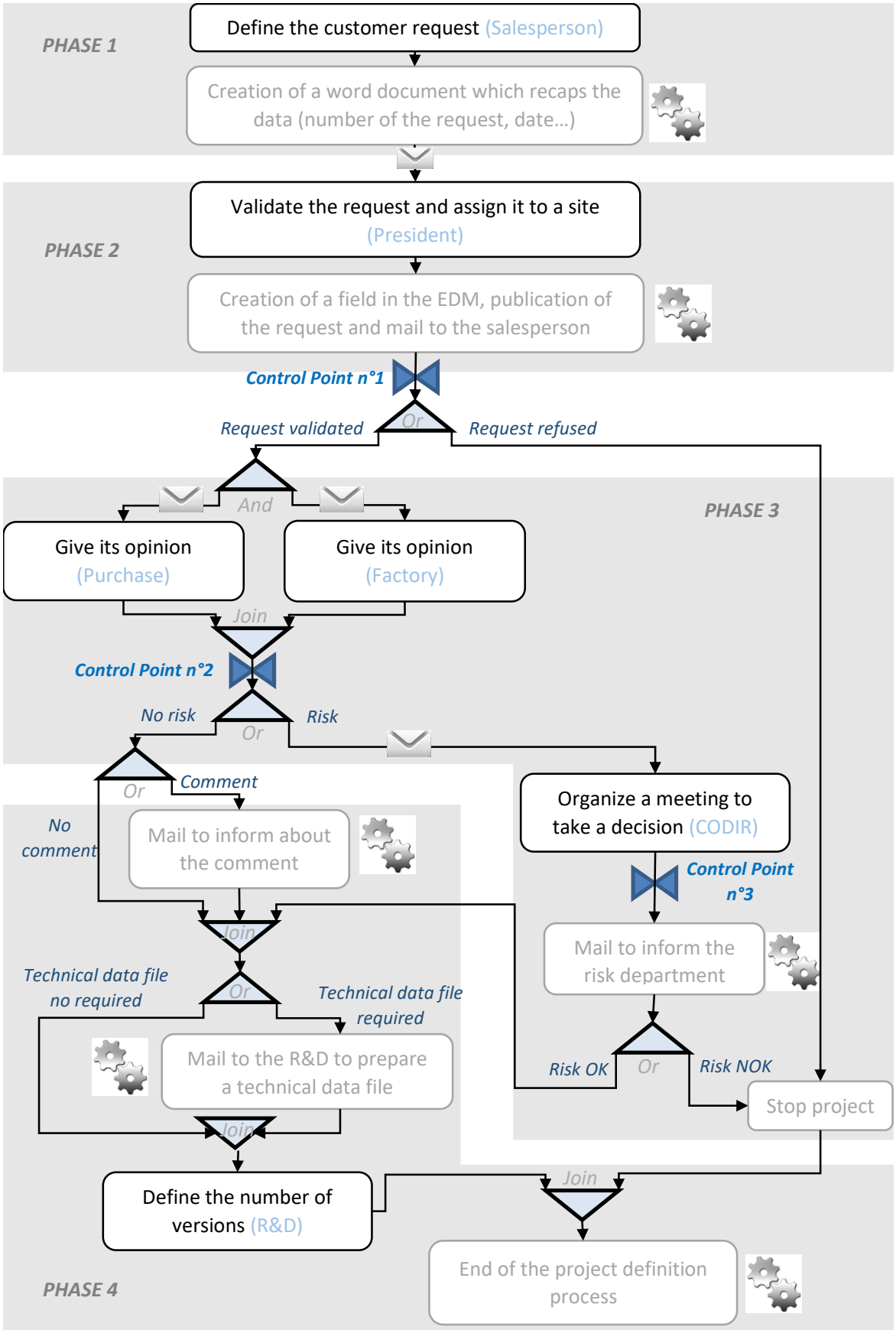


Figure 12: Description of the Project Definition Process

- Creation of Version Process

As illustrated in the Figure 13, this process is mainly automatic in order to retrieve the data of the project, to create a file in the EDM and to launch different sub processes. The first sub process is the "project specification process", and according to the results of it, the other sub process that can be launched or not is "the pre-production process". The "creation of version process" enables users also to create new versions of the project in progress if it is required.

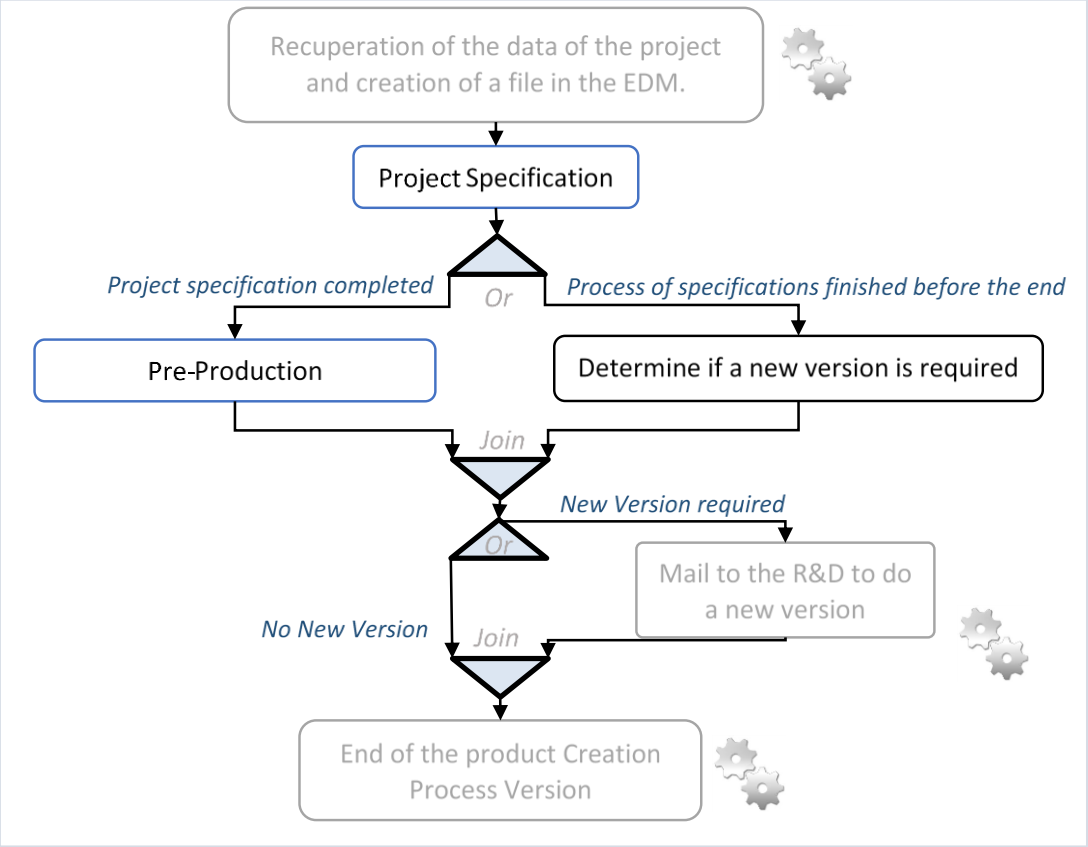


Figure 13: Description of the Creation of Version Process

Project Specification Process

The "*Project Specification*" Process enables users to define and validate the way of realizing the project. It can be divided into 3 phases (illustrated in Figure 14):

Phase 1 "Definition of the specifications":

The laboratory technician creates a specifications file of the product requested by the customer. Then the R&D department checks the compliancy of the product and completes some information (e.g. they complete whether an estimation of the cost price is required). If the product compliancy is not ok, it is possible to create a new specification file or to end directly the *project specification* process. If the compliancy of the product is ok, the process continues into phase 2.

Phase 2 "Price Cost Estimation and Feasibility Study of the product":

If the R&D department has asked for an estimation of the cost price of the product, then a sub process is launched "*cost price estimation*". If the estimation price is ok, another sub process "*Feasibility study*" is launched, if not the project specification process ends. If the feasibility study of the product is ok the process continues into phase 3.

Phase 3 "Validation of the product offer":

In this phase the sales price is defined and the salesperson creates a price sheet. The person responsible from the Sales department validates or invalidates the offer. If the offer is validated, the salesperson sends it to the customer. If the customer validated it, the next process "pre-production phase" is launched. If not, it returns to the process "Creation of version".

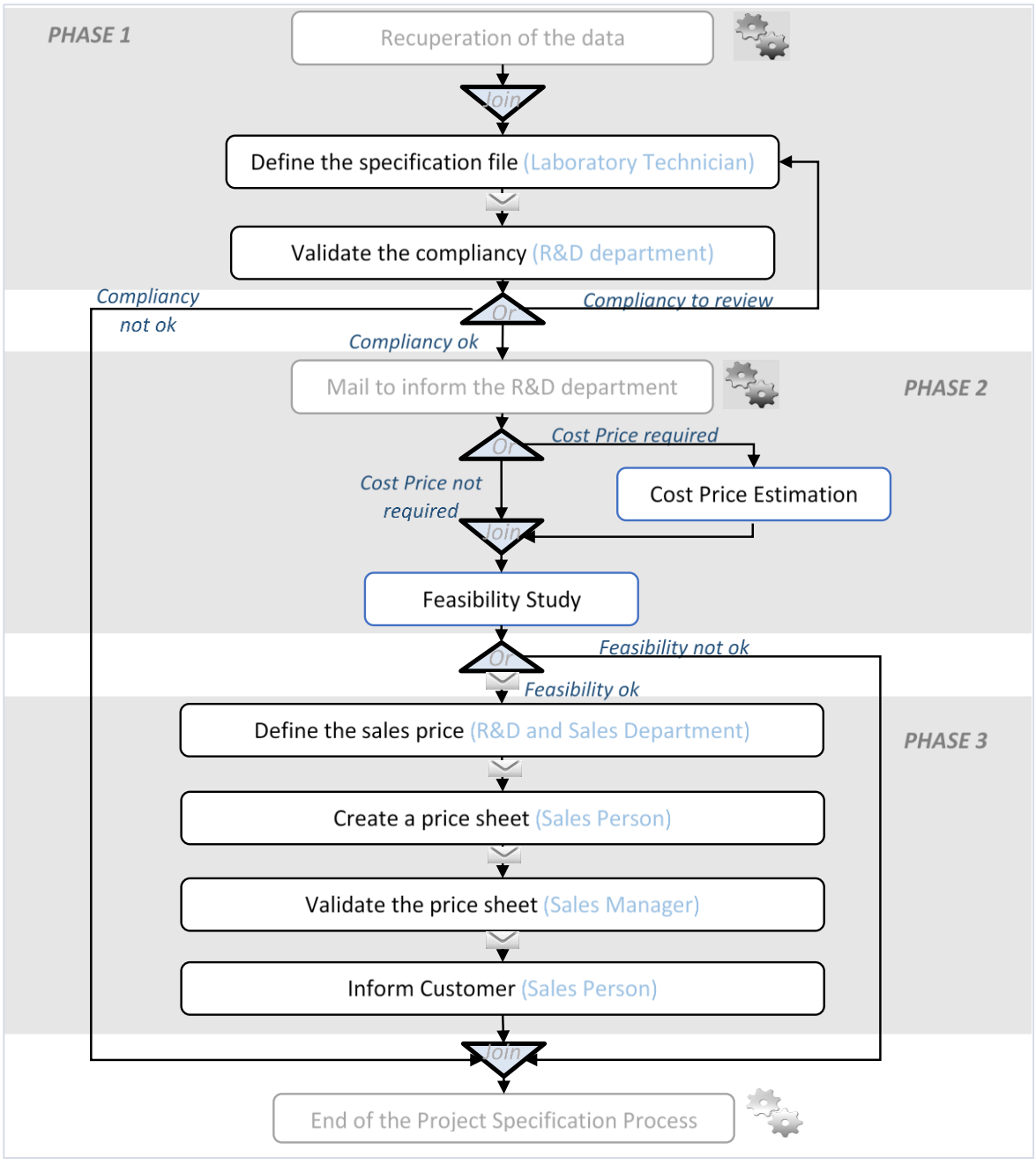


Figure 14: Description of the Project Specification Process

Cost Price Estimation Process

This process is launched only if the R&D department has asked for an estimation price of the product. It is composed of the following activities: firstly it is the Director of the factory who estimates the price. Then the R&D department gives his opinion. And after that, the assistant of the salesperson can validate or can ask to review the price. Once the price is validated it is the end of the cost price estimation process.

Feasibility Study Process

This process enables users to check if the manufacturing of the product requested by the customer is feasible. It can be divided into two main phases (as illustrated in Figure 15):

Phase 1 Manufacturing Process Definition phase: the R&D Project Manager defines the manufacturing process (line of production, type of packaging, components used…). An automatic activity done by the Agilium system informs one or several Production Line Managers and the purchaser of the manufacturing process. Each actor involved has to analyse the manufacturing process.

Phase 2 Validation of the manufacturing process phase: if the manufacturing process is validated and there is no new component to buy, a final validation is done by the R&D Project Manager. If a new component is required, the Quality Manager and the security manager give their opinions. It is possible that there may be a request for new material. In this case the validation of the methods manager is required to check if there is any risk in supplying this new material. Once all the actors have provided their comments, the R&D Project Manager validates the manufacturing process.

Martine Specialities has decided to monitor process with two control points (as illustrated also in Figure 15). The objective of this is to inform the enterprise in which step of the process the project is. The control points are the following:

- ✓ **The control point n°1** is after the activity regarding the manufacturing process definition. It enables users to inform that a manufacturing process has been proposed by the R&D project manager.

- ✓ **The control point n°2** is after the activity regarding the final validation of the R&D project manager. It enables users to follow the validation or not of the project.

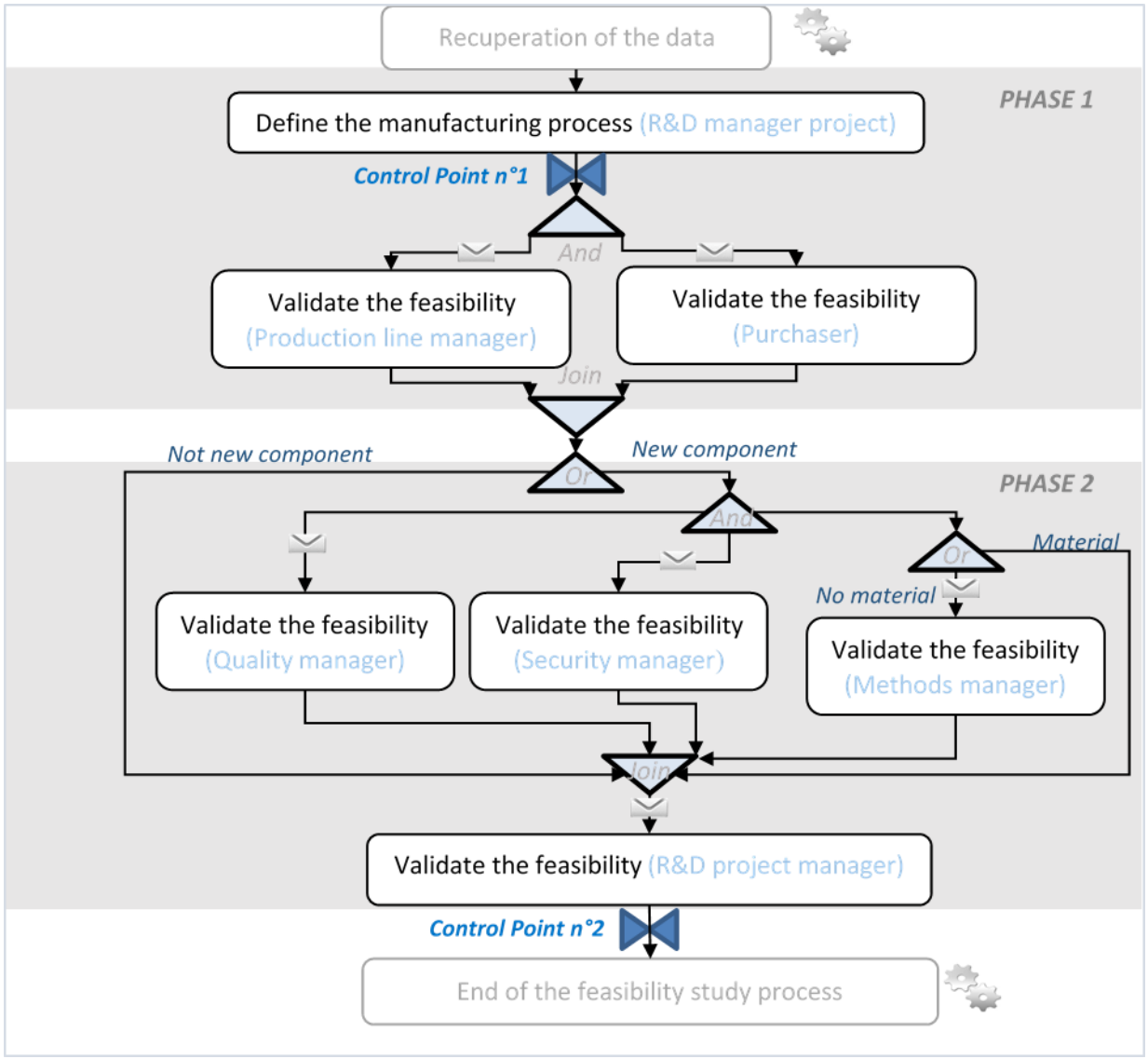


Figure 15: Description of the Feasibility Study Process

Pre-Production Process

This process illustrated in Figure 16 enables users to define the information regarding a pre-production of the customer request, and to launch, if necessary, an industrial test. This process is divided into two main phases:

Phase 1 Pre-production Definition phase: the R&D department defines the number of products that will be manufactured and the date of production; he also determines if a code of the product is required. If a code is necessary, a mail is sent automatically to all services and the Management Accountant creates a code. After that there are several activities in parallel:

- If required, the sub process “Industrial test” is launch.

