INSTITUT NATIONAL POLYTECHNIQUE DE GRENOBLE

T H E S E

pour obtenir le grade de

DOCTEUR DE L'INPG

Spécialité : «Génie Industriel»

préparée au laboratoire GILCO (Gestion Industrielle Logistique et Conception)
dans le cadre de **l'Ecole Doctorale «Organisation Industrielle et Systèmes de Production»**

présentée et soutenue publiquement

par

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le 14/11/2003

Knowledge Management for an Industrial Research Center – case study EADS

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ACKNOWLEDGEMENTS

This document is the result of a three years research project. Many people supported this project and me and made the successful completion of it possible.

First of all, I would like to express my gratitude to the members of the dissertation committee of having accepted to evaluate this research work:

- I would like to express my sincere thanks to Prof. Dr. Rose DIENG, research director at INRIA Sophia Antipolis in France of having accepted to preside the dissertation committee.
- I would like to express my gratitude to Prof. Dr. Alain BERNARD, Director of the Industrial Engineering – IRCCyN UMR CNRS 6597 – at the Ecole Centrale de Nantes, of having accepted to review this work and being part of the dissertation committee.
- I would like to express my special thanks to Prof. Dr. François VERNADAT, Director of LGIPM and head of the MACSI project – INRIA LGIPM EA 3096 – UFR MIM – ENIM/Univeristy of Metz, of having accepted to review this work and being part of the dissertation committee.
- I would like to express my sincere thanks to Prof. Dr. Horst SCHMIDT-BISCHOFFSHAUSEN, Faculty of the Economic Sciences and Information Technology at the University Carinthia in Klagenfurt, Austria, who was not only willing to examine this work as reviewer and to being part of my dissertation committee, but who previously gave very valuable and stimulating feedback on my works.
- I would like to express my gratitude to Dr. Stefan RUEGER, lecturer searcher at the Imperial College of London in the United Kingdom of having accepted to review this work and being part of the dissertation committee.

I would like to express my special thanks to Prof. Dr. Michel TOLLENAERE (Professor at the Institut National Polytechnique de Grenoble and member of the GILCO laboratory) of having accepted to be my advisor and director. I would like to thank him for his strong support and advises during the time of these three years. He was always very open to new ideas and encouraged me to go further on my research work.

I would like to express my very special gratitude to Dr. Mickaël GARDONI (Assistant Professor at the Institut National Polytechnique de Grenoble and member of the GILCO laboratory) of having accepted to be my co-advisor and co-director. His full commitment and goal-oriented management allowed freedom in my research and, at the same time, gave me strong support for the development of new ideas. His trust in my abilities greatly enhanced my performance in the projects we were working in. I would like to thank him for his strong support during the development of the tool application and for the supervision of the graduate students who developed the tool application.

I would like to thank Prof. Dr. Yannick FREIN (Professor at the Institut National Plytechnique de Grenoble and director of the GILCO laboratory) of having accepted me in his team and of supporting me in my research project.

I would like to express my very special thanks to Richard LEBLOND (Responsible for Knowledge Management at the EADS Corporate Research Center in Suresnes, France) of having accepted to be my industrial advisor for this research work. His suggestions and recommendations were always of great value for the progress of the research work. In many meetings and intensive discussions he gave me valuable feedback and supported me in new ideas. I also would like to thank him for his participation at the dissertation committee.

I would like to express my very special gratitude to Christian TRINQUIER (Head of service Knowledge Engineering at the EADS Corporate Research Center in Suresnes) of having me accepted in his team and of supporting me strongly in the development of the methodological and technical project results. His feedback was of great value to me and gave new orientations to the research work.

I would like to express my very special gratitude to Dr. Michel DUREIGNE (Scientific advisor of the Engineering and Information Technologies Department at the EADS corporate Research Center in Suresnes) for his intensive support and intensive collaboration. In long discussions, we worked on conceptual frameworks which gave a strong conceptual backbone to this work. I would also to thank him for his participation at the dissertation committee.

I also would like to thank Bernard BOIME (Head of the Engineering and Information Technologies Department at the EADS corporate Research Center in Suresnes) for giving me the possibility to conduct this research project in his department and for his support of making this work an European project.

I also would like to thank Dr. Hans LOBENTANZER (Head of Advanced Concepts and Systems Engineering department in Ottobrunn) for giving me the possibility to realize part of the research work in his department and for the support he gave to make the exchange between the research centers to a success.

Furthermore, I would like to express my gratitude to Axel MAURITZ (Manager of the service Systems Engineering at the EADS Corporate Research Center in Ottobrunn, Germany) for his support and collaboration during my stay at the research center in Germany.

Furthermore, I would like to thank all my colleagues at the GILCO laboratory, at the Engineering and Information Technologies Department at the research center in Suresnes and the Advanced Concepts and Systems Engineering Department at the research center in Ottobrunn, for their support, their patience, their encouraging cooperation and for providing me a very fruitful and stimulating working atmosphere – even after work.

Particularly, I would like to thank Hendrik BUSCH, Magnus HANSLIEN and Youssef MATROUF who made the development of the A.N.I.T.A. tool possible.

Many other people were involved in the realization of this project. I would like to express my gratitude to all these people for their support. Furthermore, the order of the acknowledgements does not reflect any importance.

My parents, Gisela and Armin, and my brother, Clemens, receive my deepest gratitude for the many years of support and especially for always believing in me. Last, but not least, I thank my partner, Carine, for her understanding and never ending support that strongly encouraged me and, in the end, made this thesis possible.

Paris, September 2003

Christian Frank

“All men by nature desire knowledge.”

