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Towards an Ontology Development Methodology for Small and Medium-sized Enterprises

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To my father, rest in peace.

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I hope that all of you who have helped and supported me throughout my research work know who you are, and know that I am forever grateful, no matter if you are one of my supervisors, a colleague, a friend, a family member, or even a horse.. Due to the reason that I most certainly will forget to mention someone I will not name anyone here, but nonetheless I am deeply thankful for the insightful comments regarding my research work, for being there when I needed you, and for being patient and not giving up on me when I saw everything in darkness. I owe it all to you.

Love,
Annika

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Chapter 1

Introduction

This licentiate thesis is part of a PhD project at School of Engineering, Jönköping. The area of the PhD project is ontology development with specific use in small and medium-sized enterprises (SME). In section 1.1 some basic background around the research area and motivation for the research are given. Then the research questions that are the basis for the work are presented (section 1.2), followed by related own publications in section 1.3, and finally, in section 1.4, a description of the outline of the remaining part of the thesis is presented, together with a short description of the work process.

1.1 Background and Motivation

The PhD project concerns the research field called information logistics. Information logistics aims at optimising information flow, by serving the right information, in the right context, at the right time, at the right place through the right channel, as described by Sandkuhl [47]. Companies and people are nowadays overloaded with information. Take the Internet as an example, lots and lots of information is out there, mailboxes are filled with mass-sent e-mails that does not concern all receivers. Obviously there is a need for optimising search techniques and personalise information retrieval.

Information overload is however not a new phenomenon, it has been observed and studied in many decades. In 1945 Vannevar Bush foresaw upcoming problems with managing the information we collect in our "bewildering store of knowledge" [8]. The interest from the scientific community within this field has increased significantly during the last ten years, due to the increased use of Internet, e-mail, and other types of information systems. The problem nowadays seems to be to find the right information among the large amount of available electronic data, not that the information does not exist.

Whenever we look at decision making situations, problem solving situations, or knowledge-intensive work, accurate and readily available information is essential. Our enterprise information systems today can support work flows and routine activities if they are well-defined by providing sophisticated solutions. However, if we have more unstructured activities, or ad-hoc tasks, there are some challenges when we want to, for example, find the required information quick. According to surveys made by the Delphi Group [14], 39% of all business executives spend more than 2 hours daily searching for the right information, and the Gartner Group [18], the average "white collar" employee spends 49 minutes per day only for managing e-mails. Thus, users spend lots of time searching for the right information. Simultaneously, more and more business executives perceive information overload, so an improved information supply would contribute significantly to saving time, and most likely to improved productivity.

Within companies and organisations there might also exist lots of well-known terms and knowledge, and sometimes the information or knowledge is not formally or explicitly defined, but mostly exists in employees minds, with the consequence that terms may be used differently and no unambiguous definition exists. It might also be the case that an employee with lots of internal knowledge quits the job and the acquired knowledge is lost.

Related areas to information overload are for example information acquisition and information use. Information use has been described as "the extent to which information influences the users' decision making" [33], and information acquisition refers to the process of obtaining information, which sources are used in this process, and the flow of information from provider to user [52]. An important contribution to improve information acquisition and use is to add value to information in order to reduce information overload, particularly when it comes to the type of information used by managers in a company when making decisions [50].

Information related problems also occur when companies want to keep track of different versions or variants of a product. There may be problems keeping track of which part is used in which product, or keeping track of the different requirements and where they are deduced from, leading to problems when trying to backtrack the different requirements.

Information logistics as a research field uses principles from material logistics, like just-in-time delivery, in the area of information supply in order to address the above mentioned challenges in information supply. Improved information provision and information flow are the main objectives. This is done based on demands with respect to content, time of delivery, location, presentation, and quality of information. The scope can be a single person, a target group, a machine/facility, or any kind of networked organisation. The aim is to explore, develop, and implement concepts, methods, technologies, and solutions for the above mentioned purposes. Sandkuhl and Billig have written an overview to information logistics concepts and approaches [46].

One way to solve the information overload and information supply problems is through the use of ontologies. An ontology is generally seen as *a formal specification of a shared conceptualisation*, meaning that it is created to form some kind of general understanding of the domain at hand. In an ontology it is for example possible to model not only the domain, but also the employees and their specific interests, or interest groups. By using this semantic structure you can further build applications that use this ontology and support the employee by providing the most important information for this person. Ontologies are not only useful for helping solving the information overload problem, but can be used for a variety of different applications, such as sharing explicit knowledge, increase communication, and help in natural language understanding.

During the last years, there has been an increasing number of cases in which industrial applications successfully use ontologies, as described by Lau and Sure [25], and Sandkuhl and Billig [46]. Most of these cases however, stem from large enterprises or IT-intensive small or medium-sized enterprises (SME). However, most of the SME outside the IT-sector probably never have heard about ontologies, but still could benefit from using them. In Sweden small and medium-sized enterprises represent by far the largest amount of enterprises, but do these SME really need ontologies? Can small and medium-sized enterprises also benefit from the use of ontologies, such as the large enterprises have done as the references above describe. Are there shortcomings and a need for improvement in specific application areas, where ontologies can be part of a successful solution, creating substantial benefits? There are some studies about IT use in SME, one is described by Lybaert [28], but they do not cover ontologies or knowledge representation techniques sufficiently. Furthermore, there are studies focusing on usage of innovative ICT technology, for example described by Koellinger [24], but they target a wider audience than SME.

Small and medium-sized enterprises probably also have information supply oriented problems, that can be solved by the use of ontologies. However, the current ontology development methodologies are not specified for small and medium-sized enterprises and their specific demands. Considering the characteristics of successful cases in larger enterprises, similar cases should also exist in SME. However, making conclusions from experiences of larger enterprises with regards to SME is not recommendable, as SME have their own characteristics [26]: SME often prefer mature technologies, which are easy to deploy, use, and maintain. They also show a clear preference for to a large extent standardised solutions, and new innovation projects typically have to create business value within a short time frame.

Thus, the area of use and development of ontologies in small and medium-sized enterprises is not very well researched, and this thesis is an attempt to fill this hole. The PhD project focuses especially on small and medium-sized enterprises, and networks of such enterprises, and the use and development of ontologies in order to optimise information flow and knowledge handling.

1.2 Research Questions

In the previous section some basic background information was given concerning the research area in the broader sense. It is impossible to capture all aspects of this research area in a thesis like this, which is why some more specialisation is needed. In this thesis, focus is set on the development of ontologies in small and medium-sized enterprises. Thus, the main research question, which is the foundation for the research work presented in this thesis, is

What comprises an ontology development methodology suitable for use in small and medium-sized enterprises?

In order to be able to answer this question, two different tracks were found, where the first one deals with the small and medium-sized enterprises and the special circumstances that may occur there. The second one deals with the current state of research when it comes to ontology development methodologies and their suitability for use within small and medium-sized enterprises.

Within the first part, two research questions have been discussed:

What are the requirements on an ontology development methodology for use in small and medium-sized enterprises?

Which application fields for ontology usage are relevant for small and *medium-sized enterprises?*

Within the first of these two questions the special characteristics of small and medium-sized enterprises will be captured, together with the impact these have on an ontology development methodology. Concerning the second question, the thought is to find out which application areas for ontologies are apparent within small and medium-sized enterprises, and whether there are problems within these areas to which ontologies can be applied as part of a solution.

The second part is, as previously stated, more concerned with current state of research, but also incorporates some results from the first part.

What short-comings - if any - do the existing ontology development methodologies have for use in small and medium-sized enterprises?

This means, depending on the outcome of the requirements on the ontology development methodology in a previous question, to see how well the existing methodologies fulfil these requirements, if it is possible to improve them somehow, and if so, what the improvements can be.

1.3 Related Own Publications

Although this thesis is written in the form of a monograph, some parts of the contents have been published as papers on conferences or in journals. The publications are listed below:

- Annika Öhgren and Kurt Sandkuhl. Towards a Methodology for Ontology Development in Small and Medium-sized Enterprises. In Proceedings of IADIS Conference on Applied Computing, Algarve, Portugal, February 2005.

- Eva Blomqvist and Annika Öhgren. Constructing an Enterprise Ontology for an Automotive Supplier. In Proceedings of 12th IFAC Symposium on Information Control Problems in Manufacturing, Saint-Etienne, France, May 2006.

  Revised and extended version of above:

  - Eva Blomqvist and Annika Öhgren. Constructing an Enterprise Ontology for an Automotive Supplier. In Engineering Applications of Artificial Intelligence (ISSN 0952-1976), volume 21, issue 3, pages 386-397, 2008.

- Eva Blomqvist and Annika Öhgren. Ontology Construction in an Enterprise context: Comparing and Evaluating two Approaches. In Proceedings of 8th International Conference on Enterprise Information Systems, Paphos, Cyprus, May 2006.

  Revised and extended version of above:

  - Eva Blomqvist and Annika Öhgren. Comparing and Evaluating Ontology Construction in an Enterprise Context. In Lecture Notes in Business Information Processing - Enterprise Information Systems (ISSN 1865-1348), volume 3, pages 221-240, 2008.

- Annika Öhgren and Kurt Sandkuhl. Do SME Need Ontologies? Results from a Survey among Small and Medium-sized Enterprises. In Proceedings of the 10th International Conference on Enterprise Information Systems, Barcelona, Spain, June 2008.

- Annika Öhgren and Kurt Sandkuhl. Information Overload in Industrial Enterprises - Results of an Empirical Investigation. In Proceedings of the 2nd European Conference on Information Management and Evaluation, pages 343-350, London UK, September 2008.

1.4 Outline of the Thesis

The work started with a literature study, which is described in chapter 2, as the frame of reference, including state of research in the specific areas: ontologies, ontology development, and small and medium-sized enterprises. In chapter 3 a short summary of interesting research approaches together with a description of the research process resulting in this thesis are described. After the literature study, the existing ontology development methodologies were evaluated, using the characteristics of SME that were found during the literature study. This is described in chapter 4 together with a new, or improved, ontology development methodology suitable for small and medium-sized enterprises. Chapter 5 describes the detailed objectives and results of an empirical investigation that was made in order to find out whether there are any application fields that are of specific relevance for small and medium-sized enterprises. A discussion of the empirical investigation can be found in chapter 6. In chapter 7 the conclusions can be found, reconnecting to the research questions in section 1.2. Finally, in chapter 8 some reflections and future work are presented.

Chapter 2

Basic Concepts - Frame of Reference

In this chapter the frame of reference is given. The work is limited to ontologies (section 2.1), ontology development methodologies (section 2.2), and characteristics of small and medium-sized enterprises together with a few examples of ontology applications in SME (section 2.3).

2.1 Ontologies

In the following sections the concept of ontology is defined, together with ontology usage areas and different ontology types.

2.1.1 What are Ontologies?

The term ontology stems originally from philosophy and refers to the subject of existence. Ontology may also refer to a branch of philosophy that deal with the nature of reality. In computer science one of the most commonly used ontology definition is from Gruber, *an ontology is an explicit specification of a conceptualisation* [20]. Explicit in this context means that types of concepts and constraints are explicitly defined and conceptualisation refers to an abstract model of some phenomenon with identified relevant concepts of that phenomenon. Another definition is made by Borst as *an ontology is a formal specification of a shared conceptualisation* [7]. Formal means that the ontology should be machine-readable, shared reflects that it captures knowledge that is accepted by a group. Uschold and Grüninger define an ontology as *a shared understanding of some domain of interest which may be used as a unifying framework* [58]. According to Studer et al, *ontologies aim at capturing domain knowledge in a generic way and provide a commonly agreed understanding of domain, which may be reused and shared across applications and groups* [11].

As you can see, instances are not included in the definition, and therefore not seen as a part of the ontology, although other definitions differ in this concern. An ontology with its instances is seen as a knowledge base.

According to Gómez-Pérez concepts can be abstract or concrete, elementary or composite, real or fictitious, anything about which something is said. Relations represent interaction between concepts of a domain and axioms are used to model sentences that are always true. [19]

In the remaining part of this report, the definition by Borst [7] will be used as an definition of what an ontology is.

2.1.2 What can Ontologies be used for?

Ontologies are used for many different areas, Obitko has mentioned some of them [38]; they can be used for expressing domain-general terms in a top-level ontology, for knowledge sharing and reuse, for communication in multi-agent systems, natural language understanding, and to ease document search to mention some of them.

Uschold and Grüninger specify three different categories where ontologies can be used [58]. The first one is communication, ontologies can be used to increase and facilitate communication among people. They can be used to create a network of relationships, to keep track of what is linked, and use this to navigate and explore. Ontologies provide unambiguous definitions of terms, meaning that people use terms in the same way, and with the same meaning and intention. A shared ontology can be seen as a standardised terminology for all objects and relations in the domain. The second usage area defined is inter-operability. Ontologies can serve as an integrating environment for different software tools. The third usage area is systems engineering, in which ontologies can play an important part in the design and development of software systems. They can help to identify requirements of a system and to explicitly define relationships among components of a system. Ontologies can also be used to support reuse of modules among different software systems.

McGuinness mentions several application areas for ontologies, some of them are mentioned here [31]. Ontologies provide a controlled and shared vocabulary. They can be used for navigation, browsing and search support. Consistency checking can also be handled with ontologies to some extent. Furthermore, ontologies can provide configuration support, and support validation and verification testing of data.