- The R&D department defines an extern technical file.

- The R&D department defines an intern technical file that will be validated by the Production Line Manager (if not the R&D department will create a new file until it is ok).

Phase 2 Pre-Production Launch phase: now that all the documentation has been created, a first manufacturing of the product is done. The last activity is the validation by the customer of the product proposed by the enterprise.

Martine Specialities has decided to monitor this process with just one control point (as shown in Figure 16). The objective of this is to inform that the project is now launched in a first production phase.

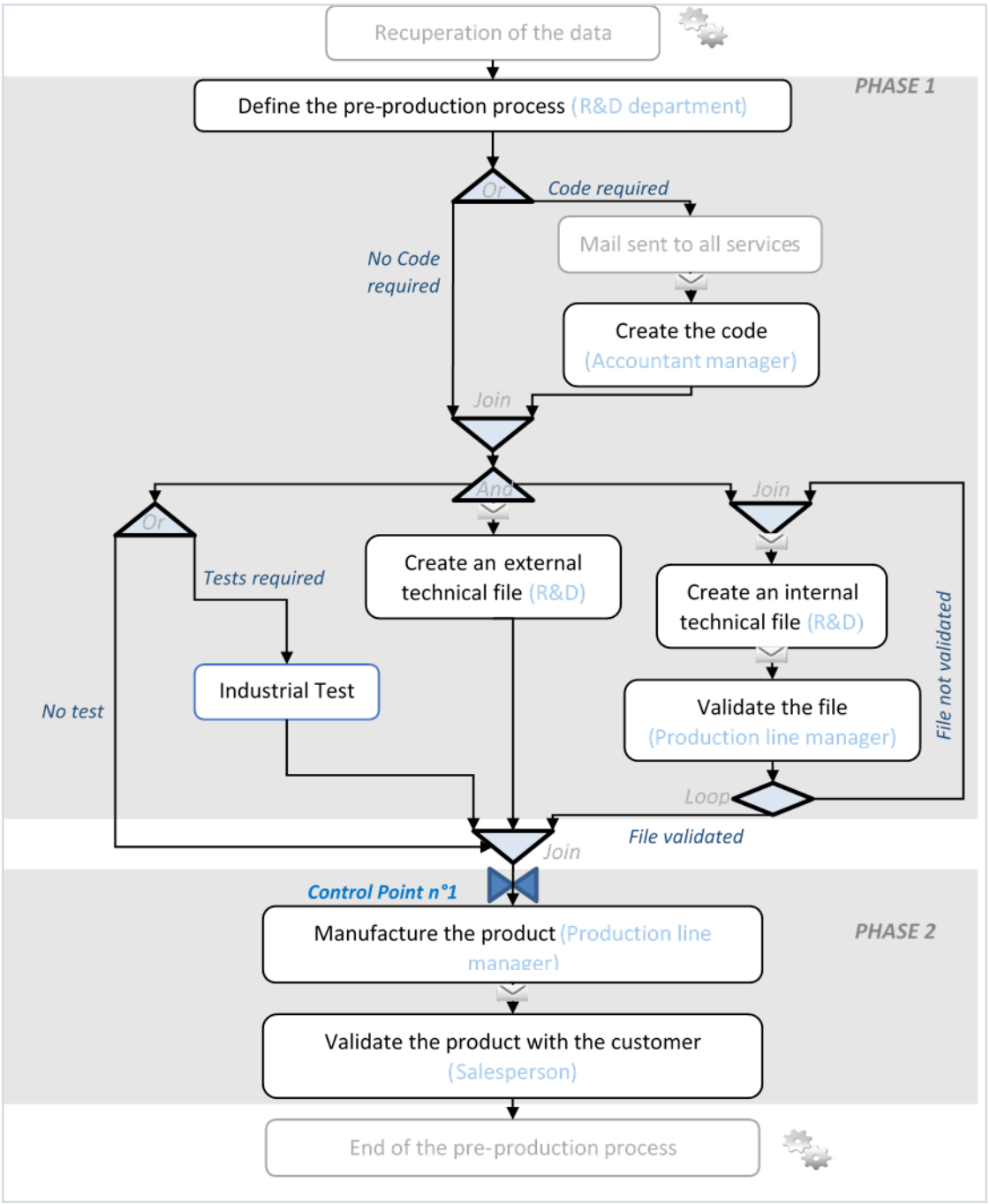


Figure 16: Description of the Pre-Production Process

Industrial Test Process

This process is executed only if the R&D department has asked for an industrial test. The first activity is a validation by the R&D Project Manager of realizing this industrial test.
If it is validated the R&D department defines the condition of the test (production line, date, volume). After that the Production Line Manager realizes the test, makes a recap of the results and publishes it to the R&D department. This process is illustrated in the Figure 17.

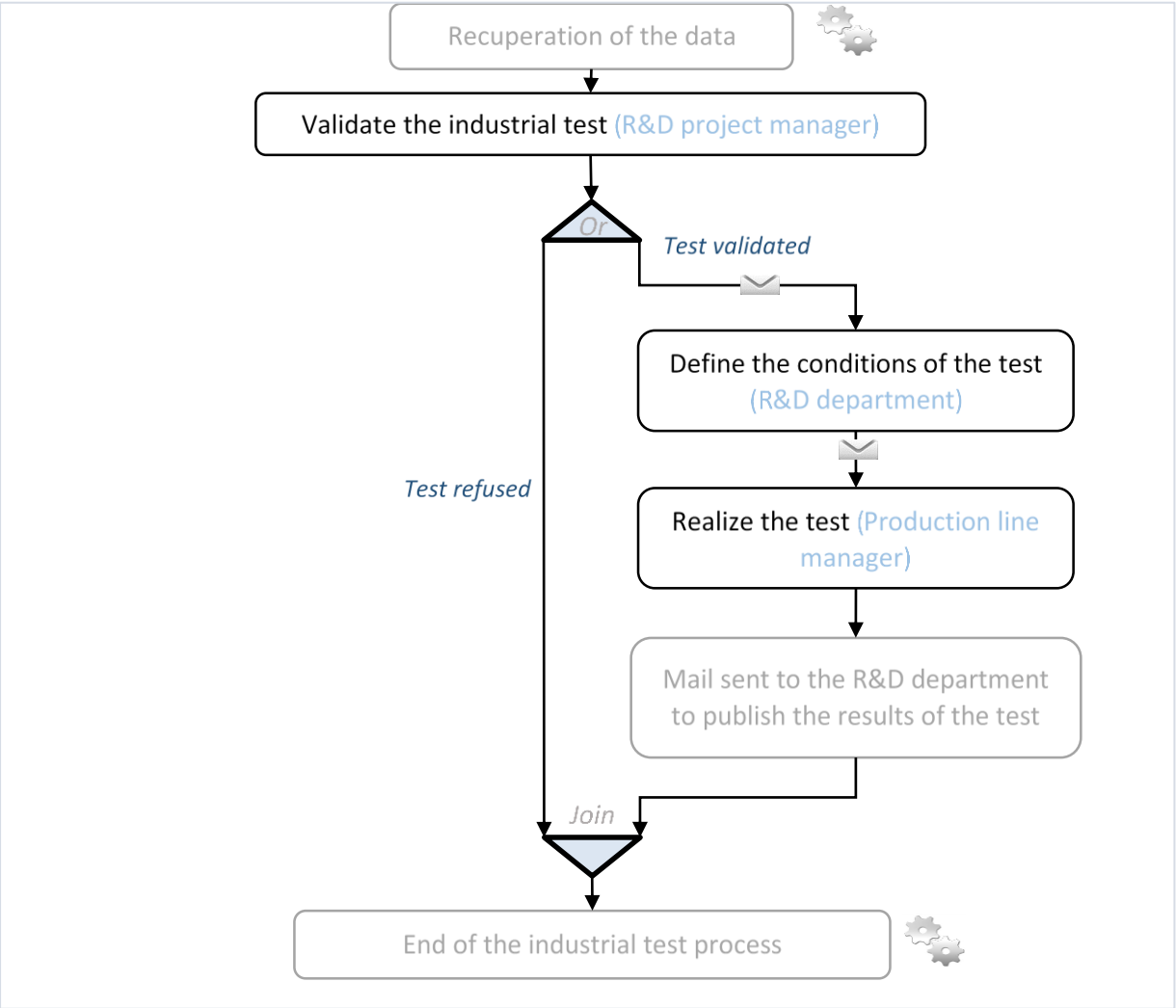


Figure 17: Description of the Industrial Test Process

3.3.3 Analysis of the Actual State of the Process Management

The previous section shown that the processes in Martine Spécialités are complex and there are several actors involved. In both processes, monitoring has been implemented with several control points. The objective of those control points is to provide indicators regarding the progress of the processes. This enables users to inform the actors in which step the process is and to make sure that it will progress in time (for example if the process makes no progress and it is for a long time blocked on the same activity, a manager can look at the monitoring document,

determine which person is responsible for the activity, and remind her that she has to realize it). In this section, an analysis of the global functionalities of the BPM system is provided.

Table 1 below lists the main functionalities relating to the different types of activities presented in the two processes.

Type of Activity	Functionalities
Form	For this type of activity, the Agilium BPM provides a form that will be completed by the actors. It can be fields to complete, check boxes, dropdown-lists… According to the setting, it is possible to make a field mandatory.
Document Creation	The document creation is a type of activity where the actors will have to create or include a document (for example a cost price sheet, a quote…). In order to do that, the Agilium BPM system offers the possibility of directly attaching a document or to create the document directly by completing different fields.
Opinion	Regarding this type of activity, the Agilium BPM system provides a recap of the information of the previous activities and the actor has to give its opinion. In this case, the objective it is to obtain the opinion of the user, there is no choice to make.
Decision	For this type of activity, the Agilium BPM system provides a screen which recaps the different information of the results of the previous activities (the form completed for example). The person in charge of this type of activity have a choice to make regarding a particular request, and have to decide to validate or refuse it (usually by selecting a check boxes and by completing a field in order to provide a comment on the choice made).

Table 1: Description of the functionalities of the Agilium BPM system according to the different types of activity

Another functionality of the Agilium BPM system is that once one activity is realized, a mail is sent automatically to the person in charge of the next activity in order to inform her she has something to do. As explained earlier also, there is monitoring available thanks to the Agilium BPM system in order to make sure the process progresses.

3.4 Conclusion

The work in this thesis will apply the use case methodology in order to obtain the functional requirements of the Agilium BPM system associated with the provenance concept. It will be done with the Martine Spécialités enterprise which is already using the Agilium BPM system but hitherto without using any provenance functionality. Currently the enterprise is managing two important processes with this system. The first one is the “Financial Process” which provides a

way to manage requests for investment made by the different departments of the enterprise. It is mainly constituted of opinion and decision activities. The second one is the “Research and Development” process which is more complex and provides a way to manage the requests made by the customers who want a new product (for example a new recipe of a fruit tart). It is constituted from several sub processes with all types of activities (forms, creation document, opinions and decisions). Now that the environment of this research study has been described, the next chapter will provide a proposal description of the combination of the provenance concept with the Agilium BPM system in the context of the processes management of Martine Spécialités. It will describe the functional requirements and the potential contribution that might be obtained for the enterprise with the combination of the two concepts.

Chapter 4 – Proposal Description

4.1 Introduction

The previous chapter defined the processes, methodology and the execution environment applied in this thesis. Two processes the *"Financial Process"* and the *"Research and Development Process"* were also described and introduced. These are managed by the Agilium BPM system in the Martine Spécialités enterprise. Based on these two scenarios, this chapter provides a description of how the provenance and the BPM functionalities can be combined and what benefits can be obtained from this combination. It is structured in three sections. Section 4.2 provides the functional requirements for the combination of provenance and BPM. Section 4.3 describes the provenance tracking in the processes and section 4.4 speculates on the potential benefits of this combination.

This thesis work is carried out according to two quality principles: the process and the evidence-based decision making approaches. The "process approach" principle has already been implemented in the Martine Spécialités enterprise since the Agilium BPM system is already used in order to manage two important processes. The subject of concern in this work is to use the concept of provenance in the Agilium BPM system in order to answer the "evidence-based decision making" principle (introduced in chapter 2 section 2.2.2). The purpose of this chapter is to determine the requirements from the combination of provenance with the processes of Martine Spécialités and to define the benefits that can be obtained from it. The first part of this chapter will describe what information of the processes is required to be tracked in order to improve the management of processes. The second part will introduce how the information will be tracked by representing graphically the provenance tracking in the processes. This is achieved by using the PROV standard, in particular PROV DM (Moreau and Groth, 2013). The third part of this chapter will speculate on a future state of the Martine Spécialités enterprise by presenting a set of potential benefits stemming from the association of the two concepts (BPM and Provenance).

4.2 Functional Requirements

According to the ISO 9001 standard, making decisions can often be challenging and involves a degree of uncertainty (International Organization for Standardization, 2015). The analysis of facts, evidence and data is recommended in order to increase confidence in decision making and to guarantee the production of the desired result. Indeed, poorly supported decisions are considered as choices that potentially waste company resources and that can risk the future of the organization (Baba and HakemZadeh, 2012). The "evidence-based decision making" principle implies that:

(1) The appropriate information has to be collected, i.e. the information which will be useful for the decision making;

(2) The appropriate information has to be provided when the person needs it, i.e. the information has to be provided when the decision has to be made and

(3) The appropriate information has to be provided to the person who needs it, i.e. the information has to be provided to the person who will be in charge of making the decision.

In this context, the functional requirements of the Agilium BPM system combined with provenance (in order to guarantee the evidence-based decision making principle) are the following:

- The functional requirement 1 is to collect the appropriate information in the process.
- The functional requirement 2 is to provide the information to the person who needs it and when the person needs it.

The next part will analyse how these requirements can be answered in the Agilium BPM system with the processes of Martine Spécialités.

Analysis of the first functional requirement: collect the appropriate information in the process

The collection of information is possible in the Agilium BPM system since it is built around the CRISTAL software (Branson *et al*. 2014) which provides provenance gathering. One aspect to consider is the implementation of provenance collection points in the processes, i.e. the points where the provenance will be implemented to track the information. Provenance collection points are indeed required in order to retrieve the information needed during the execution of the processes. The objective here is to define where information is required to be tracked and in this way, where provenance collection points could be implemented, in order to guarantee the "evidence-based decision making" principle. The following section defines the different types of information which are required when a decision has to be made.

- *The subject of the decision*

This is the primary piece of information in order to make a decision. The elements of the subject of the decision (such as who is making the decision, what is the subject of concern of this decision, why this subject of concern appears) are indeed mandatory for making a decision. This means that the Agilium BPM system combined with provenance will have to track the different inputs (related to the subject) that have been selected during the execution of the processes. For example, if the decision concerns the validation of a request for investment, the information regarding who is asking for an investment, what type of investment it is (e.g. new material or building extensions), why this order is made (the reason), how much it costs etc. are required to be able to make the decision.

- *The context*

When a decision has to be made, one important aspect to consider is the context of that decision (O'Brien, 2001). The environment and the settings are key inputs that will influence the decision making. This means that the Agilium BPM system combined with provenance will have to capture meaningful context, enabling a clear understanding of the actual situation for the decision making. For example, in the case of the Financial Process, the number of requests in progress

and the cost of those requests are useful pieces of information in order to make a decision. If the number of requests in progress is very low and the economic context of the enterprise is good, this context will encourage the validation of the current request.

- *The data of the past*

Another aspect to consider in order to aid the decision making process is past or historical data. What happened in the past can often provide important information such as a repeated situation and other evidence which influence decision making in the present. For example, it can demonstrate that in a particular context a specific decision was made. Several studies have been made in order to demonstrate the importance of collecting feedback (such as the concepts of Knowledge Management and lessons learned) (Sharif, 2005; Spilsbury, 2007; Jabrouni, 2012). In other words the Agilium BPM system combined with provenance will have to provide the audit trail of the processes (historical changes and outcomes of process). If a request for investment which is related to the purchase of new computers is made, and the audit trail shows that it is the fifth time that the same department has asked for new computers in a short period without a newcomer in the company, this could necessitate the refusal of the request. The outcome of a past decision is also an interesting and important input for decision making. It can demonstrate whether the decision made, according to its context, was a good or a bad option and thus avoid making the same mistake at a future point.

According to these three different types of information that are required to be tracked, the provenance collection points, in the processes of Martine Spécialités, will have to be implemented just after the activities which require a decision. In this way, for each execution of the process, the provenance collection point will collect the subject of the decision, the context and the past decisions that have been made. For the Financial Process, this means that the provenance collection points will be the following: the first provenance collection point will be after the activity which is related to the decision of the Logistic Director and the second provenance collection point will be after the activity which is related to the decision of the President (as illustrated in Figure 18 as a reminder from Chapter 3, which formalizes the different roles and departments involved in the processes). This is the same principle for the research and development process, where there will be the following provenance collection points:

- In the Project Definition Process :
  - One point after the activity which is related to the decision (regarding the request) of the President.
  - One point after the activity which is related to the decision (regarding the risks) of the CODIR.
- In the Project Specification Process:
  - One point after the activity which is related to the decision (regarding the compliancy) of the R&D department.
- In the Feasibility Study Process:

- One point after the activities which are related to the decision (regarding the feasibility) of the Purchaser, the plant manager, the Quality Manager, the Security manager and the Industrial manager.
- One point after the activity (regarding the feasibility) which is related to the decision of the R&D Project Manager.

– In the Industrial Test Process:

- One point after the activity which is related to the decision (regarding the industrial tests) of the R&D Project Manager.

To conclude, this part demonstrated that to answer to the first functional requirement (collect the appropriate information in the process), it is necessary to track the following data: the subject of the decision, the context and the data of the past. It shows also that to track these elements, the provenance collection points have to be implemented just after the decision activities of the processes of Martine Spécialités. One element to check is the fact that the Agilium BPM system and the processes of the enterprise (according to their design) provide those required data. The analysis is the following:

Firstly it is possible to conclude that the information regarding the subject of the decision is mainly provided. Indeed the processes are built in such a way that the subject of the decision is described. For example if the decision concerns the validation of a customer request, there is a sequence of activities which will define the request, and will provide details such as the date of the request and who is making this request.

Secondly the information regarding the context is partially provided. With the Agilium BPM system, it is possible to track the context regarding the process itself (for example the number of requests in progress) but this does not take into account the external context, such as the economic situation of the enterprise, as there is no available information in the process regarding this aspect. If the actors involved in the decision making believe that some information concerning the external context is important, then the Agilium BPM system will have to be linked with this information. This is possible since this BPM system can be linked with other applications such as an ERP (Enterprise Resource Planning) but this will have to be considered at a later date by Martine Spécialités.

Thirdly, the information regarding the past or historical data is also provided since the Agilium BPM system can track everything that happens during the execution of the process (which decisions have be taken, how much the investment required costs etc.).One missing point is related to the result of a past decision. Indeed the processes are built in the Agilium BPM system in such a way that it does not provide this information. Once the processes are executed there is no information which provides the results of the work done. For example, the execution of the Financial Process does not provide information as to whether an investment that has been made enabled some particular benefit, (e.g. a return on investment). This means that the processes of Martine Spécialités would need to be modified in order to obtain this type of information. This

could be, for example, the addition of one activity before the end of the process which enables an actor to provide the result of the decision made.

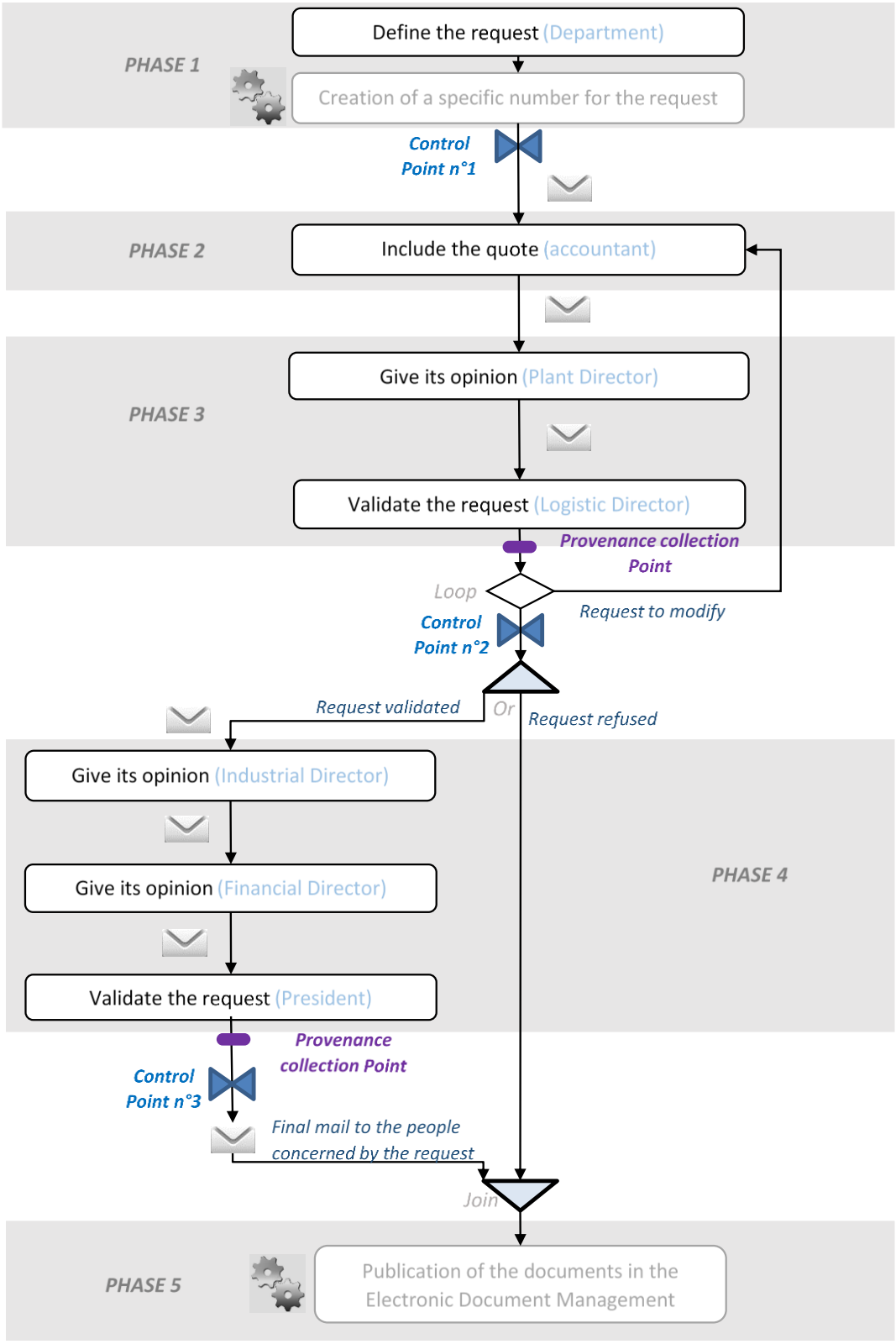


Figure 18: Provenance Collection Points in the Financial Process

Analysis of the second functional requirement: provide the information to the person who needs it and when the person needs it

The second functional requirement of the Agilium BPM system combined with provenance is to provide the information to the person who needs it and when the person needs it. As explained in Chapter 3, the processes of Martine Spécialités are composed of different types of activity: *Form*, *Document Creation*, *Opinion* and *Decision*. Since it is the "evidence-based decision making" principle which is the subject of interest in this work, this means that the information required, in order for it to help decision making, has to be provided in the decision activities of the processes. This means that when actors realize a decision activity, they will obtain, at that moment, the appropriate information that will help them to make the decision. It is important to be precise with the exact details of information that has to be provided since this will depend of the type of the process. The choice of the information to provide will not be the same, for example, for the Financial Process and the research and development process (the previous recipes that have been developed in the past will be useful for the research & development process but not for the Financial Process). It will also depend on which actor will have to make the decision. Indeed each actor works in a particular department (Purchase Department or R&D department, for example) and their needs will be necessarily different. This signifies that it will be important to take into account the needs of each actor responsible for making decisions in order to provide to them with the right information.

The fact that the information has to be provided to the person, who needs it, is guaranteed in the Agilium BPM system. Indeed for each activity of the process, there is a person responsible who has been designated during the modelling of the process. This means that when the activity is executed, the responsible person is automatically informed that he has a task to carry out. Since the person who has to take a decision is in charge of the decision activity, this guarantees that the information will be provided to them.

One important point that will have to be considered is how to represent the information provided. If the person responsible for making the decision is absent or cannot understand the data because there is too much unstructured information, the "evidence-based decision making" principle will not be reached. It is therefore crucial to package the information in a way that helps understanding the key messages. This is an implicit functional requirement of the Agilium BPM system when combined with provenance.

4.3 Provenance Collection Representation

The objective of this section is to represent graphically the provenance tracking of the processes of Martine Spécialités. It will be done according to the PROV Data Model (PROV DM). This graph model enables us to express provenance in a visual manner by illustrating schematically how the data was created. It has been formalized by the W3C (World Wide Web Consortium) and it allows domain and application specific representations of provenance to be translated into such a data model and interchanged between systems (World Wide Web

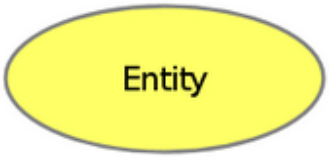
Consortium W3C, 2013). Firstly, a description of the PROV DM will be presented and secondly, a description of the provenance in the processes of Martine Spécialités with this standard will be provided.

4.3.1 The PROV Data Model

In order to illustrate provenance, the PROV DM has defined several concepts described below (according to the PROV GRAPH layout convention[1]):

- *Entity*

An entity is defined as a thing for which we want to describe provenance. It is physical (such as car or a building), digital (such as a file or a web page), conceptual or other kinds of elements with some fixed aspects. It can be real or imaginary and it is represented with a yellow oval.



- *Activity*

An activity is defined as something that acts upon or with entities over a period of time. It includes different actions on entities such as modifying, relocating, using… For example, an activity can be the modification of a document or the act of driving a car from one place to another. It is represented with a blue rectangle.

- *Agent*

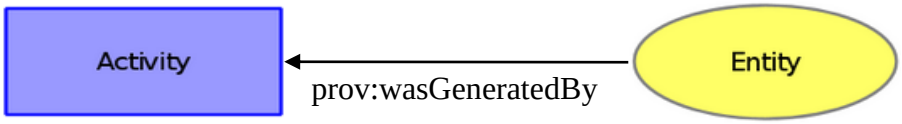
An agent is defined as something that supports responsibility for an activity taking place, or for the existence of an entity, or for another agent's activity. It is usually to answer the questions "who" or "what was responsible for the production of a thing" (such as software, a vendor etc.). It is represented with an orange pentagon.

[1] Copyright © 2015 W3C® (MIT, ERCIM, Keio, Beihang). This section 4.3.1 includes material copied from or derived from https://www.w3.org/2011/prov/wiki/Diagrams and https://www.w3.org/TR/prov-dm/

Those three concepts are categorized as “types”. In order to describe the relationships of those different elements of the graph, there are seven main concepts categorized as relations which are described below.

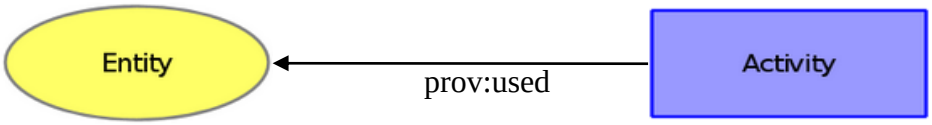
1. *Generation*

The Generation relation is used to describe the relationship between an activity and an entity, and more precisely to describe how an entity came to be. It implies that the execution of an activity generates an entity. For example it can be the creation of a document (new entity) from the writing papers activity. Graphically this is represented by an arrow between the entity and the activity, annotated with the text “was generated by”.



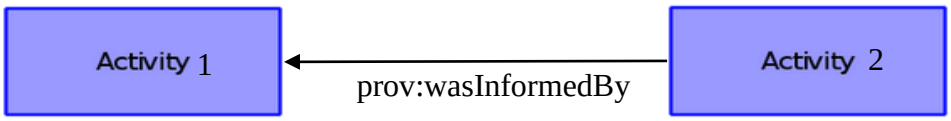
2. *Usage*

The Usage relation is also used to describe the relationship between an activity and an entity, but in a way to show the utilisation of an entity by an activity. For example it can be the use of egg (entity) in order to make a cake (activity). Graphically this is represented by an arrow between the activity and the entity, annotated with the text “used”.



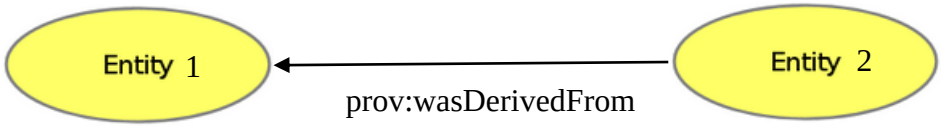
3. *Communication*

The Communication relation is used to describe the relationship between an activity and another activity. It shows the exchange of some unspecified entity by two activities (one activity using some entity generated by the other). For example it can be the fact that the activity of launching industrial tests was informed by the activity of filling request of industrial tests. Graphically this is represented by an arrow between the activity and the other activity, annotated with the text “was informed by”.



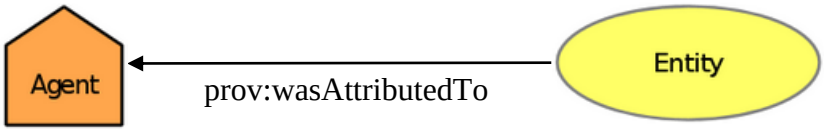
4. *Derivation*

The Derivation relation is used to describe the relationship between an entity and another entity. It shows the transformation of an entity into another in order to expresses the dependencies between data. For example it can be a quote (entity A) which derived into an order (entity B). Graphically this is represented by an arrow between the entity and the other entity, annotated with the text “was derived from”.



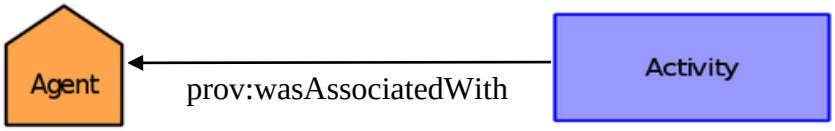
5. *Attribution*

The Attribution relation is used to describe the relationship between an entity and an agent. It shows the assignation of an entity to an agent (who or what supports the responsibility for an entity). For example the request of the customer (entity) was attributed to the salesperson (agent). Graphically this is represented by an arrow between the agent and the entity, annotated with the text "was attributed to".



6. *Association*

The Association relation is used to describe the relationship between an activity and an agent. It shows the assignment of responsibility to an agent for an activity (who had a role in an activity). For example the industrial test activity was attributed to the Production Line Manager (agent). Graphically this is represented by an arrow between the agent and the activity, annotated with the text "was associated with".



7. *Delegation*

The Delegation relation is used to describe the relationship between an agent and another agent. It shows the assignment of authority and responsibility to an agent from another agent. For example the manager delegates its task to the operator. Graphically this is represented by an arrow between the agent and the other agent, annotated with the text "acted on behalf of".

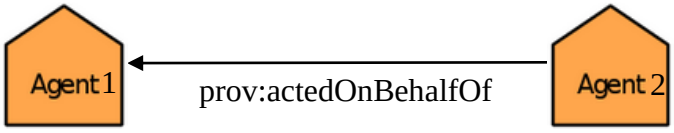


Figure 19 [**Erreur ! Source du renvoi introuvable.**] recaps the elements of the PROV graph according to three different views which provide a complete description of what has happened:

- The data flow view with the entity: this represents the flow of information or the transformation of things;
- The process flow view with the activity: this represents the activities that occurred;
- The responsibility view with the agent: this represents the assigning responsibility for what happened.

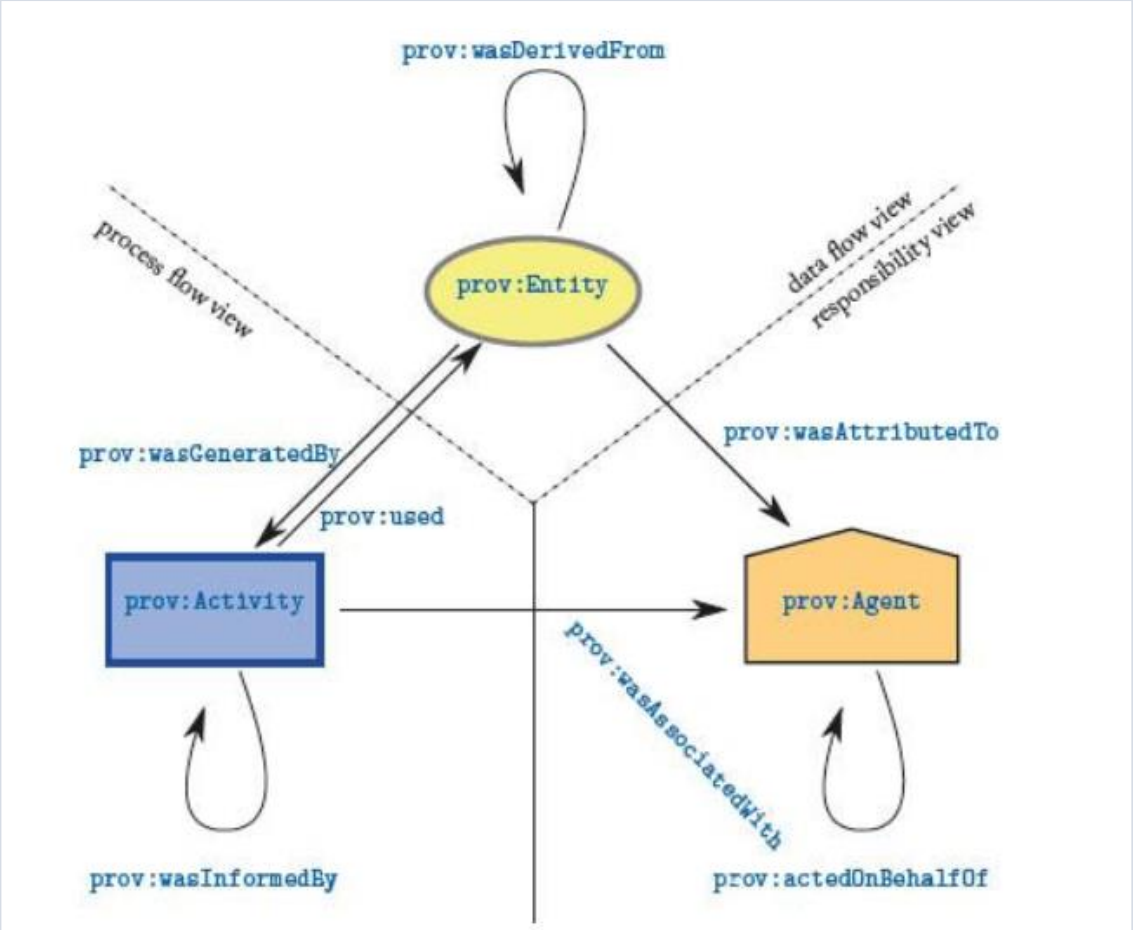


Figure 19: The PROV Graph (Figure used with permission of the author Paul Groth)

4.3.2 The PROV DM in Martine Spécialités processes

Now that the PROV DM has been explained, this section will use it in order to describe the provenance collection points of the processes from Martine Spécialités. This will be done firstly with the Financial Process, where the first provenance collection point is implemented just after the decision activity of the Logistic Director (Figure 18). Considering the elements of the process before this provenance collection point, it is possible to define the different elements which will be categorized as entity, activity and agent. Those are described in Table 2.