Within OntoWeb four different usage areas for ontologies are defined [39]. The first one is enterprise portals and knowledge management, where ontologies provide a shared conceptualisation of the application domain, and are machine-readable. The second usage area defined is e-commerce, with two different scenarios, business-to-customer and business-to-business. Ontologies in this context represent an efficient way to access and optimise a large scale of information on the Internet. There is also a need for sharing information and agreeing on standards and definitions, where ontologies can play an important part. Information retrieval is the third usage area defined. This means to use ontologies for understanding the concepts being searched and avoid the mistake of missed positives (failure to retrieve relevant answers) and false positives (retrieval of irrelevant answers). The fourth and final usage area for ontologies are portals and web communities. Web communities need intelligent providing and access of information, ontologies could be used to support this as a semantic basis.

2.1.3 Different Types of Ontologies

A number of different types of ontologies exists. It seems as if everyone who does research within ontologies has their own opinion, with the consequence that definitions and terms are not used consistently. Some of the different types of ontologies are discussed in this subsection.

Obitko defines several different types of ontologies [38]. Workplace ontologes specify boundary conditions which characterise and justify problem solving behaviour in the workplace. A task ontology consists of a vocabulary for describing a problem solving structure of all existing tasks, independent from the domain. Task knowledge gives roles to each object and the relations between them. A domain ontology can be either task-dependent or task-independent. A task-dependent ontology contains some specific domain knowledge in order to be able to solve a task. A task-independent ontology on the other hand may cover structure or behaviour of an object, or theories and principles that governs a domain to mention a few. A general ontology covers general or common objects, such that things, events, time, space, etc.

Descriptive terms on a general level are defined as a top-level ontology according to Chandrasekan et al. [11]. This might be terms like *flows* or *casuality*. It may be difficult to distinguish between domain-independent and domain-specific ontologies for representing knowledge, simply because there is no sharp division between them.

Mizoguchi et al. distinguish between task ontology and domain ontology [32]. A task ontology characterises the computational architecture of a knowledge-based system that performs a task, whereas the domain ontology characterises the domain knowledge where the task is performed.

Heijst et al. [61] classify ontologies according to two different dimensions. The first one considers the amount and type of structure of the conceptualisation, and the second considers the subject of the conceptualisation. In the first dimension there are three different categories. Terminological ontologies, e.g. lexicons, specify terms used to represent knowledge in a specific domain. Information ontologies, such as database schemata, specify the record structure of databases. Knowledge modelling ontologies specify conceptualisations of the knowledge, and have a richer internal structure than information ontologies. They are often specialised for a particular use of the knowledge they describe. In the other dimension they distinguish four different categories. Application ontologies are related to a specific application, and model the knowledge required for it. Domain ontologies are specific for particular domains. Generic ontologies define concepts that are generic across many fields. Finally, representation ontologies provide a representational framework without making claims about the world.

Yet another separation between different ontologies types are done by Cui et al. [13], and they define three different ontology types. Resource ontologies define the semantics that are used in software systems. Personal ontologies define semantics of a user or a user group, and shared ontologies define common semantics that are shared between information systems.

To summarise this, one can say that ontologies range from very general, to very application and domain-dependent. This is also connected to the level of reusability; a very application-dependent ontology is not so reusable, whereas a general ontology may be easily reused in several different projects, see figure 2.1.

In the following parts of this thesis, focus is on building ontologies for specific enterprises, so called enterprise ontologies. These should reflect the specific interest of a company, possibly its product structure, organisational structure, processes, and/or the domain.

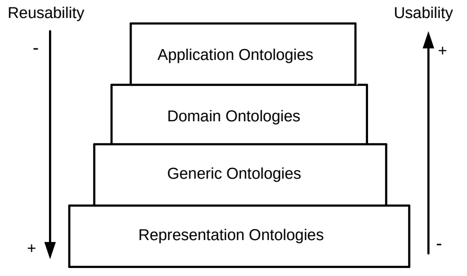

Figure 2.1: Different types of ontologies and their reusability.

2.2 Ontology Development Methodologies

There exist several different methodologies for ontology development. Some of them are mainly manual, and others use a semi-automatic approach, e.g. by using text mining, scanning through documents and proposing a list of concepts and relations to the user. Examples of systems that use semi-automatic approaches for ontology development are OntoLearn [34] and Text-To-Onto [29].

Several different environments for ontology construction and evolution exist, so called ontology editors, such as OntoEdit, Protégé, etc. For an evaluation of ontology editors see for example the work by Su and Ilebrekke [54].

Focus of this thesis is on manual methodologies for ontology development, suitable for small and medium-sized enterprises. The following subsections consist of descriptions of a number of manual methodologies for ontology development that could be used when developing an ontology for a small and medium-sized enterprise. There are other methodologies available, but these were not deemed relevant when looking at the specific focus of this thesis.

2.2.1 The Enterprise Ontology

The methodology for development of ontologies proposed by Uschold and King consists of four phases: purpose, building, evaluating and documenting [59]. In the first phase the purpose is identified, i.e. to find out why the ontology is being built and what its intended uses are. Here should also be considered who will use the ontology and how it will be used. The second phase is the building of the ontology itself and is divided into three parts: capture, coding, and integrating. Capture means to identify the key concepts and relationships, produce text definitions for the concepts and relationships, identify terms to refer to the concepts and relationships, and to agree on the above. It is necessary to review definitions and check the consistency and that no ambiguous terms exist. By coding is meant to take the result from the previous phase and to explicitly represent it in some formal language. This includes committing to a meta-ontology (the main different kinds of terms and concepts that the ontology should capture), choosing a representation language, and creating the code. The third and final part of the building of the ontology regards whether to use already existing ontologies, and if it is decided to use an existing ontology then how this should be done. The third phase is the evaluation phase, in which it should be checked that the ontology fulfils the requirements and that it does not contain any unnecessary things. The last phase is the documentation phase, in which the ontology should be documented in some way. There are (at least not today) no good guidelines about how this should be done.

This methodology was used in the development of The Enterprise Ontology [60]. The Enterprise Ontology was developed to support and enable communication between different people, people and computational systems, and among different computational systems.

2.2.2 TOVE - TOronto Virtual Enterprise

Grüninger and Fox define the goal of an ontology as *to agree upon a shared terminology and set of constraints on the objects in the ontology* [21]. The development of a new ontology must be motivated according to a scenario that describes a problem, and that also describes possible solutions to the problem. The motivating scenario(s) help developers not only to understand why the ontology is needed but also how it can and will be used. Based on one (or more) motivating scenario(s) a set of questions that the ontology need to be able to answer arise. These questions are in this stage called informal competency questions. They are used to evaluate the ontological commitments that have been made. The next thing to do is to specify the terminology of the ontology, this is done by using first-order logic. First the relevant objects are identified, then attributes of these objects are defined by unary predicates, and relations among objects are defined by n-ary predicates. The competency questions then need to be defined formally with respect to the axioms in the ontology. These questions can be used to distinguish between ontologies, by looking at what kind of problems they can solve. According to Grüninger and Fox the most difficult aspect in defining ontologies is the process of defining axioms. The difficulty lies in that the axioms must be necessary and sufficient enough to express the competency questions and their solutions. The final thing to do is to create completeness theorems for the ontology. These define the conditions under which the solutions to the questions are complete. This methodology was used in the development of the TOVE ontology, which was developed as part of the TOVE Enterprise Modelling project. The goal of the project was to create an enterprise model that could deduce answers to queries.

2.2.3 Unified Methodology

Uschold presents a unified methodology for development of ontologies [57]. He has looked at the two methodologies previously described (The Enterprise Ontology and TOVE) and combines the "best" parts in each of them into a unified methodology. The first step is to define the purpose of the ontology, i.e. why the ontology is being built. This can be done in several ways; to identify the intended users, or as in TOVE with motivating scenarios and competency questions, or a user requirements document to mention a few. Next the developer should decide what level of formality the ontology should to have. In the following phase the developer needs to find the concepts that should be in the ontology and the relations among them. Uschold prefers to go the middle-out way when defining terms and relationships, meaning to start with some basic terms and specialise and generalise from there. When it comes to building the ontology the author describes four different approaches. The first one is to skip the previous steps and use an ontology editor to define terms and axioms. Second, do the previous steps and then begin a formal encoding. The third approach is to produce an intermediate document that consists of the terms and definitions that appeared in the previous step, this document can be the final result, or be specification of the formal code or be documentation for it. The fourth and final approach is to identify formal terms from the set of informal terms. The final part that is presented is the evaluation or revision cycle, where the developed ontology is compared to the competency questions or the user requirements.

2.2.4 Ontologies for Conceptual Modelling

Sugumaran and Storey present a heuristics-based methodology for developing and creating ontologies [55]. The authors focus only on the building part, but the methodology is very detailed and easy to follow. They start by identifying all the basic terms; this is done by using use cases and then revising synonyms and related terms manually or by an online thesaurus. In the next step they identify the relationships among these terms. They define three types of relationships: generalisation, synonyms, and associations. Generalisation corresponds to "is-a"-relationships. In this step they also consider relationships between ontologies, in order to allow the ontology to evolve. Next thing to do is to identify basic constraints, which means that terms or relationships are related, e.g. one term/relationship depends upon another, one term/relationship must occur before another, one term/relationship requires another for its existence, or one term/relationship cannot occur at the same time as another. The final step takes into consideration higher-level constraints, such as domain constraints and domain dependencies.

2.2.5 Methontology

Methontology is a method developed by Fernández et al. [15]. When building an ontology the first thing to do is to specify the purpose of the ontology, the level of formality, and the scope. Next all the knowledge needs to be collected, there are several ways to do this: brainstorming, structured and unstructured interviews, formal and informal analysis of texts, and knowledge acquisition tools. In the conceptualisation phase they first proposes to build a glossary of terms with all possibly useful knowledge in the given domain. Then terms are grouped according to concepts and verbs, and these are gathered together to form tables of formulas and rules. Next thing to do is to check whether there are any already existing ontologies that can and should be used. The result of the implementation phase is the ontology codified in a formal language that can be evaluated (verified and validated) according to some references. The final part consists of the documentation, if the above methodology is followed each phase should result in a document that describe the ontology developed so far.

2.2.6 Ontology Development 101

Noy and McGuinness describe a way to develop an ontology by using an example: an ontology is created for wines and terms connected to wines [37].

Their methodology is iterative, starting with a rough concept and then revising and filling in the details. The first step in their suggested methodology consists of determining the domain and the scope of the ontology. Next thing to think about is whether to use already existing ontologies, and if so, how to use them. A list of all the terms that could be needed or used is then produced. The class hierarchy should represent an "is-a" relation, cycles should be avoided, siblings should have the same level of generality, multiple inheritance could lead to problems, and also guidelines regarding when to introduce new classes or instances are given. Now the classes are defined, i.e. the terms, and the relations and also the properties of the classes need to be specified (attributes). Here it is important to check whether some relations are inverse or not, and whether a default value for an attribute could be useful. After this, the value type of both the classes and the class properties are defined, this includes cardinality, domain and range. Finally the individual instances are created. They also describe some naming conventions and why this is important.

2.2.7 Methodology from Karlsruhe

Staab et al. describe a methodology for ontology development which covers the whole life cycle [53]. They define five different phases: feasibility study, ontology kickoff, refinement, evaluation, and last a maintenance and evolution phase. In the feasibility study problem areas and solutions are identified and put into a wider organisational perspective. The kick off phase starts with a requirements specification document containing the domain and goal of the ontology, design guidelines, knowledge sources, users and user scenarios, competency questions, and applications supported by the ontology. The initial draft of the ontology is refined and/or revised in the refinement phase. The ontology is created by formalising a description of it in a formal representation language. In the evaluation the ontology is compared to the requirements and tested in the target application environment. Another valuable input here are usage patterns of the ontology, meaning the way users use the ontology to search for concepts and relations. This helps to analyse which parts of the ontology that are most frequently used and may be expanded, and correspondingly the least frequently used parts may be something that could be deleted. The maintenance and evolution phase contains strict rules for the update/insert/delete processes of ontologies, who are the persons responsible for maintenance, and for example in which time interval the ontology is maintained.

2.3 Small and Medium-sized Enterprises

The following subsections describe selected aspects of small and medium-sized enterprises, which are necessary in the context of this work, together with some applications of ontologies in this context.

2.3.1 Characteristics

Most definitions of small- and medium-sized companies depend on their number of employees. An example is that small companies have less than 100 employees and medium-sized companies have between 100 and 299 employees. There are slight variations in the number depending on the source. Throughout this paper we define a small or medium-sized enterprise as an enterprise which has less than 250 employees and a yearly turnover of less than EUR 50 million.

There are a number of characteristics for SME, some of them are listed below:

- SME focus on a small range of products or services in a niched market [30]. This means close relationships to customers [43] and business partners, and the ability to satisfy specific demands of customers.

- SME have a weak management structure, where one individual or a small team makes the decisions [23], meaning a fast decision process [30], and possibility to operate flexibly and quickly adapt to changes in the market [42].

- SME have simple structures and systems that facilitate flexibility and short reaction times and form the basis for quick adaptation to changes in their environment. These systems are often based on one persons experience and not on objective reasons, and thus may remain unchanged even if other structures and systems could be required. [42]

- SME have limited financial resources and are often time-pressured [23]. This means they spend little money and effort on technology, and cannot afford to hire expensive IT consultants. It is important to minimise cost of projects [9].

- SME prefer simple and familiar solutions over complex, formal methods of project management [23].

- SME are dependent on a limited number of people, and it is not uncommon for employees to have several roles in the company. The smallness of the company also gives high commitment [42] and selected and motivated employees [43]. An SME is often more people-dependent than process-dependent, and there is a need for capturing knowledge in business rules and processes [23].