AGENT	ACTIVITY	ENTITY
Department of the enterprise	Fill a form to define the request	Request
BPM system	Creates a specific number of the request	Request edited
Accountant	Include a quote	Quote

Plant director	Give an opinion (1)	Request commented (1)
Logistic Director	Validate the request (1)	Request decision (1)

Table 2: the elements of the first collection point of the financial process categorized as Entity, Activity or Agent

In order to perform the mapping, the idea is to use the different elements that have been defined in the previous section (agents, activities and entities) and link them with the relationships of the PROV DM. Based on the flow of process execution, the mapping is done from the first activity of the process and describes successively which entity has been generated from it, what was associated to it (agent), which entity is used to realized it, and which other activity communicates with it, until the last activity is reached which is located just before the provenance collection point. When there are several entities and several agents, the mapping also considers if there is a link between these entities and these agents.

To illustrate the methodology of the mapping of the first provenance collection point, a description of the relationships of the first activity of the Financial Process (which is "fill a form") is provided. The idea is to analyse everything that can be linked to this activity:

- Since the result of this first activity is a request (an entity), a link "was generated by" is implemented between this activity and this entity.
- Since the person responsible for this activity is the "Department" agent, a link "was associated with" is implemented between this activity and this agent.
- Since the next activity is "create a number" and it is executed only at the end of the execution of the "fill a form" activity, a link "was informed by" is implemented between the two activities in order to show this relationship.

This is repeatedly carried out until the last activity, which is "validate the request (1)", is reached. Now that all the activities have been linked, a focus is established for the entities. For example the "request" entity become the "request edited" due to the addition of a specific number on the initial request, then a link "was derived from" is implemented between these two entities. The same is done for the agents but in this case there is no relationship between agents since there is no delegation in the current situation.

Visually, the PROV DM of the first provenance collection point, with all the relationships between the different elements (entity, activity and actors), is illustrated in the Figure 20.

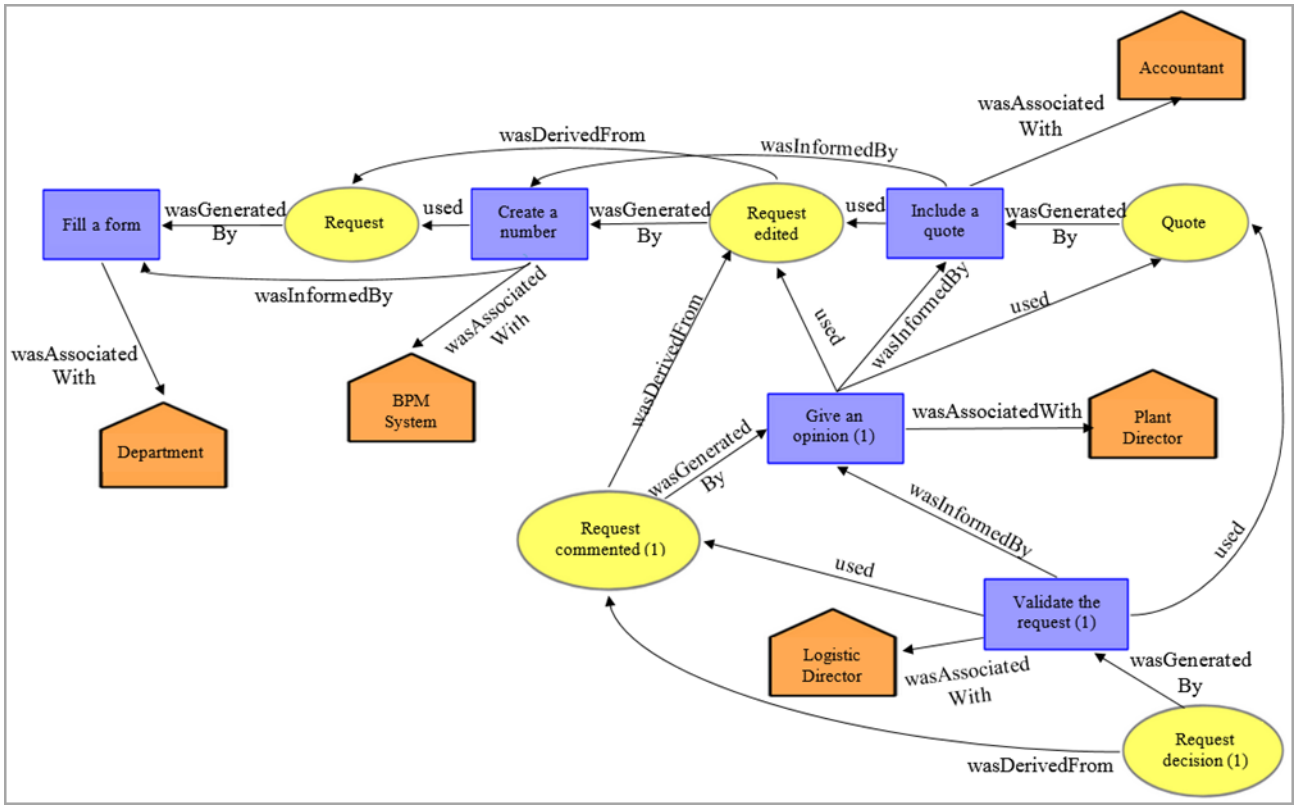


Figure 20: The PROV DM of the first Provenance Collection Point of the Financial Process

The second provenance collection point of the Financial Process is implemented just after the decision activity of the President (Figure 18). Table 3 defines the different elements of the process before this collection point, which will be categorized as entity, activity and agent.

AGENT	ACTIVITY	ENTITY
Industrial Director	Give an opinion (2)	Request commented (2)
Financial Director	Give an opinion (3)	Request commented (3)
President	Validate the request (2)	Request decision (2)

Table 3: the elements of the second collection point of the financial process categorized as Entity, Activity or Agent

In order to describe the PROV DM model of those different elements, it is necessary to include the last three elements of the first provenance collection point which are: the request validation (entity), validate the request (1) (Activity) and the Logistic Director (Agent). Indeed the next activities of the Financial Process depend on the result of the decision of the Logistic Director. It is only if the request is validated that the activity "Give an Opinion" by the Industrial Director will be executed. That is why it is important to describe the last three elements of the first control point in the PROV DM of the second control point. Keeping the same mapping methodology described previously, this enables us to obtain the PROV DM as illustrated in Figure 21.

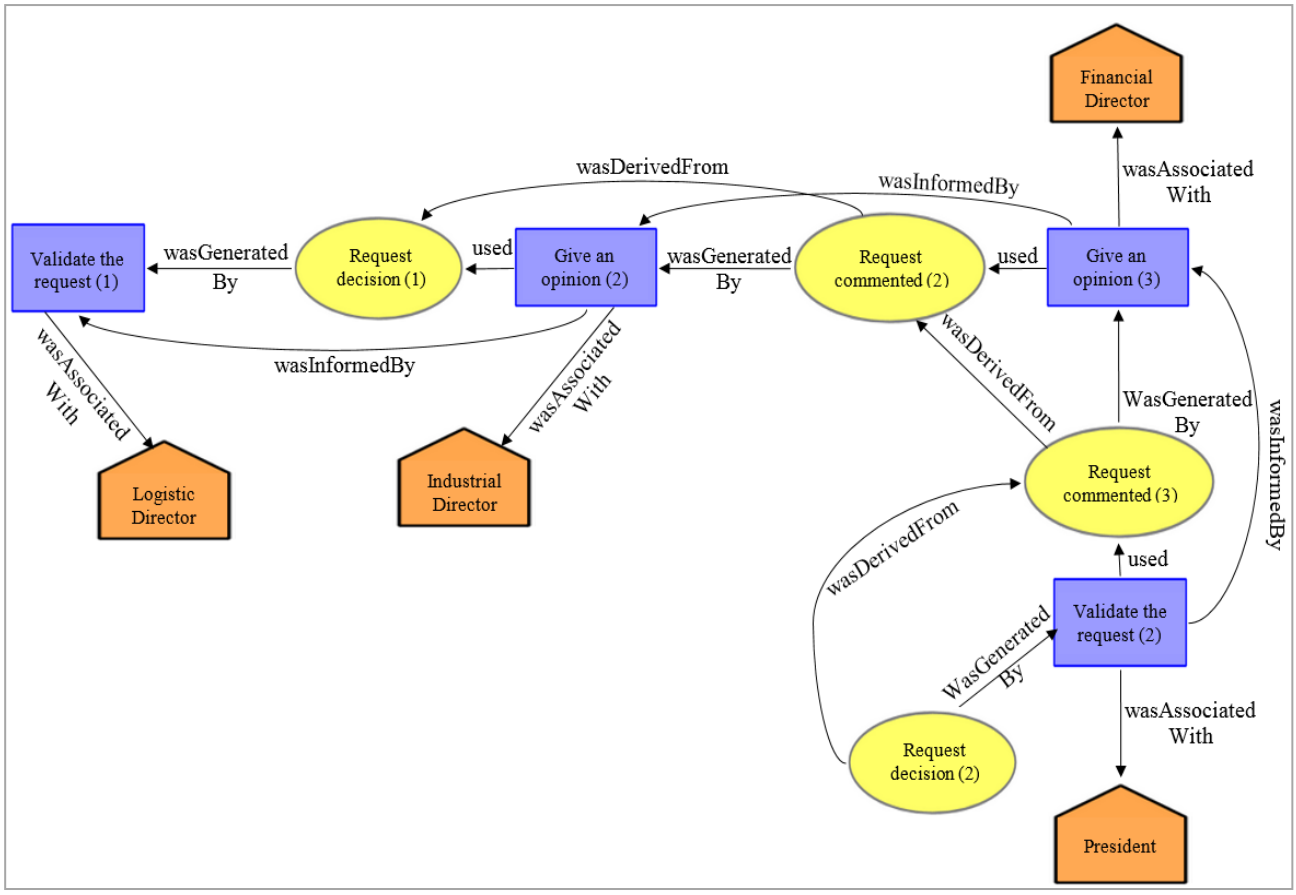


Figure 21: The PROV DM of the second Provenance Collection Point of the Financial Process

This is exactly the same logic for the Research and Development process. In order to illustrate it, the PROV DM of the first provenance collection point will be provided. It concerns the "Project Definition" Process, where the collection point is just after the decision activity managed by the President. This part of the process is composed of those different elements:

AGENT	ENTITY	ACTIVITY
Salesperson	Customer Request	Define the request
BPM system	Request Edited	Create a word document
President	Request Decision	Validate the request
BPM system	Request published	Publish the request

Table 4: the elements of the first collection point of the R&D process (precisely the Project Definition) categorized as Entity, Activity or Agent

Now that the elements have been defined, Figure 22 provides an illustration of the provenance with the different relationships of those elements. This PROV DM has been realized with the same mapping methodology which has been described for the first provenance collection point.

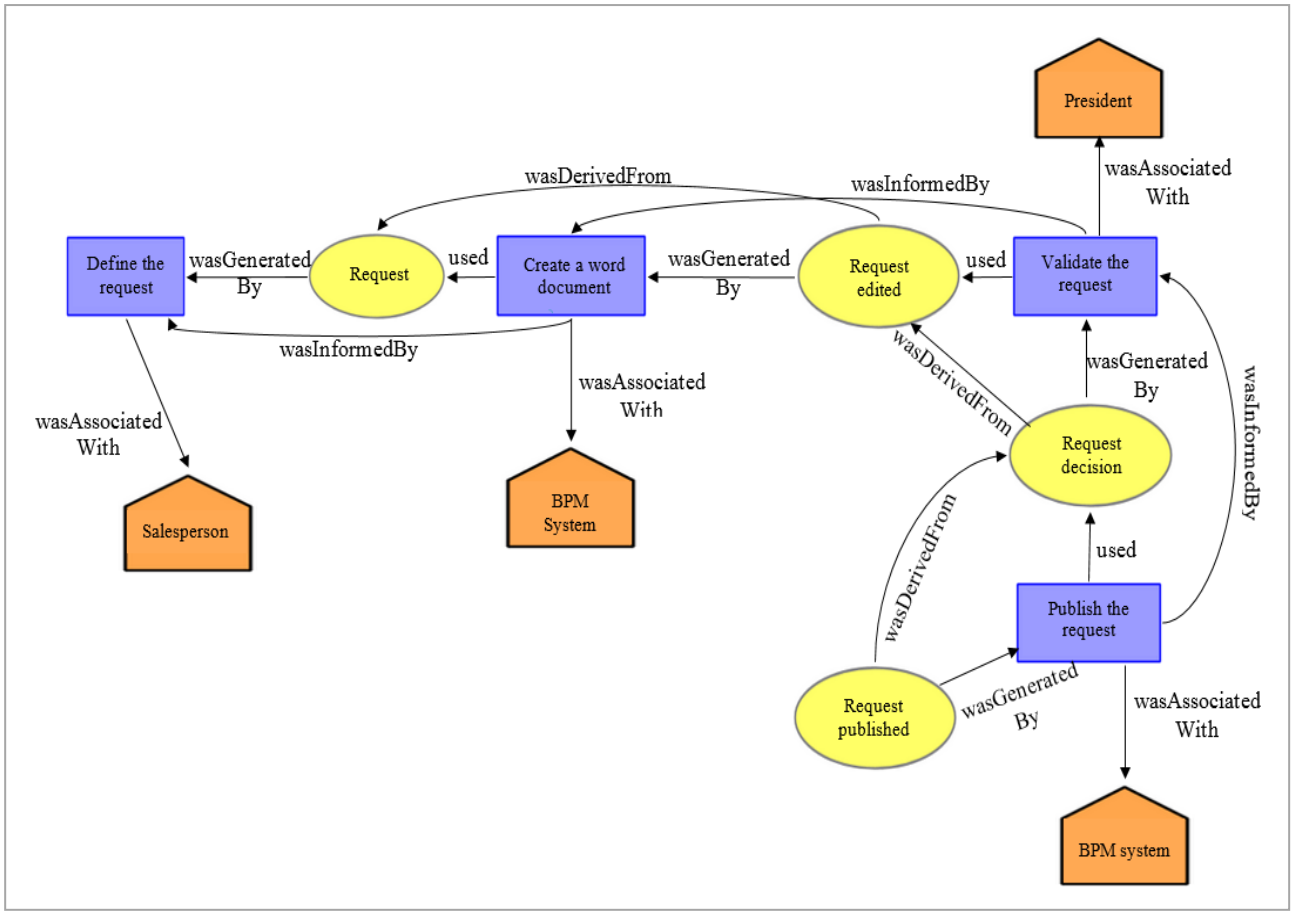


Figure 22: The PROV DM of the collection point of the R&D Project Definition Process

4.4 Potential contribution for Martine Spécialités

The previous sections defined which types of information were required to be tracked and how visually the audit trail is represented thanks to the PROV DM. The objective now is to provide the benefits that can be obtained from this tracking (or audit trail). This will be achieved by speculating on how the combination of provenance and the Agilium BPM system can contribute to the improvement of the process management of the Martine Spécialités Company. In the area of quality management, the evaluation of a project or a product is done according to three notions which are the cost, the time and the quality (Pillet and Duret, 2008). The ideal situation to be performant is to obtain a result with a low cost, in a quick time and which satisfies quality measures. According to these three notions, the benefits that can be obtained (if the Martine Spécialités enterprise uses the provenance functionality in the Agilium BPM system) are described below.

- *From a Cost Point of View*

By implementing the provenance functionality in the Agilium BPM system, the enterprise will reduce its costs and increase its benefits thanks to better decision making, as demonstrated below.
"More work with added value"

The actors involved will not lose time for searching for the data they need to make decisions, since it will be available directly in the decision activity. This will provide more time to focus on work with added value, which is beneficial for the company.

- *Example with the Financial Process*: the President who is in charge of defining the strategy of the enterprise will not be disturbed too long by the different requests of investment since he will obtain all the information he needs to take a decision quickly for validating or rejecting the requests.
- *Example with the Research & Development process*: the Quality Manager which is in charge of auditing the site will be able to answer quickly whether a new request from the customer is feasible or not.

"Mistakes whose costs are avoided"
With the possibility to look at past decisions given the context and the decision result(s), the actors of the decision making will avoid making decisions which produce bad financial results.

- *Example with the Financial Process*: the Logistic Director has accepted an order of investment which has resulted in a bad return on investment, such that if a similar demand is made by another department he will refuse it and this way save money.
- *Example with the Research & Development process*: if the President obtains the data that a customer made a same previous request which cost a lot and that has not been sold finally to him (the industrial tests failed). Then he will not validate the request and save money for the enterprise.

"Opportunities are not missed"
On the contrary of the previous point, if some decisions of the past resulted in financial benefits, the actors of the processes will not forget it and be able to reproduce it, if a similar situation occurs.

- *Example with the Financial Process*: the President has accepted an order of investment which has resulted in a very good return of investment, if a similar demand is made by another department he will accept it and this way obtain more money.
- *Example with the Research & Development process*: if a previous customer request that has been validated increases the sales and costs few in terms of development, similar requests will be accepted and the benefit of the enterprise will increase.

- *From a Time point of View*

"Reduction of the lead-time of the process, which leads to a better customer satisfaction"
An important benefit of the combination of provenance and the BPM domains, is that it enables users to provide the relevant data for the person who makes the decisions. This leads to a reduction of the time spent in searching for the required information; which leads to a reduction of the time spent to make the decision; which then leads to a reduction of the time spent to do the activity in the process; which in turn leads to a reduction of the global lead-time of the process and which then leads to an increase in efficiency and this way to a better customer satisfaction.

- *Example with the Financial Process*: the decision of accepting the request of investment will be made in a short time. This will increase the satisfaction of the person who made the request which will know quickly if it has been validated or not.
- *Example with the Research & Development process*: it is the same principle in this process with the customer requests which will be handled in a short time and which will lead to a better customer satisfaction.

- *From a Quality point of View*

"Data is accurate, secure and reliable which leads to better decisions"

Thanks to the provenance functionality, the data provided are accurate, secure and reliable. This means that the decision making is done according to trustful data and this avoids making the wrong decision.

- *Example with the Financial Process*: the validation of an investment will be made according to a trustful context which will guarantee the decision making.
- *Example with the Research & Development process*: it is the same principle for this process where the request of a customer will be considered with trustful data.

"Key indicators for the organization's performance"

In the quality approach, one important point is that the improvement has to be a permanent objective. This means it is necessary to ensure that the performance of the organization will be maintained. In order to do that, key indicators are required to check that the enterprise is going in a sustainable direction (in accordance with the strategy defined). Implementing a BPM system with provenance functionality will provide key indicators for the enterprise. Regarding the decision making, it will enable, for example, users to obtain data concerning the result of past decisions and this way demonstrate the effectiveness of past decisions. More globally this will enable users to constantly analyse the efficiency of the processes of the enterprise and to react quickly if there is something wrong.

- *Example with the Financial Process*: the number of requests for investment in progress, the historical requests with the context and the return of investment of previous requests are some key indicators that can be implemented thanks to the provenance.
- *Example with the Research & Development process*: it will be possible to track the time spent for obtaining a product which will satisfy the customer, the number of requests that have been validated by the President and the different actors but not by the customer and others key indicators which will help the enterprise to manage its work.

4.5 Conclusion

In order to answer the quality principle which is "evidence-based decision making", the functional requirements of the Agilium BPM system, combined with provenance, will provide the appropriate information to the relevant people at the moment they need it. Regarding the type

of information required, there is firstly the subject of the decision, secondly the context of when the decision is made and thirdly the data of the past (historical data). This leads to the fact that the provenance collection points of the processes of Martine Spécialités have to be implemented just after the decision activities.

Today there are two missing points in the processes of the enterprise which are the results of past decisions and the external context of the enterprise. Regarding the results of past decisions, if an implementation of the provenance functionality has to be made, this means this aspect needs to be taken into account (for example by adding one activity where it is possible to inform the result) in order to obtain all the required data to guarantee the decision making principle. Regarding the external context, the Agilium BPM system will have to be linked with other applications in order to provide the required information (such as an ERP system). It will be also important to involve each actor of the processes to define clearly which information they really need in order to make decisions and to define how the information will be represented in the decision activities thus to avoid flooding the actors with too much information. Those different requirements are an answer to the third research question "How can provenance information from BPM be used to improve quality management?"

Graphically the provenance tracking has been illustrated thanks to the PROV DM. It is possible to associate each element of the processes to the different concepts of PROV such as entity, activity and agent and graphically to represent the relationships (associated with, derived from, informed by…) of those elements. This provides an interesting illustration of the provenance tracking of the processes of the enterprise and enables us to answer to the second research question "how does one track the provenance of a process?"

If Martine Spécialités uses the provenance functionality in its Agilium BPM systems, several benefits can be obtained. For example, from a cost point of view by avoiding repeating the same mistake. From a time point of view, by reducing the global lead-time of the processes and this way increase the satisfaction of the customer. And from a quality point of view, by guaranteeing the quality of the data which is secure, reliable and accurate, and by providing several key indicators which will help to maintain the organisation's performance. These speculated benefits are inputs for the research question which is "what does provenance provide for the BPM in the quality domain". Now that the functional requirements and the potential benefits that can be obtained, have been defined, the next section will consider the opinion of the employees of Martine Spécialités by creating a survey in order to evaluate if the combination of provenance and the BPM system is an promising idea for them.

Chapter 5 – Evaluation Methodology

5.1 Introduction

The previous chapter determined the functional requirements for the combination of provenance and BPM functionalities. It provided a mapping of the provenance tracking in the processes of Martine Spécialités by using the PROV DM standard, and speculated on the benefits that could be obtained from this combination. This chapter presents the methodology that has been designed to evaluate the proposed combination of provenance and BPM approaches. It discusses the creation of a survey that has been submitted to the Martine Spécialités enterprise for validating the work carried out in this thesis. The following chapter provides an analysis of the results obtained from this survey.

Conducting a survey involves firstly identifying the research objectives of the survey, secondly deciding to whom it will be submitted, thirdly designing the questions that will be asked, fourthly defining the data collection method and lastly analysing the results obtained. Section 5.2 will describe the purpose of this survey and the target audience. Section 5.3 will define the different questions that will be asked, the format of the questions and the data collection method that will be used. Finally, the analysis of the results will be presented in Chapter 6.

5.2 Survey Methodology

The work in this thesis has been carried out according to the action research methodology (as explained in chapter 3). One important step in this methodology is the evaluation phase which provides the means to check whether the work done is satisfactory and enables continual improvement of the work. In order to complete this stage, a survey has been conducted in the Martine Spécialitiés enterprise. A survey is defined by Groves *et al*. (2009) as "a systematic method which gathers information from entities, in order to construct statistics of the attributes of the larger population of which the entities are members".

There are different reasons for conducting survey including:

- To gain an understanding of social science (to estimate the rate of unemployment for example).
- To obtain public opinion (for example to know which candidate of the Presidential election is favourite).
- To produce information that can inform commercial decision making (for example in the launch of a new product).
- To obtain feedback from customers on specific topics (surveys are ubiquitous in the quality domain in order to determine the quality of a product or a service and to evaluate customer satisfaction).

In the context of this study the objective of conducting a survey is to obtain feedback from the employees of Martine Spécialités, in order to check whether the concept of using provenance functionality in the Agilium BPM system is useful according to them. The idea is to collect information which will help in answering the following research questions:

(1) What does provenance provide for BPM in the quality domain?

(2) How can provenance information from BPM be used to improve quality management?

It will also provide inputs to check whether the functional requirements of the Agilium BPM system combined with provenance (as defined in the previous chapters) are in accordance with the needs of the employees and are complete in their nature.

According to studies, performing a survey can be a challenge because there are various elements that need to be defined (including the population to be surveyed, the questions to ask, defining the data collection method and the analysis of the results, etc.) (Groves, 2009; Leeuw, 2008; Balch, 2010). Regarding the target audience, the survey in this work has been submitted to the employees of Martine Spécialités involved in the processes of the enterprise (i.e. the actors, as defined in Chapter 3) and specifically to the employees involved in the decision making activities. These are the types of people that are able to answer the survey for the following reasons: firstly they frequently use the Agilium BPM system and secondly they are crucial to the decision making process. This means they have the knowledge and the skills to answer the questions related to this subject of research. This evaluation is therefore limited to a small group of evaluators which are responsible for making decisions in the Agilium BPM system. This represents a total of nine people: the Logistic Director, the R&D Director, the Purchase Director, the Industrial Director, the Plant Director, the Quality Director, the Marketing Director, the Security Director and the President. The next section will deal with the questions to ask in the survey and the formatting of it, and will describe the data collection method that has been used for this survey.

5.3 Question Design and Data Collection Method

5.3.1 The Question Design

Defining which questions will be asked in a survey requires attention, since the objective is to be able to retrieve information that will provide key inputs for the subject of research. The idea is to obtain answers that can be measured in order to analyse the results. Leeuw, Hox and Dillman (2008) stress the key points regarding the question design which are:

- To ask the appropriate questions (in accordance with the analytic needs).
- To ask questions that are understandable for the respondents (avoid technical terms, ambiguous adjectives and verbs, multi-barrelled questions).
- To ask questions to which respondents can provide suitable answers (avoiding proxy questions and guarantying that the respondents have the required information to answer).

- To ask questions to which respondents can provide an informative answer (give the possibility to accurately report the answer).
- To ask questions that respondents are willing to answer (avoid confidential information).

The types of questions are various (open-ended questions, closed-ended questions, rating scales etc.) and have to be chosen according to the analytic needs of the survey. For example if the objective is to evaluate an idea, the most common way is to provide a rating scale from very positive to very negative.

Based on those different recommendations, this section will describe the analytic needs of this survey and the questions which arise from it. Table 5 recaps these different elements.

ANALYTICS NEEDS	QUESTIONS
The main objective of this survey is to know whether the combination of provenance and BPM is a relevant and useful idea for the employees. This means that the analytic need here is to obtain data regarding the opinion of the employees (to know if the employees think that the provenance functionality is an interesting idea, which is also useful for them in decision making).	**Question**: On a scale of 5, how do you rate the idea of combining Provenance and BPM? **Question**: Do you think having access to more information when you made a decision is something interesting? **Question**: Would you be interested in the implementation of the provenance functionality in the Agilium BPM system? Why?
One important analytic need of this survey is to know the actual way of working of the employees for decision making. The information relative to the numbers of decisions they make, how they make the decision, the difficulty of doing it and their feelings regarding the decision making are inputs with added value. Indeed this will provide useful information to understanding the context of their work and to link it with the potential benefits that can be obtained from the combination of BPM and provenance. For example if an employee makes several decisions in a week and that each time she needs to look for some information. This means she loses time and this can lead to poor process management efficiency. In this context the provenance functionality might be interesting.	**Question**: How often do you make a decision in a month? **Question**: How easy is it to make a decision? **Question**: Do you check the result of the decision you made? **Question**: Are you satisfied with the decision you made in the past? **Question**: When you made a decision, are you looking for some information that is not in the Agilium BPM system (in an EXCEL file for example)? If yes, which type of information is missing? How long did you look for the information you need?

Another aspect to consider is the environment. Indeed the skills of the employees, the types of processes they are involved in and the types of decision they have to make might be influencing factors for the implementation of provenance functionality. It is possible, for example, that the decision making is really easy in the Financial Process, and this means the need for provenance will be optional in this case.	**Question**: What is your position in the enterprise (Purchaser, R&D Manager…)? **Question**: In which processes of the Agilium BPM system are you involved? **Question**: What type of decision do you have to make?

Table 5: the analytic needs of the survey and the question arose from it

Now that the questions have been defined, the formatting and the order of the questioning needs to be selected. Based on the recommendations of the study of Leeuw, Hox and Dillman (2008), the survey should start with a short paragraph explaining the goal of this questionnaire. This paragraph also defines, in comprehensive terms the principle of provenance in order to guarantee the fact that the respondents will be able to answer to the questions.

After that, the structure of the survey is the following: it begins with contextual questions (such as the position of the employee and the processes in which she is involved). Then the questions concerning the decision making are asked (such as the numbers of decisions made and the difficulties of doing it) and finally the last questions are related to the evaluation of the concept of the combination of provenance with BPM. A mix of different types of questions is used in order to be able to analyse the results. The use of checkboxes and rating scales are provided for facilitating the analysis. Since the Martine Spécialités enterprise is composed of French employees, the survey is in French (in Appendix).

5.3.2 Data Collection method

The objective of this section is to describe the data collection method that has been chosen for this survey. There exists different models to submit a survey such as:

- Face to Face interviews: the interviewer meets one by one the persons targeted, asks the questions directly to them and takes note of the answers.
- Mail survey: a letter is sent to the persons targeted and they have to fill the form and send it back.
- Telephone survey: the interviewer gives a phone call to the persons targeted, asks the questions and takes note of the answers.
- Web survey: a link is sent to the person targeted and they have to answer to the questions online.

Considering the fact that firstly the Martine Spécialités enterprise is located in the west of France, secondly the target audience is large and the people are not working in the same place, and thirdly that there is a time constraint (the specific duration of the project), this study uses the web survey method in order to collect the answers and to evaluate this work.

The benefits of this data collection method are the following:

- No cost: it is free of charge since there is no need to print papers for example, and free web survey tools are available.
- Ease of use: the implementation is easy and the survey is rapidly available.
- Key indicators: it is possible to be directly informed when a person has completed the survey and to check the results. This enables us to monitor the survey and to react rapidly in case of problems (such as a bad completion). Web survey tools provide also directly the results in an interesting format with all type of graphics. This enables us to facilitate the analysis of the results.

The web survey tool used for this work study is the Google form[2]. It has been chosen for practical reasons: it is a free tool, a Google account was already created and already experience in the use of Google tools was acquired.

One subject of concern regarding the survey methodology is to guarantee a high and fast response rate. With few answers, the analysis of the results is more complicated and it is difficult to conclude on the subject. The study of Newby, Watson and Woodliff (2003), demonstrates that pre-notification and follow-up mailing, are effective in significantly increasing the response rate. These are two concepts that will be used in case of non-respond of the target audience.

5.4 Constraints on the Evaluation and Conclusion

The process of evaluation of this work study is subject to various constraints. The first one concerns the limited sample for the evaluation, since the survey is submitted only to the Martine Spécialités enterprise and only to a small number of evaluators. Indeed this evaluation is intended for the employees of Martine Spécialités who use the Agilium BPM system and who make decisions in their business processes. This limits the sample of this survey to a total of nine people which, in practice, is very few. This is justified by the fact the survey is not addressed to the operators but only to the managers and as soon as we go up in the hierarchy, there are fewer and fewer people.

The second constraint is regarding the shortage of time to complete this study. This led to a focus on one use case (the Martine Spécialités enterprise) and this limited the submission of the evaluation to only one enterprise. The third constraint is due to the fact that this is a qualitative rather than a quantitative study. This means the process of evaluation of this work is exploratory

[2] https://www.google.com/intl/en-GB/forms/about/

in nature and it is used to gain an understanding of the opinion of a small sample of respondents. Finally, the last constraint concerns the fact this work is a Master study that tests and uses existing technologies rather than formulating any new detailed methodology.

To conclude, this chapter defined the evaluation methodology that has been carried out for this work. It explained the reasons for conducting a survey which are to obtain feedback from the Martine Spécialités employees and to check whether the combination of the provenance functionality with the Agilium BPM system is something interesting. This chapter defined the targeted audience (managers who make decisions in the Agilium BPM system), the question design and the data collection method for this survey. The questions have been designed according to the analytic needs and are mainly composed of checkboxes and rating scales. According to the constraints of time and the situation of Martine Spécialités, it is the web survey method that has been chosen, using the Google Form tool. The next chapter will provide a detailed analysis of the results obtained from this survey. It will enable conclusions on the subject of concern of this survey to be drawn i.e. to know whether provenance functionality combined with the Agilium BPM system is of benefit to Martine Spécialités employees.

Chapter 6 – Results and Analysis

6.1 Introduction

The previous chapter determined the evaluation methodology used to survey the concept of combining Provenance with the Agilium BPM system in the Martine Spécialités enterprise. A set of questions were defined and implemented in a Google form in order to submit it to the target audience (the employees who are responsible for making decisions in Martine Spécialités business processes). This chapter provides the results of the survey and an analysis based on these results in order to establish whether the hypothesis defined in chapter 1 holds true or false. It will enable a discussion regarding the pros and cons of the combination of provenance and BPM and it will investigate whether there are any benefits obtained in the quality domain regarding the combination of the two approaches. This will enable readers to validate the speculations made in chapter 4. This chapter is divided into two main sections: the first section is focused on the analysis of the results obtained regarding the decision making and the second section concerns the analysis of the results obtained regarding the provenance functionality.

6.2 Respondents' Typology

The survey has been submitted to nine managers of the Martine Spécialités enterprise. The number of respondents is eight which corresponds to a response rate equivalent to 88%. Considering the very small size of the sample, this response rate is satisfactory since only one answer is missing. This section describes the results of the first part of the survey that, as explained in chapter 5, considers the environment in which the concept is evaluated. Indeed it provides information regarding the respondents' typology (type of jobs they have, type of processes they are involved in and types of decisions they make) that might influence the implementation of the provenance functionality.

According to the first question of the questionnaire which concerns the position of the employee in the enterprise, the answers obtained are the following:

- Industrial Director
- Marketing Director
- Quality Director
- Plant Director
- R&D Director
- Purchase Director
- Security Director
- Logistic Director

This provides a large range of professions and will enable to check if the implementation of provenance functionality can be influenced by this factor.

Regarding the second question of the survey which is "in which processes of the Agilium BPM system are you involved), the results obtained are that a majority of the respondents are involved in the R&D Process (75%), and the rest (25%) are involved in both processes (the financial and the R&D Processes). Figure 23 illustrates this result.