- SME are often owner-manager driven [23], and the owners time is very valuable [51]. The top person spends a lot of time on doing routine tasks [23].

2.3.2 Applications of Ontologies

Within OntoWeb there has been a number of successful scenarios where ontologies have played a central role [39]. A few of them are described in the next section.

2.3.2.1 NOPIK

NOPIK (Personal Information and Knowledge Organizer Network) was a joint project with actors from Italy, United Kingdom, Greece, Germany, and Portugal [35]. The aim was to support personal information and knowledge management needs by building a distributed environment and to structure an underlying methodology to implement relevant knowledge management changes. The project considered especially small and medium-sized enterprises. For the modelling and navigation of information and knowledge resources an ontology-based approach was used. The system consists of seven different components, two of them are an ontology editor and a problem solving manager. The ontologies are used for information and knowledge management, documents can be added and attached to appropriate categories.

2.3.2.2 Arisem

Arisem is a company that provides knowledge management solutions [1] [39]. They use ontologies to construct a "Semantic Web" system of navigation, which organises skill and knowledge management within a company in order to improve collaboration, interactivity, and information sharing. They contribute to the field of information logistics by sending the entering information flow directly to the correct projects and people, and thereby reduce thousands of documents to around ten instead. Ontologies are also used to represent the organisational dimension of information.

2.3.2.3 SEWASIE

SEWASIE (Semantic Webs and AgentS in Integrated Economies) is a project within the Semantic Web Action Line of the European IST Programme [49] [48]. It focuses on enhancing information management capabilities in networks of small and medium-sized enterprises. They use semantic web technologies together with agent systems to achieve their goal. A number of data sources is used, together with intelligent agents and domain ontologies to build up a network of intelligent information sources. These information sources are used by a query manager which combines results from different sources and presents it to the user via a user interface. This user interface also considers the users' personalised information. The resulting systems help small and medium-sized enterprises to find the right information at the right time, in a multinational environment.

Chapter 3

Research Method

Research methods are a widely studied area and used topic, starting from Kuhn's paradigms, via Feyerabend's anarchistic theory, to more experimental approaches. A comprehensive overview has been written by Chalmers [10]. Within information systems research the most common approaches are to use some kind of experiments or field surveys [62]. However, some new or different approaches have been suggested, such as theorem proof, simulation, and action research [17].

The research methodologies that have been considered in the research process resulting in this thesis are mainly experiments, case studies, and surveys, and therefore a small introduction on each of these topics can be found in section 3.1. Following, in section 3.2, is a description of the research process that was followed during the work of this thesis.

3.1 Relevant Research Approaches

In the following subsections three common research strategies within the field of computer science are described: experiments, case studies, and surveys. The approaches differ in their applicability, depending on both the surrounding environment and phenomenon that the researcher wants to analyse. A summary of these aspects is found in table 3.1, this table is an extension and combination of what is discussed by Pfleeger [41] and Yin [64].

Table 3.1: Research Strategy Factors

Factor	Experiment	Case Study	Survey
Level of control	High	Low	Low
Investigation cost	Low	Medium	High
Ease of replication	High	Low	High
Form of research question	How, why	How, why	How many, how much

3.1.1 Experiments

Basili defines an experiment as a study in which the researcher has control over some of the conditions in which the study takes place, and control over the independent variables being studied [3]. Accordingly Wohlin et al. state that experiments are used when the researcher wants control over the situation and manipulate behaviour directly [63]. Furthermore Wohlin et al. give examples of when experiments can be used, such as to test theories, test people's conceptions, evaluate the accuracy of models, etc. An experiment can be used to investigate a certain situation and whether the claims are true in this specific situation.

Basili differentiates between evolutionary and revolutionary modes of discovery within the experimental paradigm. In the evolutionary approach the researcher first observes existing solutions, proposes better ones, measures and analyses the new solutions, and repeats until no more improvements seem possible. In the revolutionary approach on the other hand, the researcher proposes a new model, develops methods and applies this model, and then measures, analyses and repeats as previously stated. The new model is not necessarily based on previous models, but can be based on existing problems that are not currently solved. [3]

Remenyi and Money differentiate between laboratory experiments, which are not so applicable when doing research targeted at enterprises, and field experiments, in which the researcher can observe in a natural setting, rather than a closed laboratory. However, field experiments are on the other hand more vulnerable for contamination, meaning that it is harder to find what is causing the effect. [45]

Zelkowitz and Wallace group experimental methods in four general categories [65]:

- **Scientific method** in which the researchers develop a theory, propose a hypothesis, and test alternative variations of the hypothesis.

- **Engineering method** in which the researchers develop and test a solution to a hypothesis.

- **Empirical method** in which statistical methods are used to validate a given hypothesis, and data is collected to verify the hypothesis.

- **Analytical method** in which a formal theory is developed, and results derived from the theory can be compared to empirical observations.

3.1.2 Case Studies

A case study is, according to Yin, an empirical research process that is used to investigate a phenomenon within its real-life context [64]. Also, the boundaries between the investigated phenomenon and the surrounding environment do not have to be clearly evident. If this definition is compared to experiments, case studies do not separate between the context and the phenomenon of study. A case study tries to answer ”how” or ”why” questions regarding the phenomenon of interest. Bell defines a case study as something in which the researcher identifies a phenomenon, and collects information in a systematic way, judges relations between different variables, and the whole case study should be planned in a methodical way [4]. According to Remenyi and Money the aim of a case study is to provide a multi-dimensional picture of the situation [45]. Wohlin et al. describe a case study as something which is made in order to investigate a single phenomenon within a specific time space [63]. A disadvantage of case studies compared to experiments is that the results are harder to interpret and more difficult to generalise, due to the fact that there are more varying variables than when conducting an experiment. It is also harder to control the information, hence there is always a risk for skewed results [4].

In a short tutorial summary Perry et al. try to point out several characteristics of case studies and also what case studies are not. A case study is a defined, scientific method for posing research questions, collecting data, analysing data, and presenting the results. A case study is not an experience report, meaning that it is not enough to just afterwards describe what was done and explain what lessons were learnt from the experience. Case studies seen as a research method should include a research question and collection and analysis of data to answer the research question. However, the authors compare a case study with a single experiment when it comes to scope, and in the fact that both case studies and experiments need a series of studies to understand a certain phenomenon. [40]

3.1.3 Surveys

There exist several different definitions of what a survey is, but generally surveys are conducted to collect information from a population and can be seen as a snapshot of the situation in order to see the current status. They do not only give information about the sample, but often it is wanted to generalise the information to the underlying population. [63]

Fowler divides surveys into three critical parts: sampling, question design, and data collection [16]. By sampling he means how to select a small subset of a population that is representative for the whole population. Question design is also important in order to make sure that the questions are well understood and give meaningful answers. He also presents a number of different data collection techniques, where the main ones are interviews (either personal or via telephone) and self-administered data collections (by mail, group administration, or in households). Interviews have the advantages of higher response rates, and the possibility to answer questions regarding the survey questions, leading to more adequate answers. The largest drawback is the amount of time and cost needed. Self-administered data collections also have advantages: relatively cheap costs and the respondents are more anonymous. The drawbacks are that the design of the questionnaire is crucial, and the interviewer is not present in order to answer questions or exercise other quality control issues.

A drawback of surveys is that, if not conducted correctly, the response rates may be too low so that we cannot assume anything about the underlying population. Those who respond to the survey are likely to be different from those who do not. In order to be able to have indulgence with a low response rate it is crucial that the underlying reason for not responding to the survey is not dependent on the questions in the survey, or the survey as such. [4]

3.2 Description of the Research Process

The work on this thesis started out with a literature study, in which the aim was to analyse and document the state of research in ontology construction. The focus was on manual methods for ontology construction, as the current automatic or semi-automatic approaches did not seem mature enough. Within the literature study small and medium-sized enterprises and their characteristics were also investigated. The objective was to try to find what is specific in such enterprises, e.g. what are the aspects that are specific for small and medium-sized enterprises, and which are the requirements when looking at the ontology construction methodologies?

The next step in the research process was to evaluate the ontology construction methodologies found during the literature study. The evaluation criteria were also found during the literature study, derived from the specific characteristics of small and medium-sized enterprises. The evaluation then lead to a proposal of a new methodology, in which all the identified SME-specific characteristics are considered.

The methodology was tried out in a project case, in which an ontology was constructed for a company in the automotive industry. In this case two different ontology construction methodologies were used, the proposed manual one (in the scope of this thesis), and a semi-automatic one (part of another PhD project), thus two ontologies were constructed, but for the same purpose, using the same information, etc. The ontologies were compared to each other, and in this way also the methodologies were evaluated. This project case led to some improvements for the proposed manual ontology construction methodology, which were incorporated into the method. However, the conclusion was that the methodology needed to be further specialised, for example for a specific usage area. Therefore an empirical investigation was proposed in order to find out, when looking at a larger set of enterprises, which usage areas that exist within SME.

The empirical investigation started out with a number of conjectures, some interviews were held leading to a revised set of conjectures. Then a questionnaire was sent to a number of enterprises, the results were analysed and conclusions were drawn. A more specific description of the methodology used for the empirical investigation can be found in section 5.1. After the empirical investigation some general conclusions were made, coupling back to the research questions presented in section 1.2, and also some ideas for future work were depicted. The research approach is illustrated in figure 3.1.

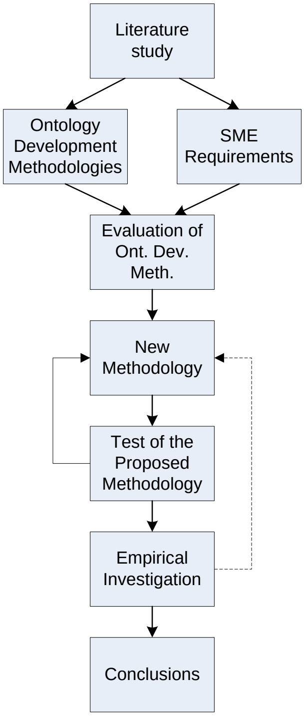

Figure 3.1: Illustration of the used research approach.

Chapter 4

Initial Ontology Development Methodology

This chapter includes an evaluation of the existing methodologies described in 2.2 (section 4.1), followed by a proposition of a new methodology (section 4.2), the application of this methodology in an application case (section 4.3), and finally a section on method improvement potentials and limitations of the proposed methodology (section 4.4).

4.1 Evaluation of Existing Methodologies

This section contains a short evaluation for each of the methodologies described in section 2.2. The evaluation criteria were developed based on the characteristics of SME, as seen in section 2.3.1.

The methodology should:

- be defined in full detail, easy to follow, and make no claims about the environment,
- cover the whole life cycle of the ontology, and
- consider reuse of already existing ontologies as early as possible in the development process.

The first criterion is that the methodology should be defined in full detail, easy to follow, and not making any claims about the environment. This includes detailed guidelines how to carry out each phase of the methodology, templates for important results or best practises. These cookbook-like instructions are expected to contribute to the reduction of development efforts and with respect to qualification, also requirements of the project team members.

The methodology should also cover the whole life cycle of the ontology, from planning to implementation and evaluation. Only a complete methodology will allow for a fairly precise estimation of the total costs of ontology development and can be the basis for a tight project supervision in order to reduce project risks.

The methodology should furthermore consider reuse of already existing ontologies. This should be done as early as possible in the development process in order to reduce the development time and effort. Reuse in this context reduces development efforts and opens the possibility to integrate with solutions available in the application domain or from key partners.

The methodology used in the development of the Enterprise Ontology covers the whole life cycle and is easy to follow but could be a lot more detailed. It considers integration of other ontologies, but late in the development. It can be improved to fit the criteria previously presented by adding details and consider integration earlier in the development.

The approach used to develop the TOVE ontology seems too formal for use in small-scale application contexts: in most application cases it is not appropriate to have such a formal ontology. It covers the whole life cycle, but does not take into account integration of already existing ontologies.

Uschold's unified approach has four different approaches in the building phase. Depending on the approach chosen, the formality and form of the ontology changes. The steps before the building phase are fairly detailed, but in total it lacks the integration part.

Methontology seems to be one of the most mature methodologies. It is fairly detailed, contains the whole life cycle, and has an integration part. The aspects that can be improved are that the integration part could be placed earlier in the development, and that from our viewpoint a middle-out approach in the conceptualisation should be preferred. The use of a bottom-up approach could lead to a lot of concepts that are not really relevant for the ontology. By using a middle-out approach instead, focus lies on most frequent or commonly used terms and concepts.

The methodology proposed by Sugumaran and Storey does not cover the whole life cycle, it almost only considers the building of the ontology. However, it has some aspects in the building phase, such as identification of

Table 4.1: Evaluation of existing manual methodologies.

Approach	Life-cycle coverage	Detailed definition	Reuse
Enterprise Ontology [59]	Whole life-cycle	No detailed guidelines	Late dev. stage
TOVE [21]	Whole life-cycle	No detailed guidelines	Not integrated
Unified Approach [58]	Whole life-cycle	Building very detailed	Not integrated
Methontology [15]	Whole life-cycle	Fairly detailed	Late dev. stage
Sugumaran & Storey [55]	Focus on building	Building very detailed	Not integrated
Noy & McGuinness [36]	Lacks parts	Building very detailed	Early dev. stage
Staab et al. [53]	Whole life-cycle	Fairly detailed	Early dev. stage

basic constraints, which can improve an ontology development methodology.

Noy and McGuinness' methodology is explicitly iterative and it has an integration part early. It lacks some of the parts of the whole life cycle of an ontology (e.g. evaluation and implementation). In the building phase they give a lot of guidelines e.g. whether to introduce a new class or not, that the siblings in the class hierarchy should have the same level of generality, etc. These detailed guidelines could contribute a lot in an ontology construction scenario in an SME. Noy and McGuinness are also the only ones that discuss naming conventions and why this is important.

Staab et al. propose a methodology which is rather mature. Their methodology covers the whole life cycle and it is fairly detailed and complete. However it could still benefit from even more details in the building phase.

A summary of existing methodologies for ontology development, and an evaluation according to our evaluation criteria can be found in table 4.1.

4.2 Proposed Methodology

Based on the discussions in 4.1, an enhanced methodology especially for use in small-scale application contexts is proposed. The methodology can be seen as a mix of some of the methodologies described earlier, taking the relevant parts from each methodology. In the following subsections a short description of the proposed methodology is described, consisting of four different phases: requirements analysis, building, implementation, and evaluation and maintenance. Documentation should be done after each phase, the requirements analysis results in a user requirements document, the building phase results in a document containing all the terms, relationships and properties, the implementation itself is a kind of documentation, and an evaluation and maintenance document. Figure 4.1 shows an outline of the proposed methodology together with its resulting documents.

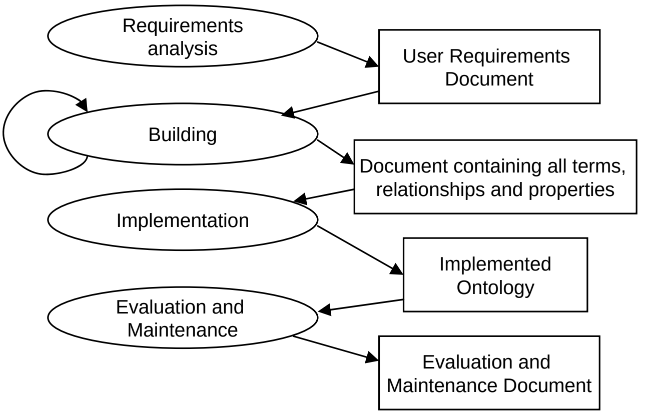

Figure 4.1: Proposed methodology with the four phases and the results of each phase.

4.2.1 Requirements Analysis

In the requirements analysis phase all formalities for the ontology are specified, e.g. the intended users and uses of the ontology, the purpose and scope of the ontology, what should be in the ontology and what should not be in it. Why the ontology is being built is an important question to answer and what the users require and expect from the ontology. It is necessary to here plan the main tasks that should be done, including how they will be performed, a time plan and what resources that are needed. Usage scenarios of how the ontology can be used should be developed. The available knowledge sources should be identified including a decision how these will be used in the building phase. This could be interviews, text analysis, databases, etc. Applications supported by the ontology should be documented. In order to shorten the development time one step is to check whether there are any ontologies that can be integrated with the one being built as soon as possible. Other things that should be specified are the level of formality (depends on the uses) and the level of detail (depends on the user requirements and available information). Before continuing with the building phase the developers need to decide on a naming convention that should be used consistently. Any other things that could help to clarify the goals and purpose of the ontology should be specified in this phase.

The result of this phase should be a user requirements document containing everything that needs to be specified before the ontology itself is built.

4.2.2 Building

The building phase is iterative, meaning that it is possible at any stage to go back and re-examine and change what has been produced so far. First, some basic terms are identified, for example by the use cases developed in the requirements analysis phase. These terms are then expanded and specified into more terms and generalised if the level of detail obtained is too specific in a middle-out approach. How these terms are found should be clear from the requirements analysis. Next, relationships among these terms are specified. This includes is-a relations, associations and synonyms. Now each term is described in natural language, this definition should be as precise and unambiguous as possible. The next thing to do is to add constraints among the terms and relationships. This includes pre-requisites, temporal, mutually inclusive and mutually exclusive constraints. If the requirements analysis resulted in one or more ontologies that should be integrated with the one being built this should be done in the beginning of this phase, it should be checked what parts that could be reused and which not. Furthermore the properties of the terms (attributes) need to be specified, including cardinality, value type, domain, and range. During this phase it is recommended to follow the rules and guidelines given by Noy and McGuinness [37]. The result so far should be a document containing all terms and relationships that should be in the ontology, with a text definition of each term/relationship, constraints among these terms/relationships and properties of the term/relationship. Finally the ontology should be reviewed and revised.

4.2.3 Implementation

The implementation phase primarily consists of implementing the ontology in an appropriate ontology tool, such as Protégé, OntoEdit, or SNet-Builder.

4.2.4 Maintenance and Evaluation

The implemented ontology needs to be evaluated and tested to check that it fulfils the requirements given in the requirements document. It should also be evaluated according to criteria such as clarity, the ontology and its terms should be clear and unambiguous, consistency, the ontology needs to be free from contradictions, and reusability, define the possibilities to reuse the ontology and the extent of reuse. It is also important to specify who should update and maintain the ontology and how and when this should be done.

4.3 Application Case for the Proposed Methodology

This section describes the application of the previously described methodology within a research project called SEMCO (Semantic Structuring of Components for Model-based Software Engineering of Dependable Systems). SEMCO aims at introducing semantic technologies into the development process of software-intensive electronic systems in order to improve efficiency when managing variants and versions of software artifacts.

The scope of the experiment was to construct a selected part of an enterprise ontology for one of the SEMCO project partners. This was done using two different methods for building ontologies, the previously described manual one, and a semi-automatic method, and thus constructing two different ontologies, but with the same purpose and with the same scope, and then comparing the results, i.e. the constructed ontologies.

In the following subsections, first the purpose is briefly discussed, then the development of the manually constructed ontology is described, and finally the evaluation is presented. More details on this experiment have been presented by Blomqvist and Öhgren [6] [5].

4.3.1 Purpose

The purpose of the ontology built in this project was to support capturing relations between development processes, organisation structures, product structures, and artifacts within the software development process. As previously mentioned, two different construction processes were used, thus constructing two different ontologies. The purpose and aim of the different ontologies were the same, the domain and scope were the same, and they also used the same set of project documents as starting point and major knowledge source. Furthermore, for the evaluation the same methods, tools, and domain experts were used. The ontologies were limited to describing the requirements engineering process, requirements and specifications with connections to products and parts, organisational concepts, and project artifacts.

4.3.2 Manual Ontology Development

The manual construction followed the four phases described in section 4.2. First of all a user requirements document was produced. Information was mainly given by the SEMCO project leader, for example on intended users and uses of the ontology, purpose and scope, and usage scenarios. Different knowledge sources were identified, and available ontology libraries on the Internet were checked for ontologies to integrate with, but no relevant ontologies were found to integrate with.

In the building phase the starting point was to use the available project documents as a basis and build a concept hierarchy from there. After a discussion it was decided that natural language descriptions for each concept were not necessary at this point. This can be added in the future if needed. It was quite hard to derive relations, constraints, and axioms from the documents so after document analysis focus was switched to the other knowledge sources: interviews with selected employees at the company.

The interviews were performed in two sessions. At the first session the interviewees first looked at the top-level concepts and discussed these. Then they went further down the hierarchy discussing each concept and its subconcepts. Feedback was given in the form of suggestions, such as "Restructure this" or "This concept is really not that important to us". After the first interview session the ontology was changed according to the suggestions. The second interview session was basically carried out in the same way, resulting mainly in minor corrections to the ontology.

The evaluation and maintenance phase was partly integrated with the building phase, where the interviewees reviewed the ontology. The other parts of the evaluation are described in section 4.3.3. The maintenance part has not yet been performed. The resulting ontology has 8 concepts directly beneath the root and 224 concepts in total.

4.3.3 Evaluation

The evaluation was divided into three parts: first a general evaluation, then evaluation done by ontology engineers, and finally evaluation done by domain experts. Throughout the evaluation the manually created ontology is compared to the ontology constructed using a semi-automatic approach.

In the general comparison some characteristics of the ontologies were collected. Notable here is that the automatically constructed ontology has a large number of root concepts (35), it lacks some abstract general notions to keep the concepts together in groups, subject areas or views. It is also quite shallow and many concepts lack subconcepts altogether. The total number of concepts in the automatically constructed ontology was 85. The manually created ontology on the other hand contains a larger number of concepts, it also contains a top-level abstraction, dividing the ontology into intuitive subject areas. There are however few attributes and relations, this might be due to that many attributes are actually represented by other specific concepts, they are just not connected by an appropriate relation. Relations seem to be harder to elicit from interviews than the concepts themselves.

In the evaluation that were performed by ontology engineers focus was put on errors in the ontologies, such as circularity errors or incomplete concept classifications. Mentionable here is that fewer errors seem to occur in the manually constructed ontology than in the automatically created one, this can probably be explained by the actual humans who discover such errors while constructing the ontology.

In the last evaluation, the one made by the domain experts, the experts were asked to score several characteristics of the different ontologies on a scale with five options ranging from "Very low" to "Very high". The characteristics that were used were, among others, "Essential concepts", "Essential relations", perspectives of the taxonomy, number of axioms, etc. Both ontologies seem to contain an appropriate number of concepts, and both cover the intended scope, but the concepts in the manually constructed ontology are deemed more essential. The automatically created ontology contains more attributes and relations, and also more non-taxonomic relations.

4.3.4 Conclusions

To shortly summarise the evaluations, especially for the manually constructed ontology, some strengths and weaknesses can be noted.

The manual approach gives, compared to the automatic approach, a less structured result, with less complex relations and axioms. Furthermore, the extent to which the application domain is covered by the ontology depends significantly on the interviewed experts, domain experts might have different impressions of the ontology scope. On the other hand, the manual approach has one big advantage, since it also captures the most specific concepts and terms that the enterprise actually uses. The level of detail can be more easily adapted to the intended application of the ontology. Also, the abstract concepts at the upper level give an intuitive idea of the scope of the ontology. None of the approaches produce too many errors in the ontology structure according to our expert evaluations.

Improvements of the manual approach could be to use a larger set of knowledge acquisition methods to elicit more complicated information structures from the document sources and domain experts.

Another evaluation approach would also be desirable, where the ontologies are tested against their goals and application scenarios. This is not possible yet, since development of a pilot application in this project is still a future task.

The application case that was used to try out the proposed ontology development methodology was not ideal for the intended purpose, as the main enterprise involved actually was not an SME. However, it was a first try with the methodology and there were no reason to think that the methodology will not suit SME later on, when further improved.

The main conclusion, which can be drawn from this experiment and its evaluation is that the approaches each have both strengths and weaknesses, and complement each other well. This might suggest that a combination of the approaches could give the best results, but it is too early to state this firmly, since the methods have only been tested in parallel for one single case. The next step is to repeat this experiment in other cases in order to be able to generalise these results and perhaps arrive at some solution for combining the approaches.

4.4 Method Improvement Potentials and Limits

In the previously mentioned experiment (the SEMCO application case, described in section 4.3) some improvements have been suggested, and should be further investigated and elaborated. An example of such an improvement is the use of a larger set of knowledge acquisition methods to elicit information. Examples on techniques that might be useful are card sorting, laddered grid, or 20 questions. Furthermore the guidelines included in the methodology should contain detailed instructions on how to use such techniques in order to elicit information, all in order to deduce the work effort of the ontology developer.

A more detailed evaluation phase would also be desirable, with detailed suggestions on how this could be handled. Here some very useful input has come from the SEMCO project, the use of several different ontology evaluations seem very powerful, however, the ontology need to be tested against its goals and application scenarios in order to see how well it fulfils its intended tasks.

However, after the development and evaluation in the SEMCO project, the impression was that the ontology development methodology could be further specialised, depending on the type of ontology, usage area, or domain. It seems hard to give more detailed instructions in the development, unless you know for example in what usage area the ontology will be for.

Chapter 5

Investigating Ontology Application Potentials in SME

In order to decide an appropriate direction for further specialising the proposed ontology construction methodology, an empirical investigation was performed exploring the application potential of ontologies in small and medium-sized enterprises.

The objectives of the empirical investigation are described in section 5.1, starting with objectives and briefly the methodology used. Then, some words about the initial interviews (section 5.2), followed by the survey, including setup, layout, sample, analysis, and limitations (section 5.4).

5.1 Objectives of Empirical Investigation

The conclusion from chapter 4 was that the methodology could probably benefit from being specialised for a specific domain, usage area, or type of ontology. In order to be able to know in which such areas or domains to specialise it, i.e. to find out which areas that seem relevant for small and medium-sized enterprises, an empirical investigation was performed. Using the background described in chapter 2 together with some intuitive ideas of the nature of SME in this region of Sweden, the five conjectures as described below were defined as application areas for ontologies in SME.

1. There is a need for supporting information searching and thus reducing the time needed to find the right information.

2. There is a need for supporting management of configurations or variations of products. This could be differences and similarities, dependencies between variants of a product, or dependencies between products, which could be used for example to improve reuse of parts of products and/or reuse of design processes.

3. There is a need for structuring documents and supporting document management, for example in order to support project work.

4. There exists a need for supporting collaboration and inter-operability in networks of companies, and/or supply chains.

5. There is a need for capturing enterprise knowledge, like development rules, process knowledge, or design principles in order to avoid dependencies from certain individuals.

As a prestudy interviews were held at several different companies of varying size (section 5.2), which led to a revised set of conjectures, excluding the last two conjectures seen above. These were then used together with background information on the applicability of ontologies, in order to prepare the questionnaire. After sending out the questionnaire and collecting the data, the data analysis was done, using the conjectures and the background information studied earlier. Finally, conclusions were drawn from the empirical investigation. The research methodology used in the empirical investigation is illustrated in figure 5.1.