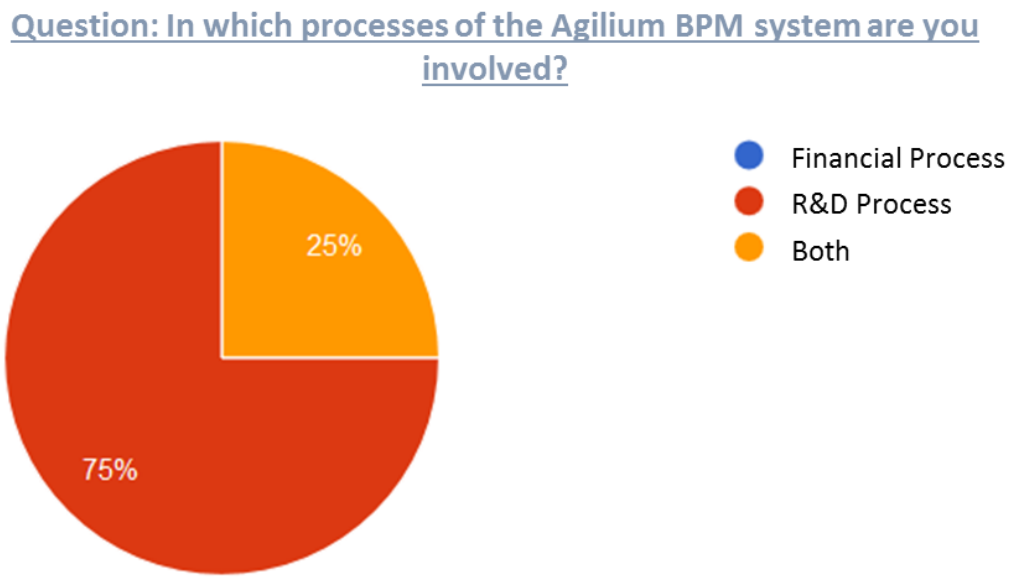


Figure 23: Processes in which the respondents are involved

The third question, which is "What type of decision do you have to make?", has obtained different results according to the respondents. Table 6 illustrates the answers associated with the positions in the enterprise of the respondents. This shows that the type of decision can be the same for various employees but will not be reached according to the same criteria. For example, the validation of the feasibility will be done according to different criteria whether it is the quality director who makes the decision or the Plant director.

Respondent's position	Type of decision
Industrial Director	Validate the requests of investment and the feasibility of new developments.
Marketing Director	Validate the request of new developments.
Quality Director	Validate the quality aspects for the new developments in terms of feasibility.
Plant Director	Validate the feasibility for the new developments according to the means of production of the plant.

R&D Director	Validate the feasibility, the industrial tests and the compliancy for the new developments.
Purchase Director	Validate the feasibility according to the availability of the products.
Security Director	Validate the feasibility of new developments in terms of security.
Logistic Director	Validate the requests of investment and the new developments.

Table 6: The type of decision made according to the position of the employees

To conclude this section, the results demonstrate that the respondents' typology is large with various professions and various decisions to make, and that the majority of the respondents are involved in the R&D Process. This is consistent with the processes design (since there are many more activities in the R&D Process rather than in the Financial Process).

6.3 Results on the Decision Making

This section introduces the results obtained for the second part of the survey regarding the different aspects of the decision making. It will enable readers to know the actual way of working of the employees for decision making, in order to understand the context and to link it with the potential benefits that can be obtained from the combination of BPM and provenance.

The first question is "how often do you make a decision in a month?". The results obtained is that 75 % of the respondents make more than four decisions in a month and 25% less than two decisions (as illustrated in Figure 24). This means the decision making is something currently realized for the majority of the employees.

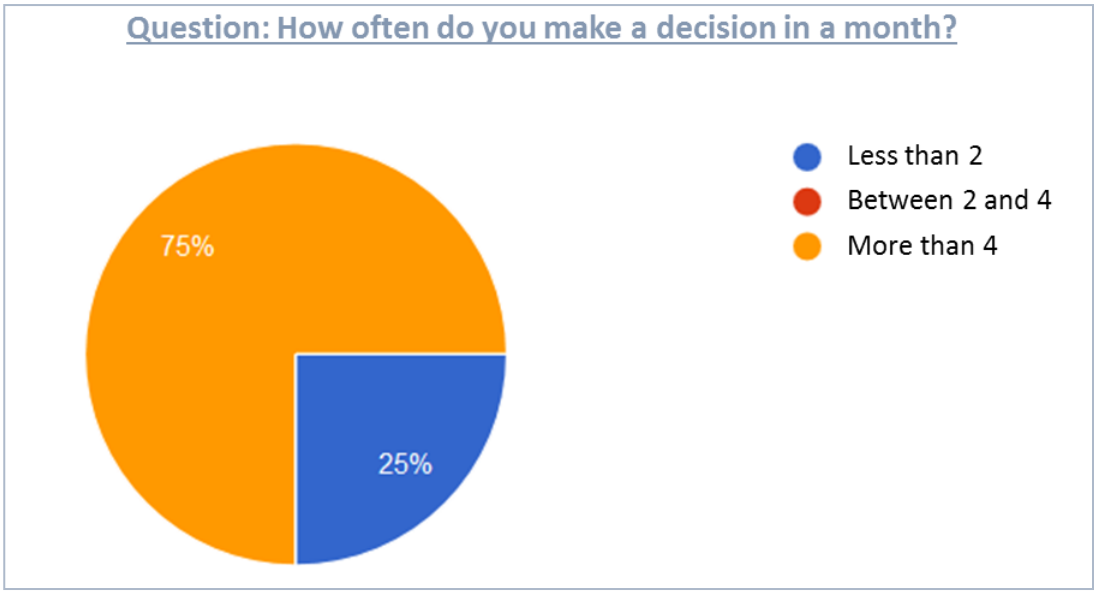


Figure 24: Evaluation of the number of decisions made in a month

The second question is "how easy is it to make a decision". The results described in Figure 25 show that none of the respondents thinks it is very difficult to make a decision. Only 12% think it is outstanding. The rest of the results are divided into two parts: half of the respondents think it is quite difficult and the other half think it is quite easy. It is difficult to conclude much on this, since the results are quite heterogeneous and the evaluation is a subjective feeling for each employee.

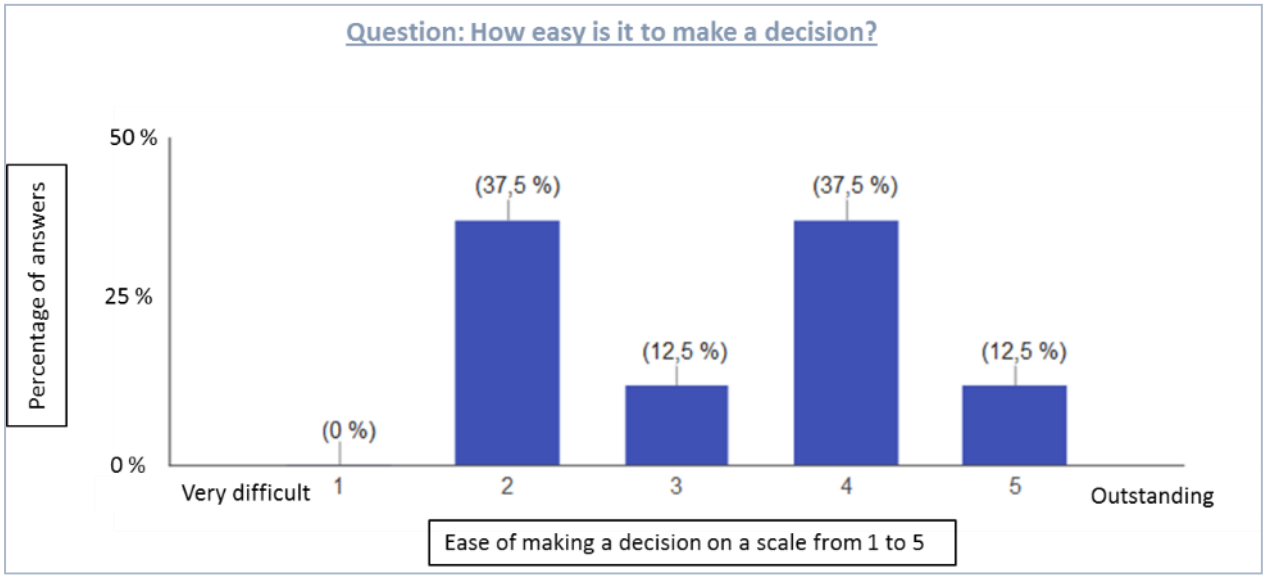


Figure 25: Evaluation of the ease of the decision making

The third question is "Do you check the result of the decision you made?". The result obtained is that 75% of the respondents do not check the results of the decisions they made, compared to 25% of them who check it (illustrated in Figure 26). This means that the majority of the employees are not considering this factor and potentially have more chance to make a decision

which is not appropriate for the enterprise several times. This also means that there are not in a philosophy of a continual improvement.

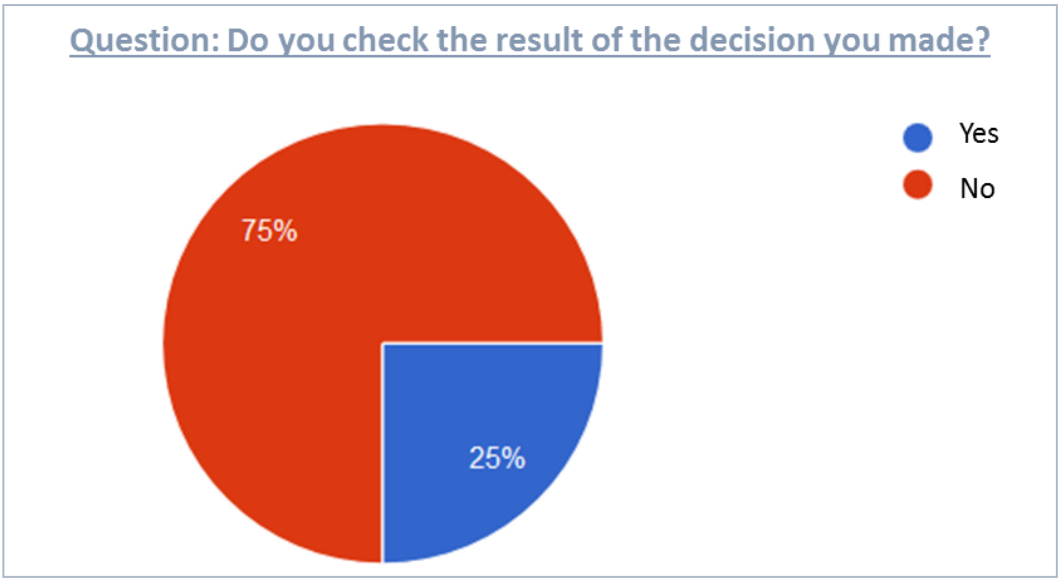


Figure 26: Evaluation of the analysis of the results of past decisions

The fourth question is the following: "Are you satisfied with the decision you made in the past?". Figure 27 illustrates the results obtained and shows that no one is unsatisfied or very unsatisfied. 50% of the respondents are neutral, 38% are satisfied and 12% very satisfied. Taking into account the previous results concerning the checking of the results of past decisions, it seems coherent that 50% are neutral since these same persons do not know the results of the decision they made.

The employees who check the results of their decisions (25% of the respondents) are satisfied or very satisfied with their decision. This means that inspecting results of past decision helps to improve the satisfaction, holds true. The remaining employees who do not check the results of their decisions are still satisfied with the decisions made (25% of the respondents). This probably means they evaluate their satisfaction according to their feelings but not with proven factual data.

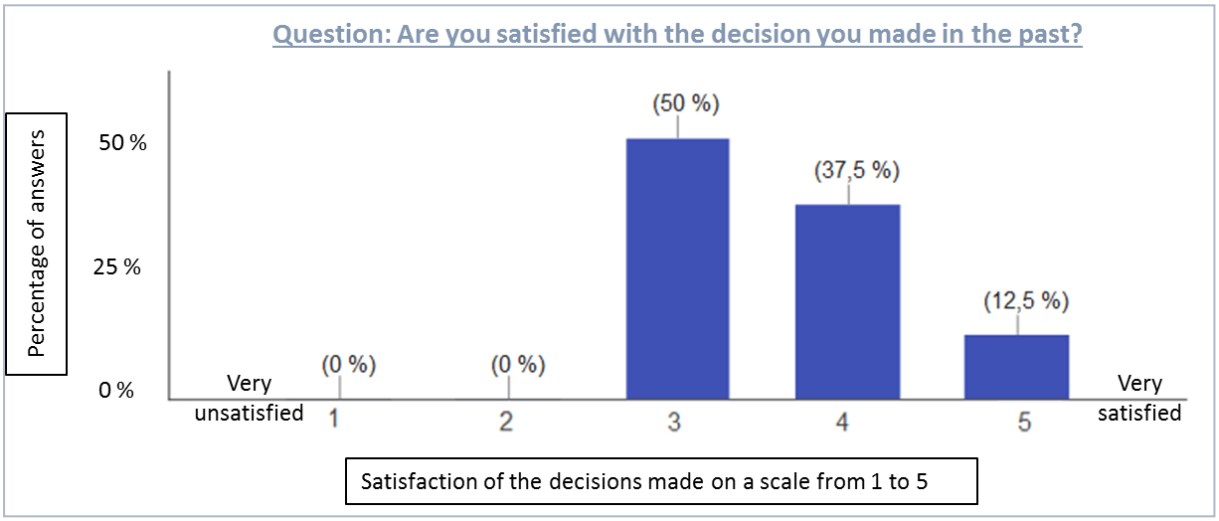


Figure 27: Evaluation of the satisfaction of past decisions

The fifth question is “When you make a decision, do you look for information that is not in the Agilium BPM system (in an Excel file for example)?”. The results obtained (illustrated in Figure 28) demonstrate that a large majority of the respondents (88%) need to look for other information and only 12% already have the required information at hand to make a decision. This means the actual data included in the Agilium BPM system are insufficient for decision making.

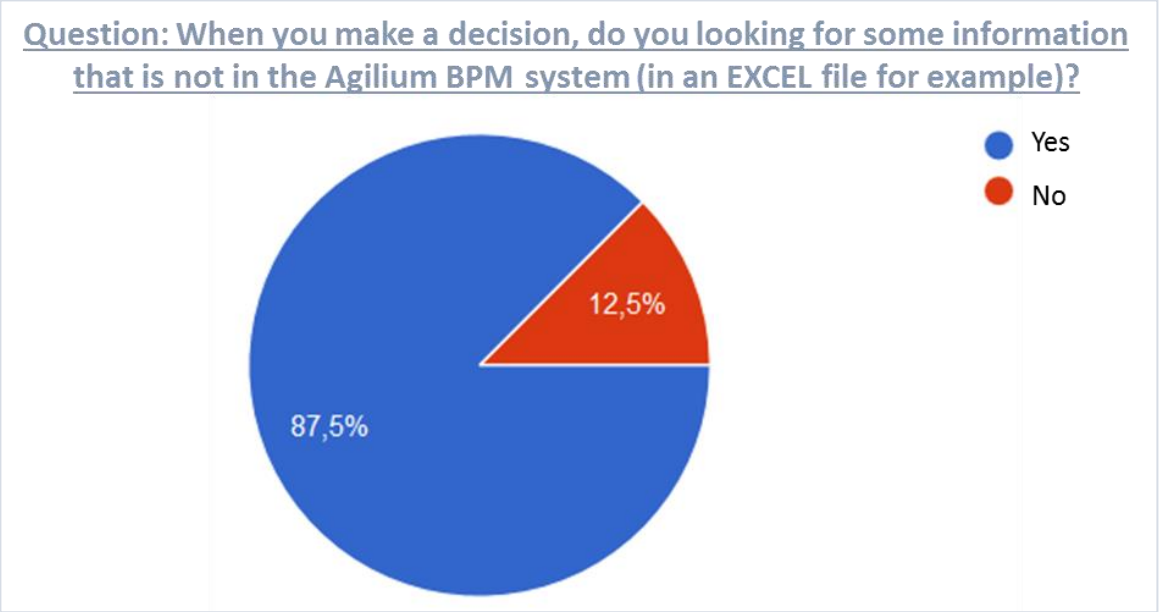


Figure 28: Evaluation of the need of other information (not included in the Agilium BPM system)

The sixth question is “which type of information are you looking for?”, (with several answers possible). Figure 29 shows that the type of information most searched for is related to the subject of decisions, with a score of 88%. The next is the type of information related to the environment and the context with a score of 62%. And the last one is related to the historical decision results. Only 12% are not looking for other information which is in coherence with the previous results which demonstrate that 12% have already the required information. These results are interesting since they prove that basic information regarding the subject of the decision (i.e. who is making the decision, why, for what etc.) are not included in the Agilium BPM system. It also shows that contextual information is needed for most of the employees and the historical decision results are also required for half of the respondents.

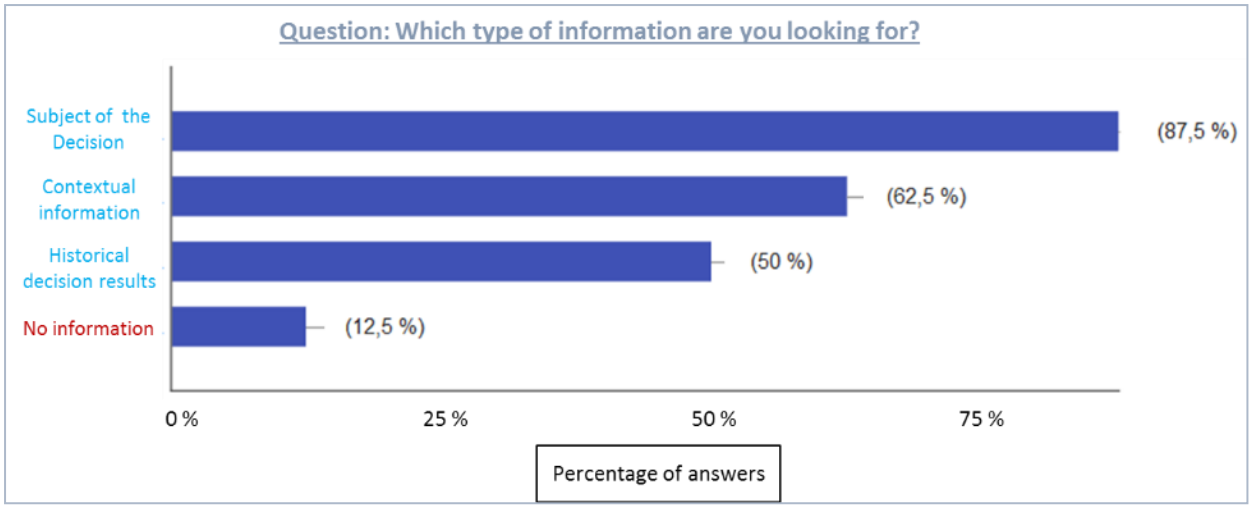


Figure 29: Evaluation of the type of information required

The last question is "How long did you look for the information you need?". The result obtained (illustrated in Figure 30) is that 63% of the respondents spend between 6 to 10 minutes for searching the information they need to make the decision. 25% spend between 0 to 5 minutes and 12% are not looking for information. This proves that the majority of employees are wasting time to look for the information they need during the decision making.

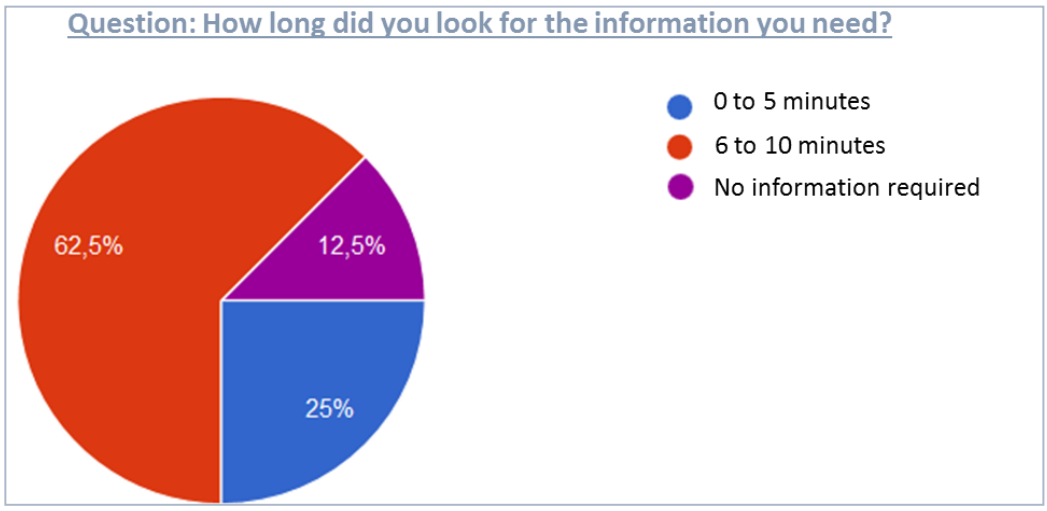


Figure 30: Evaluation on the time spent for searching information

The results obtained on the decision making enable readers to conclude that the majority of the employees make many decisions in a month (more than once in a week). By comparing the results obtained from the question "Do you check the result of the decision you made?" and the question "Are you satisfied with the decision you made in the past?" it is possible to conclude that the employees, who checked the results of their decisions, are more satisfied than the majority who did not check the results. It is difficult to conclude anything on the ease felt by the employees when they make a decision since the results are somewhat ambiguous. An interesting point is the fact that a large number of respondents need to look for information that are missing in the Agilium BPM system. This proves that the provenance information can be very useful for the decision making which is an important point regarding this work thesis.

The type of information missing is the information regarding the subject of the decision, following by the contextual information and the historical decision results. The time spent by the employees looking for information required is predominantly comprised between six to ten minutes. Considering the fact that the majority of the employees make many decisions and the fact that they spend time looking for information in order to be able to make decisions, this shows that there is a waste of time during the execution of the processes of Martine Spécialités. This is an argument for using the provenance functionality. Indeed this demonstrates that one potential benefit that can be obtained thanks to the provenance functionality is to save time which leads to a better process efficiency. With the provenance functionality, the employees will have the data they need in order to make a decision. This means they will not lose time and that they will realize the activities of the processes more efficiently. This way it will reduce the global lead-time of the processes.

6.4 Results on the Provenance Functionality

This section provides the results of the third part of the survey related to the combination of provenance functionality and the Agilium BPM system. This will enable readers to know whether the combination of provenance and BPM is a relevant and useful idea for the employees. The first question of this part is "Do you think having access to more information when you made a decision is something interesting?". The results illustrated in Figure 31 demonstrate that 62% of the respondents think it is an idea interesting, 25% think it is very interesting and only 12% think is not at all interesting. By analysing the previous results of the survey, the 12% who think it is not interesting are the same 12% who do not need to look for information during the decision making. This proves the coherence of the results.

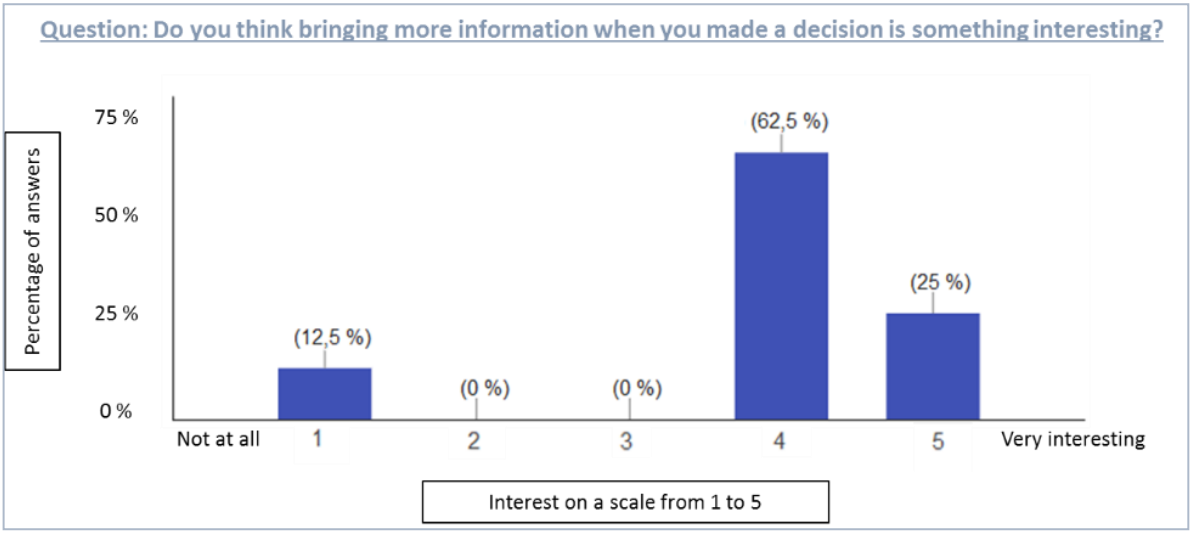


Figure 31: Evaluation of the idea of providing more information

The second question concerns the interest of the employees for the implementation of the provenance functionality in the Agilium BPM system. Figure 32 shows that the results are the following: 75% of the respondents would be interest to implement the provenance functionality in the Agilium BPM system, opposite to 25% that would not.

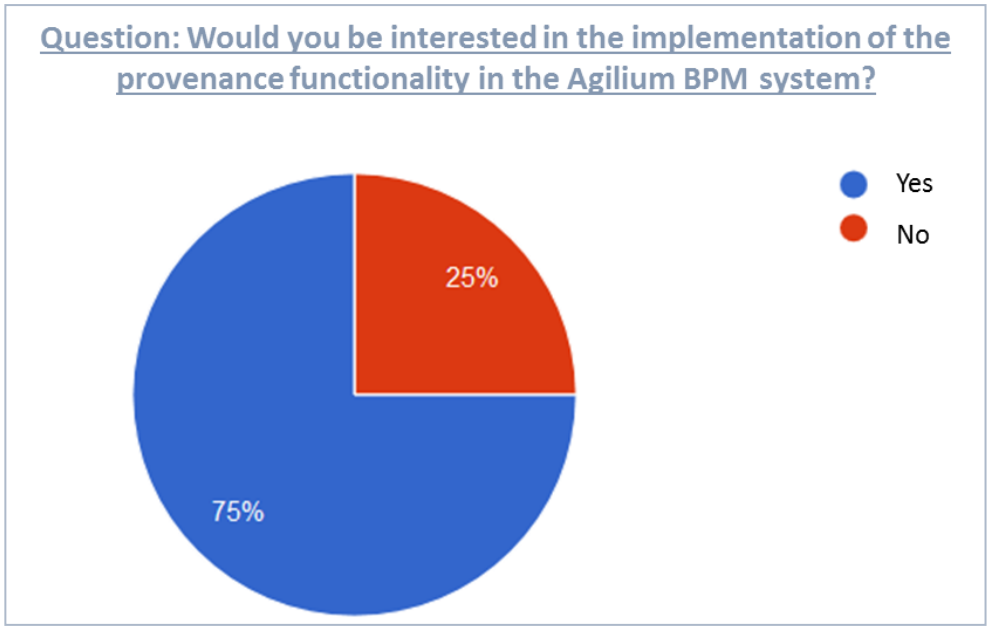


Figure 32: Evaluation of the idea of implementing the provenance in the Agilium BPM system

The following question (which is: "would you be interested in the implementation of the provenance functionality in the Agilium BPM system?"), enables readers to obtain various justifications that are summarised in Table 7. Several benefits are provided according to the employees who are in favour of the implementation of provenance functionality, such as the fact to have the information they need in order to make the decision, the fact to save time, and the fact to make better decision. For those who are against the implementation of this functionality, one reason is related to the fact there are already too many developments in progress in the Agilium BPM system that need to be done before adding a new one. This means the respondent is not against the idea but it is the context that is not favourable according to him. Finally the other person who is against the idea justifies his choice by the fact that he has already the information he needs to make the decision.

The last question of this survey is "On a scale of 5, how do you rate the idea of combining Provenance and BPM?". The result obtained is an average noted equivalent to 3.8/5. This is rather positive and means that the respondents think that the combination of provenance with the Agilium tool is something useful. To conclude this section, the feedback of the employees of Martine Spécialités is mainly positive regarding the idea of combining provenance and BPM. The potential benefits that can be obtained from it have been underlined and there is a coherence of the answers obtained in the second part of the survey (for the decision making) and the answers obtained in this part (for example the one who is not interested in this concept is the one who does not need to look for other information).

Respondent's position	Opinion for the implementation	Reasons
Industrial Director	No	Today there are too many developments in progress in the Agilium BPM system that must be done before adding a new one.
Marketing Director	Yes	Several iterations in a process can be produced. With provenance it will avoid looking for other information regarding the context that are actually missing in the Agilium BPM system
Quality Director	Yes	Provenance will provide information of what has been done and modified during the process execution.
Plant Director	Yes	Being a new employee (I arrived two months ago), the decision making is not possible without asking explanations to collaborators. Having a vision on the history would be an advantage for the decision making.
R&D Director	No	I have all the information I need for the decision making.
Purchase Director	Yes	The provenance will enable to save time during the decision making.
Security Director	Yes	The provenance will help me to make decisions and this way it will save time for my work.
Logistic Director	Yes	It will enable me to check at past decisions results and helps me to make better decision.

Table 7: Justifications on why it would be (or not be) interesting to implement the provenance functionality in the Agilium BPM system

6.5 Global analysis and Conclusions

The objective of this section is to provide a global analysis of the survey and the conclusions that arise from it, by taking into account simultaneously the results obtained from the three parts of the survey. Based on the analytics needs that have been defined in Chapter 5, this will enable us to establish if the hypothesis defined in Chapter 1 holds true or false and it will allow us to conclude whether there are any benefits obtained in the quality domain regarding the combination of the two approaches (and this way to validate the speculations made in Chapter 4).

Conclusions on the factors which might influence the implementation of the provenance functionality.

The first thing that can be concluded is that the implementation of the provenance functionality might be influenced by the need for information by the employee when he makes a decision. Indeed the only respondent who answered he does not need to look for information during the decision making is the one who is not interested at all by the provenance functionality. He thinks it is not useful to bring more information during the decision making, he is not interested by the implementation of the provenance functionality in the Agilium BPM system (he provided a score of 2/5 for this question).

The second conclusion is that the implementation of the provenance functionality might be compromised if the BPM tool is not fully operational. Indeed, the Industrial Director of Martine Spécialités who thinks it is an interesting idea to combine provenance with BPM is not interested in the implementation of the provenance in the Agilium BPM system. He justified it by the fact there are too many developments in progress that must be done before adding new functionality. This point demonstrates the fact it is important that the BPM system is up to date and stable before adding the provenance functionality.

Finally, even if the typology of the respondents of the questionnaire provides a large range of professional skills, with different decisions to make, it is difficult to conclude whether those factors (skills of the employees, type of decisions and type of processes) are influenced or not regarding the implementation of provenance. Statistics are missing since the survey has been submitted only to one company.

Conclusions on the benefits that can be obtained thanks to the combination of provenance and BPM.

The different results obtained in the survey demonstrate that several benefits can be obtained thanks to provenance functionality. The table below provides a recap of the benefits that have been speculated on Chapter 4 and the benefits that have been raised thanks to the survey.

Benefits speculated on Chapter 4	**Benefits obtained in the survey**
<u>From a cost point of view</u>: - More work with added value. - Mistakes which costs are avoided. - Opportunities are not missed.	The results of the survey have demonstrated that the majority of the employees have more than one decision to make in a week and that the majority needs to look for information in order to make the decision. This means they are losing time for each decision to make. This validates the benefits speculated which promote the fact that the provenance will enable more work with added value. The results also show that the employees who are looking for the results of past decisions are more satisfied regarding their decisions. This means the provenance functionality will help in improving the decision making and that it will help to avoid mistakes which cost financially and time wise, and to not miss opportunities.

<u>From a time point of view:</u> - Reduction of the lead-time of the process which leads to a better customer satisfaction.	One important benefit that has been underlined by the respondents is that the provenance functionality will enable them to save time by not searching anymore of the information they need to make the decision. This validates the benefits speculated: thanks to the provenance there will be a reduction of the time spent to search the required information, which leads to a reduction of the time spent to make the decision; which then leads to a reduction of the time spent to do the activity in the process; which leads to a reduction of the global lead-time of the process; which leads to an increase of the efficiency and this way to a better customer satisfaction.
<u>From a quality point of view:</u> - Data accurate, secure and reliable which leads on better decision. - Keys indicators for the organization's performance	Some of the feedback from the respondents proves that the provenance functionality will help them to make better decisions since they will have the possibility to check past decision results. This validates the benefit speculated in Chapter 4 which is that provenance provides better decision making. As also explained earlier, the employees who check the results of their decisions, are more satisfied than the majority who do not check the results. This confirms the better decision making thanks to provenance. Regarding the key indicator for the organization's performance, this survey enables to prove that it is interesting for the majority of the respondents to bring more information during the decision making.

<u>Table 8: Recap of the benefits speculated in Chapter 4 and the benefits obtained in the survey</u>

These different benefits enable us to:

- Validate the hypothesis of this thesis work which is the following: "The gathering and use of provenance information for BPM can positively facilitate the improvement of quality management processes in an organisation". Indeed the results demonstrate that thanks to the provenance information in a BPM system, the "Evidence-based Decision Making" principle of the quality approach is satisfied. This leads globally to a better efficiency of the process management with a decision which is made more quickly and with a better quality.
- Answer to the following research questions: the first research question "what does provenance provide for the BPM in quality domain" and the second research question "how can provenance information from BPM be used to improve quality management". To the first question, the answer is that provenance provides useful and accurate information which will help the employee in the decision making. To the second question, the answer is that the provenance information can be used as key indicators during the decision making in order to lead to a better decision making.

Conclusions on the employees' feedbacks regarding the idea of combining provenance and BPM.

The first analytic need of this survey was to know whether the combination of provenance and BPM is a relevant and useful idea for the employees. The results of the questionnaire have demonstrated that the majority of the respondents:

- Think it is an interesting idea to bring more information during the decision making.
- Are interested by the implementation of the provenance functionality in the Agilium BPM system.
- Evaluate positively the idea of the combination of the provenance with the Agilium BPM system.

This feedback is positive and enables us to bring value to the idea developed in this thesis. It is important to state that this work is at an early stage and further work is required to develop this idea more. This will be introduced in the following chapter which will provide a global conclusion on the work carried out.

Chapter 7 – Conclusions and Future Directions

7.1 Introduction

This thesis has analysed the provenance tracking of Business Process Management (BPM) in the quality domain in order to see whether the combination of these two concepts can provide benefits regarding the quality management processes in an organisation. It studies the effects of the provenance functionality in a BPM system according to the quality principle which is evidence-based decision making. This chapter concludes this thesis by providing a recap of what has been done to resolve the overall hypothesis and the research questions, in section 7.2. It discusses, in section 7.3, the contributions to knowledge that have been achieved in this research study and its limitations. Finally the future directions possible for this work are presented in section 7.4.