5.2 Interviews

In total eleven people from seven companies were interviewed to see their view on problems and ideas regarding the conjectures and to identify suitable fields and questions for a questionnaire survey.

The companies ranged from three employees up to 2300 (3, 9, 15, 90, 120, 130, 2300). The companies also differs in type and industrial sectors. Two of them are more networking companies, offering contacts between enterprises or offering other types of services to their customer companies. One is the university, where the focus of the interview was on connections to the industry. The other four companies are genuine development companies, two software development companies and two suppliers of automotive industry.

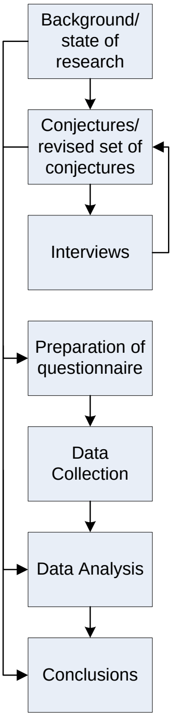

Figure 5.1: The research methodology used in the empirical investigation.

The roles of the respondents varied, but most had some kind of middle-level management position, such as IT-manager, or project leader.

The interviews were held in a semi-structured way, were the interviewer led the interview and asked questions connected to for example the production and development processes, documents and information, available support systems, and personal knowledge.

The interviews resulted in that a decision to go on with a questionnaire to further investigate three of the hypotheses listed previously, namely information search, versions/variants of products, and document structuring. The interviews gave indications that some problems exist within these areas and that ontologies could be a fruitful way to solve or at least help in solving these problems.

Within the field of supply chain or networks of enterprises most information were based on personal knowledge, which was deemed very hard or even not possible to document. This leads of course to very personal dependent organisations but the interviewees still did not see any other way to handle this, personal connections is part of their work. IT-systems such as databases can of course help to document some information concerning this, but still the personal relations and knowledge are very important. The result of this was to stop with questions regarding both supply-chains or network of enterprises and documenting expert knowledge. When the respondents did not see that it would be possible to avoid personal dependencies it seems as an extremely hard task to use ontologies for this.

5.3 Judging Ontology Application Potential

In section 2.1.2 several application areas for ontologies where identified, which potentially are of interest for SME. One task of the survey is to confirm that these fields really can be found in the SME sample under consideration, e.g. that a sufficient part of the SME have product configuration challenges, need support in document or information retrieval, or work in collaboration projects with suppliers requiring inter-operability.

The mere existence of an application field alone, however, does not indicate that the use of ontologies is appropriate in this field. Small projects or simple product configurations, to just take two examples, might well be manageable in an efficient way without any IT support at all. How to judge when it makes sense to consider the use of ontologies? In this thesis we will follow the opinion of various scholars in the field that the complexity of an application case is an essential parameter to take into account when deciding about the use of ontologies. The more complex the application scenario, the more likely the usefulness of ontologies. In the context of this thesis, project complexity and product complexity are of particular interest. Approaches for determining or even measuring project complexity and product complexity could directly contribute to identifying the share of SME with either complex project situations or complex products.

A review regarding the concept of project complexity performed by Baccarini proposes to define complexity as "consisting of many varied interrelated parts", to distinguish between organisational and technological complexity, and to operationalise this in terms of "differentiation and interdependence" [2]. Differentiation refers to the *number of varied elements*, e.g. tasks or components; interdependence characterises the interrelatedness between these elements. Regarding organisational complexity, Baccarini identifies among other indicators the *number of organisational units involved* and the division of labour. For technological complexity, the diversity of inputs and output and the *number of specialities* (e.g. subcontractors) are considered.

In the area of product complexity, work of Hobday regarding distinctive features of complex products and systems identifies dimensions defining the nature of a product and its complexity [22]. The not exhaustive list of 15 critical product dimensions provided by Hobday includes *quantity of subsystems and components*, *degree of customisation of products* and *intensity of supplier involvement*. These dimensions will be used in combination with Baccarini's project complexity indicators when evaluating the survey results in chapter 6.

5.4 Survey

This section describes the survey, including survey setup, data analysis, and limitations.

5.4.1 Survey Setup

In the following subsections the survey setup is described, starting with the survey layout, followed by the sample, a presentation of data collection and the response rate, and finally a section describing the analysis methods used, together with some words about validity and reliability.

5.4.1.1 Survey Layout

The questionnaire was divided into five parts of varying size, where the first four questions concerned the company: number of employees, yearly turnover, industrial sector, and the respondent's role within the company.

The next part included eleven questions and dealt with document and information management and included questions about how much time the respondent used daily to find and save information connected to his or her work. How and where the information was found was also investigated and also some information concerning the information flow, if the company had any form of Intranet or document management system, DMS, and how often this was used.

The third part concerned only companies working in projects and included six questions about the number of employees in each project, how long time the projects ran, and some information about the documents in the projects.

The following twelve questions were only for producing companies and handled questions about how many products the company had, how many components each product consists of, how many suppliers that contribute to each product, and how many variants the products had. There were also a couple of questions regarding reuse of products, how much this was done and whether it would be possible to do it more. Some questions regarding how differences between variants of products were documented were also included, and whether they used taxonomies or nomenclatures, and if so, what they were used for.

Finally there were two questions regarding non-documented personal knowledge and whether it would be possible to document this knowledge. This was added just to see the respondents view on this kind of problems. The questionnaire finally consisted of 35 questions on six pages.

5.4.1.2 Sample

In order to reach out to an appropriate number of companies, the university's host company database was used. The host companies are used to connect students and (mainly) regional companies in order to enforce the connection between theory and practise. These companies already have a connection to the school and were therefore deemed more interested in responding to such a questionnaire than companies without an established connection to the education and research performed at School of Engineering. Within the database there exist also contacts to each company, to whom the questionnaire was directly addressed to. The roles of these contacts are not specified and therefore not clear at this point.

Also, the size and industrial sector of the companies were not investigated at this time, but rather included as questions in the questionnaire. This was done to be able to exclude large companies, and look at if there are general differences between small and medium-sized companies, and also to be able to notice possible differences between roles of the respondents and industrial sector of the companies.

5.4.1.3 Data Collection and Response Rate

The questionnaire was in the end of November 2005 sent to the 436 companies previously discussed. The deadline for responding to the questionnaire was set to three weeks, in order to get the answers before Christmas.

24 of the sent questionnaires came back unopened due to wrong addresses or unknown addresses, which means that the number of possible respondents was reduced to 412.

164 answers were received, all of them were considered useful and were used in the analysis, giving a response rate of 39,8% (164/412).

5.4.1.4 Analysis Methods, Validity, and Reliability

The tool used in the data analysis was SPSS (version 16), and the main analyses were descriptive statistics, using frequencies. In some cases compare means was used to compare different groups, e.g. different roles, or enterprise sizes. No further correlation coefficients were used. The idea of the survey was not to achieve results of statistical significance, but rather to get an idea of what kind of problems that may exist within SME.

Validity measures to what extent the chosen method measures what the researcher wants to measure [27]. The big question here is how to interpret the results, e.g. what does it mean that a certain percent of the respondents have a large number of products and variants. This was partly discussed in section 5.3 and will further be discussed in chapter 6.

Reliability is defined as the capability to generate the same result at different points of time, thus reducing the error of measurement [27]. Some of the questions in the survey are directed to the enterprise as such, and thus should not be dependent on coincidences, such as for example the respondent's mood on the specific day of answering the questionnaire. However, some other are more dependent on the respondent and could be subject for reliability discussions, e.g. the perceived information flow. This is taken into consideration when analysing the data, but since the objective of the survey is to get ideas on which application fields for ontologies that are apparent within SME, no detailed investigations regarding reliability has been performed.

5.4.2 Data Analysis

In this section the results of the survey is presented. The data concerning small and medium-sized enterprises is found in the following subsection, followed by the data concerning industrial enterprises. In the last subsection, data from the entire survey is presented. The reason to include data from industrial enterprises, thus not limiting to SME, was that a large number of the enterprises were within the industrial sector, and some interesting

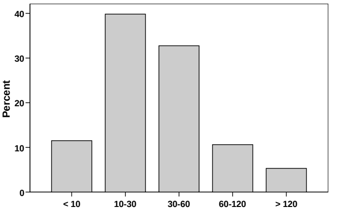

Figure 5.2: Time needed daily to find the right information for the work at hand (in minutes).

aspects were found, and this was also partly compared to the results from SME. The data from the entire survey was included basically since it was available, but also to see if there were any big differences between SME and larger enterprises.

5.4.2.1 Small and Medium-sized Enterprises

The size of the sample taken into account for this part of the thesis were the responses from 113 small and medium-sized enterprises with approximately half of them with less than 50 employees.

In the survey, a clear majority of the sample perceive that they receive "far too much" (41%) or "too much information (28%). 27% think the amount of information is adequate, only 4% think they do not receive enough information.

Regarding the time needed daily to find the right information for the work at hand, the distribution is as shown in figure 5.2. Even though half of the sample needs less than half an hour daily to find the right information, it can be noted that a substantial part of the working hours is consumed by searching for information. 33% of the sample consume between 30 minutes up to an hour daily, 11% need more than one hour, 5% even more than two hours.

The participants were also asked how difficult it is to find the information needed for the work task at hand. Within the sample, nobody answered that it is "very difficult" to find the required information. "Relatively easy" and "medium difficult" both received approx. 40%; "very easy" and "difficult" both approx. 9%. Not surprisingly, the respondents with a higher daily time effort for finding information also had a tendency to perceive it as more difficult to find the right information.

Concerning the sources for finding required information, joint file servers in the companies and the Internet are the most often used sources, followed by the PC: 70% answered that the file server is "often" or "very often" the source for information, 64% the Internet and 49% the PC. Intranet and document management systems (DMS) are less frequently used (36% and 26%, respectively), which to some extent will be based on the fact that 29% of the sample do not have an Intranet and 31% do not have a DMS.

The established DMS and Intranet solutions in enterprises are used quite intensively: 40% of all respondents use these systems several times a day, 29% nearly every day. 17% use these IT-systems a few times during the week and 14% use them only a few times in a month or even more seldom.

Regarding the question how to find the requested information in the above mentioned sources, most respondents rely on their memory from earlier cases (67%), use keyword search (60%) or the existing directory structure (59%). Furthermore, a substantial part of the respondents ask their colleagues for the needed information (29%).

Considering the potential for improving information management in SME, not only the introduction of Intranet or DMS in companies without those system types is a possibility, but also the improvement of these systems as such. Among the respondents who have an Intranet or DMS 50% of the respondents note that it is not possible to subscribe new or changed information, 17% stated that they got too many hits when searching for information, 19% claimed they got irrelevant hits, and others wish for an improved structure of the information, either with relation to the work process (19%), or with regards to the product structure used in the company (33%).

Another part of the survey was addressing the issue of product complexity. In industry domains developing or manufacturing physical products, the number of components in the product, potential versions and variants of the product and number of suppliers contribute to product complexity. The product related part was answered by 61 of 113 SME. The following part of the results is based on these 61 responses.

The number of products found in the sample was quite high: 62% of all respondents stated that they have more than 50 products. 5% and 13% have between 11 and 25 or between 26 and 50 products, respectively. 15% of all respondents have between 4 and 10 products, 5% even less than 4 products.

Most of the products have a small number of variants. 47% of the respondents answered that there are on average less than 6 variants, 23% between 6 and 12. 4% stated that there are between 13 and 25 variants, 9%

between 26 and 50, and 17% more than 50 variants.

The average number of components in these products is either quite high or quite low. 35% of the respondents state that a product on average has more than 50 components. 42% have less than 10 components per product (23% less than 4 components; 19% between 4 and 10). 21% state the average number is between 11 and 25. At 2% of the respondents it is between 26 and 50.

In the large majority of the enterprises, a description is available which components are parts of what product: 88% answered that some kind of product structure exists, 8% answered there is no such structure, the remaining did not know. The existence of such a description or product structure would ease the development of an ontology in the field of variability management.

The average number of suppliers contributing to a product is less than 3 at 16% of the respondents, between 3 and 5 at 27%, between 6 and 9 at 16%, between 10 and 15 at 15% and more than 15 at 26% of the participating SME.

Reuse of components in new products or new variants of an existing product could be improved considerably, according to the opinion of a majority of the respondents. 26% state that currently there is no reuse of components at all, 15% answer that there is nearly no reuse. 26% answer that reuse happens sometimes, 20% state that reuse happens often, 13% very often. On the question whether it would be possible to reuse more, 16% respond "definitively possible", 48% "yes, probably" and 36% think it is not possible.

The survey also included a number of questions on projects performed in the enterprises. Main intention was to investigate the complexity of projects performed and the documentation involved. The project related questions were answered by 71 out of in total 113 SME participating in the survey. The following part of the results is based on these 71 answers.

In order to get information about project complexity, the survey included questions about the number of project members, run time, number and volume of project documents, structure and content of project-related documents. Based on the respondents' answers, the projects in SME are rather small in terms of project members. 39% state a project has only up to 3 members, 51% have between 4 and 8 members and only 10% have more than 8 members. The large majority of the projects has a run time of more than one month but less than one year: 39% state that the average project run time is between 1 and 4 months, 32% have an average run time between

4 and 12 months. Enterprises with average project length of less than one month (20%) and more than one year length (9%) are in the minority.

The number of documents produced in a project varies considerably within the sample: 37% of the respondents state that there are on average less than 10 documents, 35% between 11 and 25 documents, 13% between 26 and 60, and 15% more than 60 documents in a project.

Most of the documents are quite small in terms of number of pages. 51% state that the documents on average have less than 4 pages and 37% between 4 and 10 pages. Only 10% of the respondents have an average document size of between 11 and 25 pages, 3% between 26 and 50 pages.

Regarding the document structure, standardisation seems to be common practise. In more than 85%, the document structure is identical in different projects (38%) or nearly identical (47%). 11% state that the structure sometimes is similar. A not at all similar structure in different projects can be found only at 4% of the respondents.

5.4.2.2 Industrial Enterprises

The size of the sample taken into account for this part of the thesis were the responses from 131 industrial enterprises, of which 71% were considered small and medium-sized enterprises.

In the survey, a clear majority of the sample perceive that they receive "far too much" (37%) or "too much information (29%). 28% think the amount of information is adequate, only 5% think they do not receive enough information. Regarding the time needed daily to find the right information for the work at hand, it can be noted that a substantial part of the working hours is consumed by both searching for information and save and sort information. The results to these queries can be seen in figure 5.3.

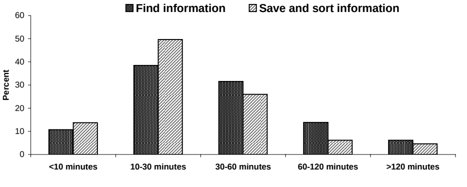

Figure 5.3: Time needed daily to find information and save and sort information.

The participants were also asked how difficult it is to find the information needed for the work task at hand. Within the sample, nobody answered that it is "very difficult" to find the required information. "Relatively easy" and "medium difficult" received 43% and 42% respectively; "very easy" received 8%; and "difficult" 7%. Not surprisingly, the respondents with a higher daily time effort for finding information also had a tendency to perceive it as more difficult to find the right information.

Concerning the sources for finding required information, joint file servers in the companies and the Internet are the most often used sources, followed by the own PC: 71% answered that common file servers are "often" or "very often" the source for information, 66% the Internet and 51% the own PC. Intranet and document management systems (DMS) are less frequently used (44% and 32%, respectively), which to some extent is based on the fact that 21% of the sample do not have an Intranet and 26% do not have a DMS. Among the respondents who have an Intranet or DMS 46% of the respondents note that it is not possible to subscribe for new or changed information, 20% state that they got too many hits when searching for information, 25% claim they got irrelevant hits, and others wish for an improved structure of the information, either with relation to the work process (20%), or with regards to the product structure used in the company (35%).

When it comes to how to find the requested information in the above mentioned sources (multiple choices were allowed), most respondents rely on their memory from earlier cases (62%), use keyword search (62%) or browse the existing directory structure (60%). Furthermore, a substantial part of the respondents ask their colleagues for the needed information (26%).

The survey also included a question regarding the use of taxonomies or nomenclatures. 15% of the respondents answer that they do use some kind of taxonomies or nomenclatures, 65% state that they do not, and the remaining 20% do not know.

Another part of the survey was addressing the issue of product complexity. In industry domains developing or manufacturing physical products, the number of components in the product, potential versions and variants of the product, and number of suppliers contribute to product complexity. The product related part was answered by 83 of 131 industrial companies.

The number of products found in the sample was quite high: 68% of all respondents stated that they have more than 50 products. 11% have between 26 and 50 products, 5% have between 11 and 25, 13% of the respondents have between 4 and 10 products, and only 4% less than 4 products. Most of the products have a small number of variants. 42% of the respondents answered that there are on average less than 6 variants, 26%

between 6 and 12. 5% stated that there are between 13 and 25 variants, 9% between 26 and 50, and 18% more than 50 variants.

The average number of components among these products is either quite high or quite low. 36% of the respondents state that a product on average has more than 50 components. 41% have less than 10 components per product (19% less than 4 components; 22% between 4 and 10). 17% state the average number is between 11 and 25. At 6% of the respondents the number of components is between 26 and 50. The average number of suppliers contributing to a product is less than 3 at 12% of the respondents, between 3 and 5 at 23%, between 6 and 9 at 13%, between 10 and 15 at 15% and more than 15 at 37% of the participating enterprises.

In the large majority of the enterprises, there exists a description denoting which components are parts of what product: 86% answer that some kind of product structure exists, 10% answer there is no such structure, the remaining do not know. There was also a question regarding how differences between variants of a product are documented (multiple choices were allowed). 63% answer that it is written in product specifications, or requirements specifications, etc. 27% document it using a product structure, and 7% in a specification of a product group or a product line. 9% state that it is not documented at all.

Reuse of components in new products or variants of an existing product could be improved considerably, according to the opinion of a majority of the respondents. 22% state that currently there is no reuse of components at all, 15% answer that there is nearly no reuse. 24% answer that reuse happens sometimes, 27% state that reuse happens often, and 13% very often. On the question whether it would be possible to reuse more, 14% respond "definitively possible", 53% "yes, probably" and 33% think it is not possible.

The survey also included a number of questions regarding projects performed in the enterprises. Main intention is to investigate the complexity of projects performed and the documentation involved. The project related questions were answered by 76 out of in total 131 industrial companies participating in the survey.

The projects in these industrial enterprises are rather small in terms of project members. 34% state a project has only up to 3 members, 51% have between 4 and 8 members and only 15% have more than 8 members. The number of documents produced in a project varies considerably within the sample: 28% of the respondents state that there are on average less than 10 documents, 36% between 11 and 25 documents, 19% between 26 and 60, and 17% have more than 60 documents in a project. Most of the documents are quite small in terms of number of pages. 46% state that the documents on average have less than 4 pages and 39% between 4 and 10 pages. Only 15% of the respondents have an average document size exceeding 11 pages (12% between 11 and 25 pages and 3% between 26 and 50 pages).

Regarding the document structure, standardisation seems to be quite common. In more than 83% the document structure is identical in different projects (31%) or nearly identical (52%). 11% state that the structure sometimes is similar. A not so similar structure in different projects can be found at 5% of the respondents. The same type of document content is also quite common, in 55% of the cases it is the same or nearly the same type of document content in different projects (11% and 44% respectively). In 32% of the cases the content type is similar and in 13% it is not so similar.

5.4.2.3 All Enterprises

The first four questions handled more general questions regarding the enterprise and the respondent's role within the enterprise.

The first question concerned the respondent's role within the enterprise. Here the answers were grouped together forming three different groups: Owner/CEO, Other Manager, and Other. In the Other Manager group we have for example economy managers, personnel directors, and computer systems managers. Among the respondents in the Other group, we have all that are not CEO nor managers, such as designers, secretaries, and technicians.

Among all respondents, 28% fell into the first group, Owner/CEO. Furthermore, 44% belonged to the second group, Other Manager, and the remaining 28% were put into the third group, Other.

The following two questions regarded the number of employees and the yearly turnover. These two were used together when grouping the enterprises into small, medium, or large enterprises. 22% stated that they had fewer than 25 employees. 19% had between 26 and 50, 16% between 51 and 100, 19% between 101 and 250, and the rest (24%) had more than 250 employees. The yearly turnover had a similar division; 20% had less then 25 Mio SEK in yearly turnover, 12% between 25 and 50, 14% between 50 and 100, 13% between 100 and 200, 13% between 200 and 400, and 28% had more than 400 Mio SEK in yearly turnover.

The enterprises with 50 or less employees and a yearly turnover less than 100 Mio SEK is considered small enterprises. Enterprises with less than 250 employees and a yearly turnover not exceeding 400 Mio SEK is considered to be of medium size. Enterprises with more than 250 employees, or more than 400 Mio SEK in yearly turnover is considered large enterprises. This definition is comparable to one of the European Union, see [56] for more details. This resulted in 63 small enterprises, 50 medium enterprises and 51 large enterprises.

Regarding the industrial sectors the largest group is the engineering industrial enterprises (40%). The second largest sector is the constructing enterprises (21%). The remaining enterprises are scattered among it/electronics (9%), advertising (3%), public sector (7%), services (4%), other technical enterprises (9%), and other (6%).

Document and Information Management 10% of the respondents state that they use less than 10 minutes each day to find the information needed for the work at hand. For 40% this takes between 10 and 30 minutes and for 32% it takes between 30 and 60 minutes. For 12% of the respondents this takes between one and two hours, and 6% even state that it takes more than two hours.

The same type of question were asked regarding the time needed to save and structure the information. 15% say that it takes less than 10 minutes, 49% that it takes between 10 and 30 minutes and 25% that it takes between 30 and 60 minutes. For 7% it takes between one and two hours, and for 4% even more than two hours.

The following question regarded how easy it was to find the information needed for the work at hand. 7% stated that it was very easy, 43% that it was fairly easy, 43% that it was of average difficulty, and 7% stated that it was fairly hard. As a follow-up question on this, we asked the respondents whether they could state something that made this particularly easy or hard. 65 % of the respondents answered this question, these answers have been divided into six different categories. The categories are not exclusive, some of the answers fit to more than one category, they are also partly overlapping.

The first category concerns Internet, and how it has changed the information management. 20% of the answers concerned this issue, most of them stating that Internet has eased the way to find information, also high availability is pointed out. Although Internet has made it easier to find information, it has also some drawbacks, such as too much information available and bad designed homepages makes it hard to find the information needed. It might also be hard to know if the "best before"-date has expired.

The second category concerns the use of intranets and information systems, 27% of the respondents mentioned this topics. Here the opinions diverse into two contradictory parts, one that thinks that using intranets and other information systems really makes it easier to find information ($\approx$ 2/3) and one that thinks the structure and information mass makes it hard to find what you need. Among the comments one can also mention the importance of availability.

The third category follows the second, by looking further into structure and human factors (26% of the answers). What can be pointed out here is the importance of a well established routines and individual disciplines. The involvement of many different persons and large information amounts may make it harder to follow routines. Also, the structure needs to be focused on what you are doing, if you are a producing company, then the structure needs to reflect that in order to make the structure logical and ease information management.

The information amount was discussed in 26% of the answers, and is the fourth category discussed here. The main opinion on this is that it is too much information available, possibly in different places, using different information sources, etc. Also mentioned here is the lack of uniform nomenclature and metadata.

The fifth category concerns searching and the critical use of search words (10% of the cases). There is a great sensitivity in the systems, if you do not use the correct word or phrase to search for, you will not get the information you need. Another drawback is that the information is language dependent.

The sixth and last category sums up the remains of the answers to this question (15%). Here it is a big diversity, from "broad subject" to "public authorities", and that some information might be irrelevant for the ones responsible for it, but relevant for the ones that use it.

The next question concerned where the necessary information normally is found. There were six different alternatives, and for each the respondents were supposed to fill in how often it was used (from very seldom to very often, or does not exist). The first was locally saved information, such as local PC, etc. Here, 7% state that this happens very seldom, 14% seldom, 22% sometimes, 28% often, and 26% very often. 3% stated that they did not have this.

The second was common server space, 4% state that they use it very seldom, 6% seldom, 18% sometimes, 25% often, 44% very often, and 3% did not have this.

The third alternative was Intranet, 1% used this very seldom, 12% seldom, 19% sometimes, 21% often, 25% very often, and 22% stated that they did not have this.

The fourth alternative, document management system (DMS), received the following results: 5% very seldom, 18% seldom, 21% sometimes, 16% often, 13% very often, and 27% did not have this.

The fifth alternative, Internet, was very seldom used by 3% of the respondents. 6% stated that they used it seldom, 24% sometimes, 40% often, 26% very often, and only one respondent claimed that they did not have it.

The sixth and final alternative was Other, and here the respondents could fill in their own choice. 3% stated that this was used very seldom, 7% seldom, 23% sometimes, 33% often, and 30% very often. Among the answers here some are repetitive, such as colleagues, specialist literature, and the personal bookshelf (both books and files).

Question 10 concerned how the information needed for the work at hand were found. There were five alternatives: search words, your own memory, good structure, ask colleagues, and other. Multiple choices were allowed. 62% stated that they used search words to find the necessary information, 65% used their own memory, they knew what they had done previously and this is easy to find, 59% had a good folder structure that made it easily sortable and easy to find the right information, and 30% asked their colleagues. Among the ones that answered other, personal relations and looking for it on the desktop can be mentioned.

The following question regarded the experienced information flow, in for example mail-merges, Intranet, etc. 38% stated that they received far too much information, 27% think they got too much information, 31% stated that the information amount was appropriate, and only 4% think they did not get enough information.

The next two questions were only answered by the respondents who had an intranet or DMS. The respondents were asked to check whether the given statement was true for their system. 49% stated that it is not possible to subscribe to new information. 21% thought searching gave too many hits (6% that searching gave too few hits), and 24% stated that searching gave irrelevant hits. 20% wanted the intranet or DMS to be more structured according to the work process, and 32% wanted it to be more structured according to the products. It was also possible to give comments and some people thought that there could be a better structure, and easier to search in. Another thing worth mentioning is the difficulty to get discipline when it comes to information storage.

The other question connected to intranets/DMS were regarding how often the intranet/DMS was used. Approximately half of the respondents state that they use it several times each day, 25% use it nearly every day, 15% use it once or twice a week, 6% once or twice a month, and only 4% more seldom.

Project Management This section contained six questions, where the first one regarded the number of employees in a project. Most project are quite small in number of employees, 86% of the respondents have fewer than 9 members in each project (35% less than 4), 9% have between 9 and 15 members, 9% between 16 and 25, and only 1% have more than 25 employees in a project.

The runtime of a project is most often between one month and one year (1-4 months 39%, 4-12 months 33%). Projects between one week and one month, and projects longer than 12 months are in the minority (14% and 13%. Projects with average shorter runtime than one week is very rare, only at 2% of the respondents this happens.