7.2 Recap of the work following the hypothesis and the research questions

This thesis has sought to test the following research hypothesis: "The gathering and use of provenance information for BPM can positively facilitate the improvement of quality management processes in an organisation". The aim of this work has been to determine whether the provenance functionality applied in a BPM system can provide benefits in the quality domain by utilising an "evidence-based decision making" principle (this has been limited to the Agilium BPM system). By tracking the history, ownership and its processing, provenance information provides accurate, secure and reliable knowledge. The benefits of this functionality has been determined partially in chapter 2 which was a review of the state of the art. Already used in several domains such as the scientific one (e.g. Neuroscience), this study focused on the analysis of provenance in the BPM field and the quality domain through a use case from the Martine Spécialités enterprise. This business is specialized in manufacturing of pastry-based goods to both food retail outlets and the catering industry and was introduced in chapter 3. This enabled a description of the environment and the context in which the analysis of this work has been established.

The hypothesis and associated research questions were resolved through the results of the survey that has been submitted to the managers who make decisions in the day-to-day processes of Martine Spécialités (chapter 6). The design of a survey (the questions and the data collection method) has been determined in chapter 5 along with the constraints on the evaluation (such as the small sample of evaluators). This survey enabled concrete feedback to be obtained from the Industrial Director, the Marketing Director, the Quality Director, the Plant Director, the R&D Director, the Purchase Director, the Security Director and the Logistic Director which already use the Agilium BPM system without the provenance functionality. The results demonstrated that the majority of the employees make several decisions in a month and that the relevant information required to make the decision is missing in the Agilium BPM system. This means

they need to look for the missing information and this leads to a waste of time for each decision making process. The type of information missing is, in a majority of cases, the information related to the subject of the decision (i.e. all the data concerning the context of the decision such as who, what, why and how). Then it may be the information regarding the context of the enterprise (for example the economic environment of the enterprise), followed by the information related to the historical decision results (i.e. the history of what have been done in the past and the results of it). This problem can be solved by provenance functionality which can track all the data and can provide the information needed. A relevant point for resolving the hypothesis is the opinion of the majority of the employees, who think that the combination of provenance and BPM is interesting since it can, according to them, help them for the decision making. The benefits quoted by the respondents are time saving and improved decision making. This leads to a cost benefit for the enterprise by having more work with added value, thus avoiding mistakes and consequently avoiding missing business opportunities. In this way this feedback enabled us to validate the fact that the gathering and use of provenance information for BPM can positively facilitate the improvement of quality management processes in an organisation.

In order to address the above hypothesis, a number of associated research questions from section 1.4 were answered during the course of this work. These will now be considered in turn. Research question one was "What does provenance provide for BPM in the quality domain?" This question was answered partially in chapter 2 by analysing the state of the art. This indeed enabled us to determine the global benefits of provenance and provided a first use of it in the industry field which is for compliancy. Chapter 4 provided a list of speculations regarding this research question and chapter 6 validated this list of benefits through an analysis of the results of the survey that have been submitted to Martine Spécialités. The conclusion on this is that provenance provides trustful and accurate information which are useful for improving the decision making.

The second research question was "How does one track the provenance of a process?" This was answered in chapter 4. This was accomplished firstly by defining the functional requirements needed for the combination of provenance with the Agilium BPM system, which were to provide the appropriate information to the relevant people at the moment they need it. These requirements enabled us to determine the provenance collection points (i.e. the points which will enable to retrieve the information needed during the execution of the processes) which are located just after the decision activities. Secondly this was accomplished by illustrating the provenance tracking of the processes of Martine Spécialités through the PROV DM standard. This was done by associating each element of the processes to the different concepts of PROV such as entity, activity and agent and by graphically representing the relationships (associated with, derived from, informed by…) of those elements. These different graphs enabled us to show how it is possible to track the provenance of a process.

The third and final research question that this thesis answered was: "How can provenance information from BPM be used to improve quality management?" This was addressed in both chapter 4 and 6. In chapter 4, this was done by defining the functional requirements needed in order to answer to the quality principle which is "evidence-based decision making". It showed

which type of provenance information can be used to optimize the decision making. In chapter 6 this was determined through the analysis of the results of the survey. Indeed this demonstrated that provenance information can be used as key indicators during the decision making in order to lead to a better decision making. The next section in this chapter will present the contributions made by this thesis.

7.3 Contributions to Knowledge

The major contribution from this work is the analysis of what the combination of provenance and BPM provides to the quality domain. The fact that provenance combined with a BPM system enables us to provide benefits by answering the quality principle, which follows "evidence-based decision making", is an important consideration for the industry domain. Indeed, even if previous works have provided some use of provenance in the business field such as compliancy, this thesis has shown that provenance is useful for the evidence-based decision making principle. This work has demonstrated, through the Martine Spécialités use case, that some information is missing during the decision making process and that employees are obliged to look for the data they need in order to make appropriate decisions. This leads to a loss of time which can be solved thanks to the provenance functionality. After having speculated on the benefits that can be obtained with provenance, the survey of this work (submitted to the managers of Martine Spécialités who are responsible for making decisions) demonstrated the advantages of this functionality. This proved that:

- Firstly, provenance enables us to improve the efficiency of the processes by reducing the time spent looking for the information required. By providing all the information needed, the person responsible for making the decision realizes the activity in less time, which leads to a reduction of the global lead-time of the process and this leads to improved customer satisfaction.
- Secondly, provenance enables the improvement of the decision making process since the data provided by the provenance are more accurate, secure and reliable. This also enables us to provide key indicators such as the results of past decisions, and in this way guarantee that the persons involved in the decision making are continuously improving their work by avoiding repeating the same mistakes and by not missing new opportunities.
- Thirdly, provenance enables us to optimize the costs of the enterprise. Indeed, thanks to provenance, the people involved in the decision making save time and make better decisions. This has an effect on the global costs of the enterprise creating more added value.

One further important and final contribution of this thesis is the framework of how provenance information from BPM can be used in order to improve quality management. Firstly, this was accomplished by determining the functional requirements of the combination of the Agilium BPM system and provenance, in the context of the evidence-based decision making principle.

This demonstrated that:

(1) It is necessary to provide appropriate information i.e. the information that is required to make decisions such as the subject of each decision, the context and the history of the results of past decisions.

(2) The appropriate information has to be provided to the relevant people, i.e. to the ones who are making the decision.

(3) The appropriate information has to be provided at the appropriate moment, i.e. when the persons make the decision.

This leads to the fact that the provenance collection points (which have to be implemented in order to retrieve the information needed) must be located in the processes just after the activities which influence a decision making.

Additionally, this was completed by providing a graphical representation of the provenance tracking of the processes of Martine Spécialités. This has been established according to the PROV DM standard. Indeed each element of the processes has been associated to the elements of the PROV DM (entity, agent and activity) and linked with the different relationships. Since there was no implementation of provenance in the Agilium BPM system, this enabled us to show how in future the information can be tracked in the processes and this provides a framework for future work.

The limitation of this work is the fact that this study has been done according to one single use case. Indeed the analysis has been done through only the Martine Spécialités enterprise which is specialized in manufacturing of pastry-based goods to both food retail outlets and the catering industry and which managed just two processes with the Agilium BPM system. This means this work is very specific and this limits the degree to which findings might be generalised. This is especially true for the results of the survey which has been submitted to a very small group of evaluators. To allow this work to be genuinely re-usable, the principles need to be tested in other environments; this is future work.

Additionally, deeper analysis on the functional requirements needs to be realized in order to guarantee that the combination of provenance with the Agilium BPM system will satisfy customers. This study built the functional requirements according to the ISO standard and its quality principles. This can be extended by organizing meeting with the managers who are responsible for making decision. Discussing with them will provide other inputs which will be helpful to obtain all the specifications required to combine BPM and provenance

Another limitation of this work is that it concerns only the first cycle regarding the guidelines of the action research methodology. Due to time constraints no concrete implementation of the concept has been able to be realized. This work is limited to the functional aspects of the Agilium with the analysis of what provenance can provide in a BPM system regarding the quality domain. There is no concrete technical study that demonstrates how the provenance information will be represented in the decision activities of the processes. This means this work is only a starting

point for the development of the Agilium BPM system combined with provenance; further work is clearly needed to examine further these concerns.

7.4 Future Directions

One major direction for the continuation of this work is to pursue the analysis in the Martine Spécialités enterprise in order to determine the prerequisites which might contribute to providing genuine provenance-informed BPM. This is our primary future effort and will constitute a second iteration of the action research methodology that might be carried out in four distinct stages.

Stage 1

The first stage concerns the improvement of the current Agilium BPM system. One important feedback obtained through the survey is the fact there are too many developments in progress in the Agilium BPM system that need to be done before adding new provenance functionality. It is important to firstly complete these developments in order to add the provenance functionality in a favourable context. This will guarantee a better result for the implementation of provenance.

Stage 2

The second stage is related to the redesign of the processes of Martine Spécialités. The functional requirements defined in chapter 4 demonstrated that there are some aspects missing in the current system that would be required in order to provide the information required to make informed decisions. This has been confirmed in chapter 6 by the fact that the majority of the managers of Martine Spécialités are looking for information that is not included in the application. This missing information is, according to them, related to the subject of the decision, the context and the historical decision results. Since provenance tracks all the data obtained during the execution of the processes, it is important to guarantee that all the information required for the decision making is included somewhere in the processes. This means a study has to be realized with the managers to define clearly which information is missing and how that information can be added in the processes. For example if one information missing is related to the justification of why a request for investment is made, this means the first activity of the Financial Process has to be redesigned in a way that the person who makes the request can add the reason for why he is doing it. Regarding the contextual information, these can be added by adding a link with other applications that can provide the required information. This means the processes will have to be revisited and maybe redesigned in order to obtain all the required information. In this way it will guarantee that the provenance will track everything that is needed.

Stage 3

The third stage concerns the implementation of a pilot project in which an area of the Agilium BPM system is made provenance informed/aware for the processes of Martine Spécialités. This will enable users to concretely test the idea and establish a future strategy for the combination of the provenance in the Agilium BPM system. It will for example enable users to define how the provenance information can be represented in the decision activities of the processes. The

objective will be to guarantee the evidence-based decision quality principle. This means it will be important to consider how the package of the information will be done in a way that will help understanding the key messages.

Stage 4

The fourth and final stage regarding the work with Martine Spécialités is a future release of the Agilium BPM system with the new provenance functionality supported. In a period of about two or three years this concrete prototyping may be carried out in the enterprise in order to obtain the prerequisites which might contribute to providing genuine provenance-informed BPM.

One other essential future direction in regards to this work is generalizing the analysis to other enterprises which are using the Agilium BPM system. Indeed this thesis work is just a first step towards the analysis of the combination of provenance and BPM in the context of the evidence-based quality principle. This work has demonstrated that it can be interesting to combine both concepts but it needs to be extended to different types of enterprises in order to provide more precision on the analysis. This means the study needs to be extended by submitting the survey to a larger population in order to be able:

- to generalize the fact that the majority of the persons who are involved in activities concerning a decision, has to look for information that is not included in the BPM system;
- to generalize the fact that the majority of the persons are interested in the implementation of the provenance functionality in the BPM system;
- to generalize the benefits that can be obtained from the combination of provenance and BPM;
- to determine if the type of processes, the skills of the employees and the type of decisions influences the argument for or against the combination of provenance and BPM and
- to check whether the functional requirements determined in chapter 4 (i.e. to provide the appropriate information to the relevant people at the moment they need it) are sufficient or need to be augmented.

This deeper analysis will enable us to complete or modify the different functionalities defined for the prototype that might eventually be realized with Martine Spécialités. Once these two steps have been completed, the Agilium BPM system with the provenance functionality might be viably commercialized directly to new customers.

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APPENDIX – Martines Spécialités Survey

Etude sur le pilotage des processus avec Martine Spécialités

L 'objectif de ce questionnaire est d'obtenir des retours sur l'outil de gestion des processus AGILIUM et plus particulièrement sur les activités des processus de Martine Spécialités qui nécessitent une prise de décision. Ceci est réalisé dans le cadre d'un projet de recherche avec l'université de Bristol.

*Obligatoire

INFORMATIONS GENERALES

Quel est votre poste au sein de l'entreprise ? *
(responsable achats, opérateur logistique...)

Votre réponse

Dans quels processus AGILIUM êtes-vous impliqué ? *

- ○ Processus FINANCIER
- ○ Processus R&D
- ○ Les deux

PRISE DE DECISION

Cette partie a pour objectif d'en savoir plus sur la prise de décision avec l'outil AGILIUM. Certaines tâches que vous réalisez avec AGILIUM concernent une décision (telle que la validation de la conformité d'un produit). Ce sont ces tâches qui sont le point d'intérêt de ce questionnaire.

Quel type de décision devez-vous prendre ? *
Est-ce par exemple valider une demande d'investissement ? Valider une demande de développement ? Valider les risques d'un projet ? Valider la faisabilité d'un projet ? Merci de décrire la ou les tâche(s) AGILIUM de ce type, qui vous concerne(nt).

Votre réponse

Combien de fois par mois devez-vous prendre une décision (c'est à dire réaliser la tâche concernant une prise de décision) ? *

- ○ Moins de 2
- ○ Entre 2 et 4
- ○ Plus de 4

Est-il facile pour vous de prendre une décision ? *

	1	2	3	4	5	
Très Difficile	○	○	○	○	○	Très Facile

Est-ce que vous prenez le temps d'analyser le résultat des décisions que vous avez prises ? *

- ○ OUI
- ○ NON

Est-ce que vous êtes globalement satisfait(e) des décisions que vous avez prises ? *

	1	2	3	4	5	
Insatisfait(e)	○	○	○	○	○	Très satisfait(e)

Lorsque vous prenez une décision, est-ce que vous devez chercher des informations qui ne se trouvent pas dans l'outil AGILIUM ? *

Le but de cette question est de savoir si vous allez récupérer des informations dans un fichier EXCEL, WORD ou autres applications, différentes d'AGILIUM?

- ○ OUI
- ○ NON

Quel type d'informations allez-vous chercher ? (plusieurs réponses possibles) *

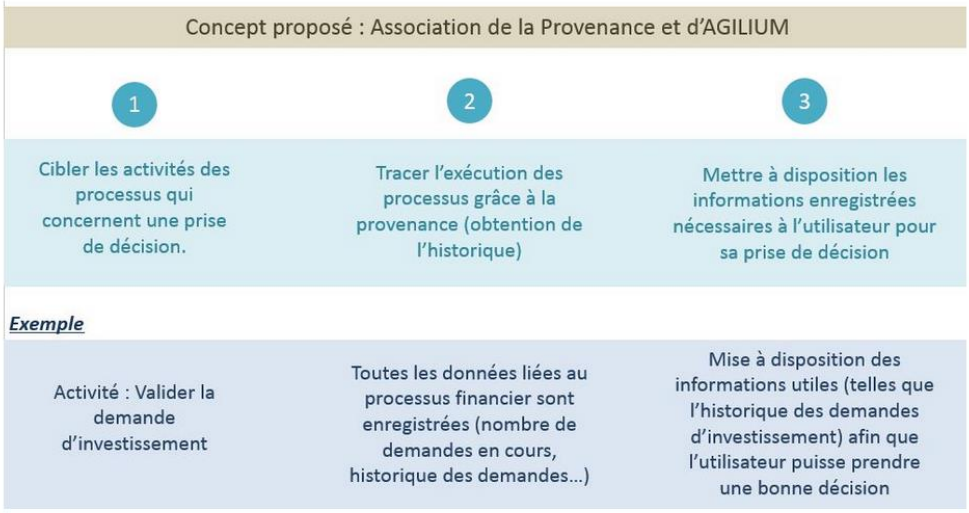
- [ ] Informations pour obtenir plus de précisions sur le sujet de la décision (qui fait la demande ? quoi ? où ? comment ? pourquoi ?)
- [ ] Informations contextuelles (contexte économique de l'entreprise par exemple)
- [ ] Informations sur l'historique des décisions prises dans le passé
- [ ] N/A (je ne cherche pas d'informations)

Pendant combien de temps cherchez-vous des informations supplémentaires (c'est à dire, non présentes dans l'outil AGILIUM) pour prendre votre décision ? *

- ○ 0 à 5 minutes
- ○ 6 à 10 minutes
- ○ 11 à 20 minutes
- ○ Plus de 20 minutes
- ○ N/A (je ne cherche pas d'informations)

Provenance et AGILIUM

Provenance = traçabilité. Lorsqu'un processus est exécuté, la provenance enregistre tout ce qui s'est déroulé et peut ainsi historiser et ressortir tous types d'informations du passé. L'objectif de cette section est de savoir si vous pensez qu'associer la provenance avec l'outil AGILIUM est une idée intéressante pour faciliter la prise de décision. L'image ci-dessous décrit le concept sur lequel un retour est demandé.



Pensez-vous qu'apporter plus d'informations (indicateurs) lors de la prise de décision est une chose intéressante ? *

	1	2	3	4	5	
Pas du tout intéressant	○	○	○	○	○	Très intéressant

Seriez-vous intéressé(e) par le fait de mettre en place de la provenance dans l'outil AGILIUM ? *

- ○ OUI
- ○ NON

Pourquoi ? *

Développer les raisons de votre réponse (par exemple : vous avez répondu NON car selon vous, toutes les informations requises pour prendre une décision sont déjà présentes dans l'outil AGILIUM)

Votre réponse

Comment notez-vous l'idée de combiner la provenance avec l'outil AGILIUM *

Sélectionner

RETOUR ENVOYER 100 % : vous avez réussi.

N'envoyez jamais de mots de passe via Google Forms.