The number of documents that are produced in a project varies quite much. 4% of the respondents have less than 4 documents in a project, 28% have between 4 and 10 documents, 34% have between 11 and 25 documents, 17% have between 26 and 60 documents, and the remaining 17% have more than 60 documents in each project.

Concerning document size, it can be concluded that in most projects the documents are quite small in terms of number of pages. In 48% the documents have fewer than 4 pages, and in 39% between 4 and 10 pages. 11% between 11 and 25 pages, and 2% between 26 and 50 pages. None of the respondents had more than 50 pages in each document.

Most of the respondents seem to have a similar document structure in their different projects, 33% answered ”yes” and 48% answered ”yes, pretty similar”. At 13% this was the case ”sometimes”, ”no, not so similar” at 5%, and ”no, not at all similar” at only 1%.

Concerning the document content, and whether it is of the same kind in different project, it varies a bit. 10% answered that it is the same, 40% that it is often similar, and 34% that it is sometimes the same. 14% answered that it is not so similar, and 2% that it is not similar at all.

Product Management In the first question in this section we were interested in how many different products each of the companies had. The largest part, 64% state that they have more than 50 products, 11% between 26 and 50 products, 8% have between 11 and 25 products, 14% between 4 and 10 products, and only 3% answered that they have less than 4 products.

The next question concerned how many components each product consists of (on average), and here the results are quite varied. 20% have less than 4 components per product, 22% have between 4 and 10 components, 17% have between 11 and 25 components, 6% have between 26 and 50 components, and the remaining 35% have more than 50 components per product.

Concerning the number of suppliers that (on average) contributes to a product, the results are as follows: less than 3 suppliers at 14% of the respondents, between 3 and 5 suppliers at 23%, between 6 and 9 at 14%, between 10 and 15 at 15%, and 35% of the respondents have more than 15 suppliers for each product.

We also asked a question regarding the number of versions or variants that a product has. 43% state that each product has less than 6 variants, 26% has between 6 and 12 variants per product, 5% between 13 and 25 variants, 8% between 26 and 50 variants, and more than 50 variants per product were found at 18% of the respondents.

The following three questions concerns the amount of reuse, and whether it would be possible to reuse more than what is done at the moment. In the first question we asked to what extent components where reused, in for example another product, or in later versions of the same product. 22% state that they do "not reuse" at all, 18% that it happens, but "rarely", 23% that it happens "sometimes", 25% that it happens "often", and 12% state that it happens "very often". In the next question we asked whether it would be possible to reuse more, 14% answered "yes, definitely", 51% "yes, probably", and 35% "no". The last question regarding reuse concerned with what would be necessary to do in order to increase the amount of reuse within the company. Among the answers a few concepts are reoccurring, such as standardisation, better structure of both documents and components, better search possibilities, better documentation of the products, and better communication between units in the organisation.

14% state that they use some kind of taxonomies or nomenclatures, 68% state that they do not, and 18% does not know. Regarding which taxonomies or nomenclatures that exist and what they are used for, the answers were that they are mainly used as definitions of the concepts within a specific type of business.

The next question dealt with how differences between variants of a product is documented, here multiple choices were possible. In 62% of the cases this is documented in product specifications, requirements specifications, or similar. A product structure was used in 27% of the cases, and at 6% of the cases this was documented in a specification of a product group, or product line. At 10% of the respondents this was not documented at all.

In the following question we simply asked whether the company used some kind of product structure, 86% answered "yes", 9% answered "no", and the remaining 5% did not know. Among those who answered yes, we wanted to know what it was used for. The answers were not so surprising, the product structure is used in the production planning, stock planning, work orders, producing is based on it, etc, i.e. anything that has to do with the manufacturing of the products.

Personal Knowledge 64% of the respondents answered that there is a lot of personal knowledge that is not documented. Another 28% stated the same, but that it is only valid for some positions in the enterprise. Only 8% think that there is no such knowledge, or there might be for a single position.

82% think that it is possible to document this kind of personal knowledge, although 55% think that it is going to be hard. 16% think that it is probably not possible to document it, and only 1% think that it is absolutely not possible.

5.4.3 Limitations of the Survey

The main limitations of the survey are:

- the size of the sample was not large enough, nor was the sampling process done in a random way,
- the majority of SME participating in the survey were manufacturing companies,
- the survey only included enterprises from a geographically limited area (south of Sweden), and
- the survey did not investigate which product data management solutions exist in enterprises. Defining the actual improvement potentials in this area requires a more detailed investigation and should anyhow be performed individually for each enterprise, as the organisational goals, work flows, and infrastructure should be taken into account.

These limitations should be taken into account when investigating whether the results are transferable to other areas, to what extent they are generalisable, or applicable in other research contexts.

Chapter 6

Discussion of Empirical Investigation

In this section the results are first discussed regarding small and medium-sized enterprises, followed by a discussion regarding industrial enterprises, and finally the complete survey results are discussed.

6.1 Small and Medium-sized Enterprises

The first conjecture, presented in section 5.1, addressed the *need for supporting search and information retrieval* in SME. Experiences from using ontologies for structuring information or within search engines show clearly that they can contribute to improving precision. Examples of investigations within this field has been done by for example Ciravegna and Petrelli [12] and Redon et al. [44]. However, the main question to discuss from an SME perspective is which approach creates the best benefit/effort ratio, i.e. substantial benefits at a reasonable price.

As a considerable part of SME neither have Intranets or DMS, and as even the established systems have improvement potential, these improvements should be made first before starting on ontology development.

Thus, the conclusions regarding use of ontologies for supporting information management in SME are:

- the SME participating in our survey perceive diverse information management problems, like difficulties to find the right information, short-comings in the established IT-systems or information overload. This presents an application field for ontologies,

- the use of conventional technologies should be given preference to ontologies when improving information management in SME.

The second conjecture addressed the need for *supporting management of product configuration and variation.* The fact that 61 of 113 SME responded to the questions regarding product variability in the survey gives a first indication that many SME actually provide physical products consisting of various parts. In section 5.3 the concept of product complexity was briefly discussed including indicators for product complexity. For the purpose of evaluating the product complexity in the sample, four criteria were included, which are connected to four questions in the survey:

- number of products,
- average number of components per product,
- average number of suppliers per product,
- number of variants.

These four criteria match directly to the indicators proposed by Baccarini and Hobday (see section 5.3). For each of these four criteria, the survey questions offered five different choices. Mapping these choices on a scale from "very low" to "very high", i.e. the choice with the lowest number of products, components, variants and suppliers is mapped to "very low" and the choice with the highest number is mapped to "very high", helps to visualise the distribution of the answers regarding the four criteria. Figure 6.1 shows this distribution.

Furthermore, it is important to know whether there is a correlation between the four criteria, for example whether companies with a high number of products also have a high number of variants and many suppliers. When investigating this aspect, 31 cases were found with at least two criteria receiving at least "high". Of these 31 cases were 21 with two times "very high" and 16 with three times at least "high". Figure 6.2 visualises these 16 cases.

In terms of complexity, at least the 16 cases shown in Figure 6.2 are considered as complex enough to seriously investigate the use of ontologies. The 16 cases show both, a very high degree of differentiation and interdependencies between the criteria. Even for the other 15 cases, who at least

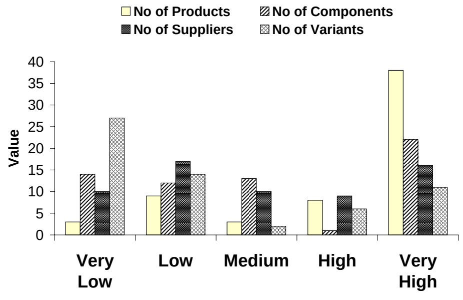

Figure 6.1: Distribution of the four product criteria.

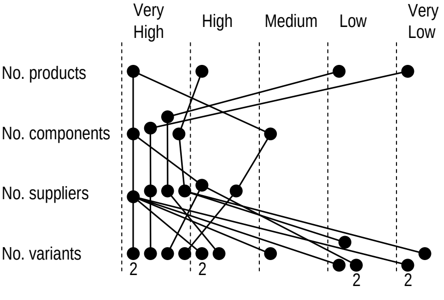

Figure 6.2: Cases from the survey with highest product complexity.

receives two times ”high” or ”very high”, there are development potentials for ontologies, as all of them at least have one criteria on ”medium” level, which contributes to substantial differentiation and interdependencies.

Based on the above discussion, the conclusion is that there is a need for supporting variability management. Approximately a quarter of all SME in the sample and more than half of those SME answering the product related questions have a substantial complexity in their product portfolio.

Conjecture 3 focused on the need for *supporting document management in project work*. 71 of 113 SME responded to the questions regarding project work, which indicates that many SME actually use project organisation based on documents. Evaluating the complexity of document management in projects again included four criteria, which are connected to questions in the survey:

- average number of employees in a project,
- average number of documents per project,

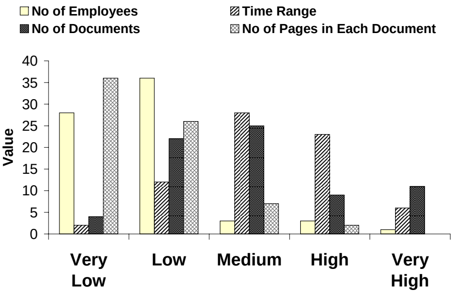

Figure 6.3: Distribution of very low to very high for the four project document management-related criteria.

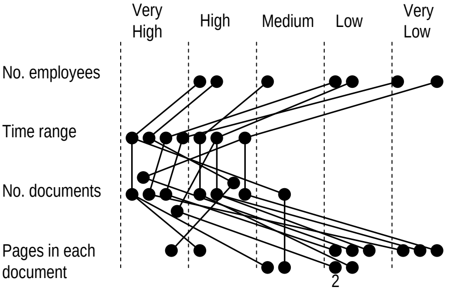

Figure 6.4: Cases from the survey with highest project document management complexity.

- average duration of projects,
- average number of pages per documents.

The first two criteria directly relate to Baccarini's work (see section 5.3); the other two were derived in order to represent document complexity. The survey questions offered five different choices for each of these four criteria, which were mapped on a scale from "low" to "very high". Figure 6.3 visualises the distribution of the answers regarding the four criteria.

Considering the correlation between the four criteria, there were 13 cases with at least two criteria receiving at least "high". Of these 13 cases were 5 with two times "very high". Figure 6.4 visualises these 13 cases.

In terms of complexity, at least the 13 cases shown in Figure 6.4 are considered as complex enough to seriously investigate the use of ontologies. These cases show both, a very high degree of differentiation and interdependencies between the criteria. Comparing these figures with the situation in product complexity (conjecture 2), the significance of a need for supporting project document management is not as high. However, 18% of the SME working in project organisation and 11% of all SME in the sample show a high complexity, which from our perspectives is sufficient motivation to aim at supporting project document management.

6.2 Industrial Enterprises

The first conjecture addressed whether information overload is perceived as a problem in industrial enterprises. Considering the fact that 2 out of 3 parts of the sample stated that they receive "far too much" or "too much" information, this conjecture was clearly confirmed. The conjecture is further supported by the time needed to save and sort information. 37% of the sample needs at least half an hour daily to take care of this task. Compared with the Delphi study, our results support the first conjecture better, although the Delphi group concluded that 37% of all participants of the survey needs more than 2 hours per day; in our study this is just 6%. However, the Delphi group study was performed much earlier (in 2002), focused on another target group (business professionals), and another geographic area (U.S.), which limits the comparability.

Conjecture 2 focused on the need for supporting information retrieval in industrial enterprises. A considerable part of the sample needs between 30 minutes and one hour daily (32%) or even more than an hour (20%) to find the right information, which indicates the need for improving support for information retrieval. Improvement potential seems to exist for both pull and push information supply:

- only 51% of the sample perceive that it is "relatively easy" or "easy" to find the information needed, i.e. nearly half of the sample experience difficulties when searching or browsing for information,
- 46% of the sample who have a DMS or an Intranet do not have the possibility to subscribe for new or changed information. Such filtering of information would reduce the need for actively searching and the time consumed for this purpose.

The survey results also indicate where improvement potential can be expected. Introducing Intranet or DMS solutions with advanced searching, browsing, or subscription functionality should lead to an improvement in the enterprises who do not have these system types implemented (21% and 26% respectively). Among the enterprises which already have such Intranet or DMS solutions it seems to be possible to improve the systems. Subscription functionality or higher relevance of the hits by improved search functionality would be two possibilities in this context.

The third conjecture aimed at the need for supporting management of product configuration and variation. In the area of product complexity, the work of Hobday, as presented in section 5.3, regarding distinctive features of complex products and systems identifies dimensions defining the nature of a product and its complexity. The not exhaustive list of 15 critical product dimensions includes quantity of sub-systems and components, degree of customisation of products and intensity of supplier involvement.

For the purpose of evaluating the product complexity in the sample, we covered four product dimensions in the survey: the number of products, the average number of components and of suppliers per product, and the number of variants. For each of these criteria, the survey questions offered five different choices. Mapping these choices on a scale from "very low" to "very high", i.e. the choice with the lowest number of products, components, variants and suppliers is mapped to "very low" and the choice with the highest number is mapped to "very high", helps to visualise the distribution of the answers. Figure 6.5 shows this distribution.

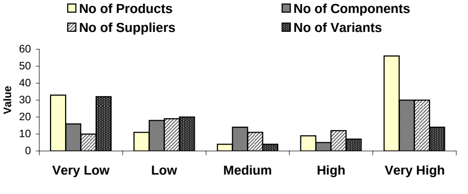

Figure 6.5: Distribution of product complexity-related criteria.

Furthermore, it is important to analyse the correlation between the four criteria, for example whether companies with a high number of products also have a high number of components and many variants. When investigating this aspect, 48 cases were found with at least two criteria receiving at least "high". Of these 48 cases were 35 with two times "very high", 27 with three times at least "high", and 15 with three or four times "very high". Table 6.1 visualises these 15 cases.

Table 6.1: Cases from the sample with at least three product criteria at least "very high".

<table>
<tr><th>No of Products</th><th>No of Components</th><th>No of Suppliers</th><th>No of Variants</th><th>No of cases</th></tr>
<tr><td rowspan="8">very high</td><td rowspan="6">very high</td><td rowspan="10">very high</td><td>very high</td><td>3</td></tr>
<tr><td>high</td><td>1</td></tr>
<tr><td>medium</td><td>1</td></tr>
<tr><td>low</td><td>2</td></tr>
<tr><td>very low</td><td>2</td></tr>
<tr><td>unknown</td><td>2</td></tr>
<tr><td>high</td><td rowspan="4">very high</td><td>1</td></tr>
<tr><td>very low</td><td>1</td></tr>
<tr><td>low</td><td rowspan="2">very high</td><td>1</td></tr>
<tr><td>very low</td><td>1</td></tr>
</table>

In terms of complexity, at least the 27 cases with three times at least "high" as considered complex: these cases show a very high degree of differentiation and interdependencies between the criteria. The conclusion is that there is a need for advanced information management solutions complementing current IT support. Approximately one third of the enterprises answering the product related questions and a quarter of all enterprises in the sample have a substantial complexity in their product portfolio. Within these enterprises there should be specific support for management of information related to these complex products, which complements the functionality in traditional systems managing product data, e.g. product lifecycle management systems. Examples are taxonomies or nomenclatures easing search or navigation in information. As seen in the survey, most enterprises do not have such structures implemented.

Conjecture 4 focused on the need for supporting document management in project work. A review regarding the concept of project complexity performed by Baccarini proposes to define complexity as "consisting of many varied interrelated parts", to distinguish between organisational and technological complexity, and to operationalise this in terms of "differentiation and interdependence" [2]. Differentiation refers to the number of varied elements, e.g. tasks or components; interdependence characterises the interrelatedness between these elements. Regarding organisational complexity, Baccarini identified among other indicators the number of organisational units involved and the division of labour. For technological complexity, the diversity of inputs and output and the number of specialities (e.g. subcontractors) are considered.

Evaluating the complexity of document management in projects again included different criteria, which are connected to questions in the survey: average number of employees in a project, average number of documents

Table 6.2: Cases from the sample with at least two project criteria at least "high".

No of employees	No of pages per doc	No of documents	No of cases
very high	very high	high	1
high			1
		medium	1
		low	1

per project, and average number of pages per documents. The first two criteria directly relate to Baccarini's work; the last one was added in order to represent document complexity. The survey questions again offered five different choices, which were mapped on a scale from "very low" to "very high". Figure 6.6 visualises the distribution of the answers.

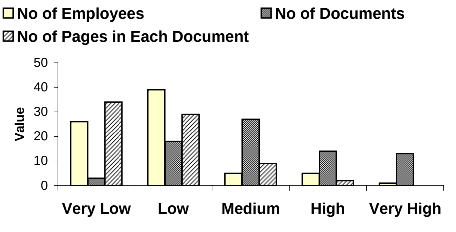

Figure 6.6: Distribution of project complexity-related criteria.

Considering the correlation between the three criteria, 4 cases with at least two criteria receiving at least "high" were identified, shown in table 6.2. In terms of complexity, only these 4 cases are considered complex enough to seriously investigate whether advanced project document solutions could improve information supply and reduce information overload. Comparing this figure with the situation in product complexity (conjecture 3), the significance of a need for supporting project document management is quite low.

6.3 All Enterprises

This section contains a comparison between the whole sample (all enterprises) and the small and medium-sized enterprises. The main objective of this section is to depict whether there are any differences between these two groups of enterprises. Another objective is to discuss some of the questions that have not been addressed in the previous sections, such as personal knowledge and free text answers.

When looking at the first four questions that regarded the enterprise as such, the respondents among SME were more often owner/CEO or manager of some kind (38% compared to 28% when including all enterprises (i.e. both SME and larger enterprises)). Regarding the sectors, the amount of engineering industrial enterprises are slightly larger within the SME sample, of course the public sector is smaller, and also the group Other technical enterprises is slightly larger within SME.

When looking at where the information is normally found, among all enterprises it was more common to use intranets and document management systems, when comparing to SME. This is not very surprising, since the larger enterprises are more likely to have invested in this kind of solutions. Also, the intranet/DMS solutions were more used. However, it was not more common to use joint file servers, and actually more common to use personal computers at all enterprises compared to SME. It was also more common to use other alternatives, such as colleagues or other type of literature. There were also more complaints or problems with the existing intranet/DMS solutions among all enterprises, especially concerning the search function and the fact that it gives either too many or too few hits, or irrelevant hits.

The information flow is seen as slightly more adequate among all enterprises.

The projects among all enterprises have slightly more members than among SME. The time frame is also somewhat longer. Following from this, the number of documents in each project is also larger, however the number of pages in each document is not greater. The document structure is quite similar (when comparing all enterprises and SME) and the same is true concerning the content in the documents.

When looking at the product management questions, the first mentionable difference between all enterprises and SME can be found when looking at the number of suppliers that contributes to each product. This number is larger among all enterprises than among SME. Reuse is also more common among all enterprises than among SME. Besides this, there are not many apparent differences that can be directly distinguished from the existing material.

There are lots of undocumented personal knowledge around, as 64% of the respondents state. It is quite interesting that 82% of the respondents think that it is possible to document this knowledge, even though 55% think that it will be hard. Only 18% state that they do not think that it is possible to document it. This would be an interesting question for future research.

To summarise the section including all enterprises, the same problems seem to occur within large enterprises as within SME.

Chapter 7

Conclusions

In this section the main conclusions will be discussed in conjunction with the research questions presented in section 1.2.

The main research question: *What comprises an ontology development methodology suitable for use in small and medium-sized enterprises?* was divided into several smaller research questions, the first one:

What are the requirements on an ontology development methodology for use in small and medium-sized enterprises?

As presented in section 4.1 several criteria for an ontology development methodology with specific use in small and medium-sized enterprises have been discussed. The methodology should be defined in full detail, easy to follow, and not make any claims about the environment. There should be detailed guidelines on how to carry out the different phases of the ontology development, including templates for important results or best practises. This was also learnt from in the experiments with SEMCO (as presented in section 4.3). The more detailed the instructions can be, the easier it will be for the ontology developers to construct the ontology.

The methodology should also cover the whole life cycle of the ontology, from planning to implementation and evaluation. This is required in order to be able to estimate the total costs of the project, and also it will be easier to supervise the project in order to reduce project risks.

In order to further reduce development time and effort the methodology should consider reuse of already existing ontologies as early as possible in the development process.

Following the SEMCO project was the idea that the ontology development methodology could be further specialised, for example depending on the ontology type, usage area, or domain. This then violates a previous statement, that the ontology should make no claims about the environment. However, it seems hard to give enough detailed instructions in the development, unless for example the usage area or domain of the ontology is clear.

This leads us into the next research question: *Which application fields for ontology usage are relevant for small and medium-sized enterprises?* The ontology development methodology should be further specialised, but which are the application fields of interest for small and medium-sized enterprises in the region?

The main conclusion from the survey, as presented in section 6.1, is that SME need ontologies mainly in the area of product configuration and variability modelling. Another area of interest is document management for supporting project work, which in turn can be seen as a sub-area of information search and retrieval with specific focus on project support. The information search and retrieval area can also be seen as a possible application field, as many of the respondents spend lots of time finding and saving information, and perceive that the information flow is too much to handle without further support.

The final research question was: *What short-comings - if any - do the existing ontology development methodologies have for use in small and medium-sized enterprises?*

As presented in section 2.2 the existing ontology development methodologies have their strengths and weaknesses. The evaluations concluded that none of the existing methodologies fully fulfils the requirements on an ontology development methodology for small and medium-sized enterprises. Therefore a new methodology has been proposed, as seen in section 4.2, in which the drawbacks of the existing methodologies have been avoided, focusing on using the strengths of each of the methods.

The proposed methodology consists of four different phases. In the first phase, the requirements analysis all formalities for the ontology should be specified, such as intended users, purpose, scope, etc. When all the prerequisites are documented it is time to start building the ontology in the building phase. This is proposed to be done in an iterative manner with a middle-out approach. In the implementation phase the ontology is implemented into a suitable ontology tool. The last phase is the evaluation and maintenance phase in which the ontology is evaluated against the prerequisites defined in the requirements analysis, and also to some other criteria such as clarity, consistency, and reusability.

After testing the methodology in the SEMCO project some further adjustments were proposed, such as using a larger set of knowledge acquisition methods to elicit information, and a more detailed evaluation phase, all in order to deduce the work and ontology knowledge needed by the ontology developer.

Coming back to the main research question, a final answer has not been concluded, but preliminary results show that there is reason to believe that the structure of the methodology proposed in section 4.2 holds, based on experiences from SEMCO. Furthermore the conclusion has been drawn that specialisation is needed, for example within a specific domain, in order to make the ontology development methodology detailed enough. The empirical investigation gave suggestions on at least two such domains for which the methodology could be specialised, namely product configuration and information search and retrieval.

Chapter 8

Future Research

When looking back at the research questions, the main research question has not been fully answered in this thesis, which leads to some further research that can be done.

What comprises an ontology development methodology suitable for use in small and medium-sized enterprises?

What still remains is to further develop the methodology for the specific uses in the cases described in the conclusions, i.e. product configurations, information search and retrieval, and document management. Of course it would also be beneficial to try these methodologies in each of the cases. Regarding how the methodology should be further developed, there are at this point no clear ideas, it might be possible to somehow use patterns, so that for a given scenario in a certain use case the ontology developer uses a number of patterns as a base for the ontology, and then continues with the more specific, case-dependent terms and concepts.

It would also be beneficial to try the methodology as it is now in more cases, and further develop it, depending on the outcome of the cases.

Another way could be to look back at the survey and see where it would be possible to improve. The size of the sample and the response rate is one thing that could be improved, the big question is how? The geographically limited area of southern Sweden is quite easy to solve, simply by expanding the survey to the rest of Sweden or whatever is desirable. The size of the sample could also be easily solved, simply by sending the survey to a larger set of companies. The question is to which companies? Do we want all SME? Or do we want ”high-tech” companies? Maybe it is not so interesting to know if the hairdressing salon at the corner has problems with information (most likely they will not), but how to restrict the companies in some way, without missing the interesting enterprises. It seems quite hard to define the population as such, when not all of the small and medium-sized enterprises seem interesting or relevant, but on the other hand, what defines a "high-tech" company, and how are these found? If it is somehow possible to define the population, the sample should be made in some random way, and then try to encourage the persons who has received the questionnaire to answer it in some way. One way could be to have follow-up phone interviews, further encouraging the respondents to send in their answers, or maybe make it into a lottery, so that a number of respondents win something.

If another survey would be of interest it would also be desirable to look at the questionnaire again and improve it. There were some questions that were misunderstood, or possible to misunderstand in the survey, these would of course be corrected in the preparation of the next survey. Also, it might be interesting to get further details on which solutions, apart from intranets and document management systems, that exist in enterprises and how these can be further developed, if needed.

Another way to proceed would be to make case studies at some of the enterprises, and make more detailed interviews of the problems, solutions, and issues for each of the enterprises. The problem, as always with qualitative studies, would then be that the results might not be generalisable in a larger context.

The survey shows that there are lots of personal knowledge that is not documented, but most of the respondents seem to think that it could be documented. This could also be a subject of further research, to see whether this really is a problem when, for example, an employee leaves his or her employment at an enterprise and the knowledge is lost.

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Titel
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Towards an Ontology Development Methodology for Small and Medium-sized Enterprises

Författare
Author

Annika Öhgren

Sammanfattning
Abstract

This thesis contributes to the research field information logistics. Information logistics aims at improving information flow and at reducing information overload by providing the right information, in the right context, at the right time, at the right place through the right channel.
Ontologies are expected to contribute to reduced information overload and solving information supply problems. An ontology is created to form some kind of shared understanding for the involved stakeholders in the domain at hand. By using this semantic structure you can further build applications that use the ontology and support the employee by providing only the most important information for this person.
During the last years, there has been an increasing number of successful cases in which industrial applications successfully use ontologies. Most of these cases however, stem from large enterprises or IT-intensive small or medium-sized enterprises (SME). The current ontology development methodologies are not tailored for SME and their specific demands and preferences, such as that SME prefer mature technologies, and show a clear preference for to a large extent standardised solutions. The author proposes a new ontology development methodology, taking the specific characteristics of SME into consideration. This methodology was tested in an application case, which resulted in a number of concrete improvement ideas, but also the conclusion that further specialisation of the methodology was needed, for example for a specific usage area or domain. In order to find out in which direction to specify the methodology a survey was performed among SME in the region of Jönköping.
The main conclusion from the survey is that ontologies can be expected to be useful for SME mainly in the area of product configuration and variability modelling. Another area of interest is document management for supporting project work. The area of information search and retrieval can also be seen as a possible application field, as many of the respondents of the survey spend much time finding and saving information.

Nyckelord
Ontology Development, Ontology Engineering, Small and Medium-sized Enterprises, Survey

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