-*Aristotle*

THE CONTEXT OF THE STUDY

Today, people argue that we are living in a knowledge oriented society (Amidon, 1996). Knowledge is the new asset that industrial organizations have to manage in an effective way in order to stay competitive.

Industrial research centers being part of industrial organizations have to manage various knowledge and information flows. One objective of the researchers is to optimize these flows in order to produce research results with the highest possible quality, with estimated risks and the lowest possible costs.

Indeed, Miller (Miller and Morris, 1999) talks in his fourth generation R&D framework already about "knowledge channels" of distribution and the need to raise the productivity of the "knowledge worker". All participants in an innovation system should be self-motivating, responsible for creating new knowledge as a way of adding value to the corporation and the customers. In this case, managers will monitor a "knowledge flow". Information technology, with sophisticated computer communications systems, should embody knowledge processing capabilities that learn feed forward intelligence to all participants to the R&D activities.

The fact that the industrial researcher is embedded in intensive collaboration networks increases the mass of accessible information and knowledge he has to manage for his activities. As the different networks have also different objectives, the different information and knowledge have different use context.

To this, he has to add the new information and communication means, described here as intelligent knowledge processors, which enable the networking but which also increase the available information. New technologies like the internet or electronic mail systems provide the industrial researcher with supplementary information. All this information coming from these various sources need to be managed in order that the industrial researcher becomes a "self managing knowledge worker".

In order to manage the different information and knowledge flows, the concepts of knowledge management seem to provide appropriate elements. Although we can observe a great variety of knowledge management initiatives in industrial organizations, these initiatives usually do not take into account industrial research centers.

Indeed, there is very little research work concerning the organization of industrial research and the functioning of an industrial research center from a knowledge perspective. There is no work providing structural elements for research activities from a knowledge perspective. However, these structural elements are necessary in order to provide a correct support with knowledge management concepts, methods and technologies.

Therefore, we analyze in this thesis the different concepts of industrial research and verify them with use cases. We propose to merge these concepts with different concepts of knowledge management in order to provide a general knowledge management oriented framework architecture. This architecture allows structuring and analyzing the actual used tool support and the needs of the researchers. This analysis showed that there is a missing support for the management of written information content.

CONTRIBUTIONS

Based on the different concepts for industrial research, the concepts for knowledge management and the analysis of the different practices in the field study we proposed a general knowledge management oriented framework architecture for industrial research activities in an industrial research center. Based on a part of the CIMOSA enterprise model we proposed a framework architecture which consists of three layers:

- The general objective oriented research process framework as the basis layer. This process model structures the research activities in three research process phases: investigate, focus and deploy.
- The general activity management framework. This framework structures the different knowledge and information relevant activities in the different research process phases. The activities are: identify, acquire, structure, combine, share, distribute, use and preserve. These activities are based on the knowledge manipulation activities from different knowledge management models. Therefore, this second layer links the industrial research activities with a knowledge management approach.
- The resource element content knowledge typology and research activity content structure framework. For this framework, we elaborated a shared ontology for industrial research activities. The resource element content knowledge typology represents an ontology for the information content of information coming from various resources and needed to produce new research results. We characterize this ontology with the concept of aboutness from information retrieval concepts. The research activity content structure represents an ontology to structure information content according to research objectives. We characterize the ontology with the concept of relevance from information retrieval concepts.

This three-layer framework architecture allowed us to analyze the existing tool structure used by the researchers and to structure the different needs and requirements for a better information and knowledge management support.

Based on the requirements we proposed a tool which we named A.N.I.T.A. (ANnotation tool for Industrial TeAms), for a better management and exploitation of written information content in teams of industrial researchers.

Indeed, researchers need further support to exploit written information content to produce new research results in a more effective way and with higher quality. Common operational tool applications usually limit their content exploitation with a management of documents.

With the A.N.I.T.A. tool, we proposed to structure and exploit document zones of documents in various formats. In order to support the identify, structure, combine, share, use, and preserve activity of the industrial research framework architecture, we propose three modules:

- An attribution of points of views and annotation module where the user has the possibility to structure and combine document zones and documents (therefore information content) according to the concepts of aboutness and relevance and with additional annotations.
- A dynamic retrieval and visualization module where the user has the possibility to re-access and analyze structured information content in a dynamic way.
- An assembling module where the researcher has the possibility to assemble existing information content to new research results.

The A.N.I.T.A. tool corresponds to the needs and requirements of the researchers and to the framework architecture for industrial research.

In conclusion, we proposed in this thesis a global knowledge management oriented framework architecture for industrial research activities. This framework architecture structured the practices, needs and requirements of the industrial researchers and helped to define a tool proposition for a better management and exploitation of written information content.

READING PLAN

In the first chapter, we study and analyze the concepts of knowledge and knowledge management for the context of industrial organizations. A distinction between the notions of data, information, knowledge as well as a clarification between the concepts of tacit and explicit knowledge leads us to a definition of knowledge for our study.

For the managing of knowledge, we have a closer look on different knowledge management models. Here we focus on knowledge manipulation activities as one possibility to approach the problem of knowledge management. With this conceptual basis for knowledge and knowledge management we orient our discussion towards practical applications.

As our study takes place in a multicultural environment, we have a closer look on cultural influences on knowledge management. This leads us to a description of some typical characteristics of knowledge management practices in general and to possible technology support.

Knowledge management technology support deals largely with information in various formats. Many tool applications deal with written information. Their objective is to support a better management and exploitation of written information content. Therefore, we will have a closer look on different concepts which allow to characterize and handle document content and written information content in general.

In order to introduce knowledge management in an industrial organization, the literature proposes several systematic processes. We describe one process which will also guide to certain extent our introduction for a knowledge management framework for an industrial research center.

Industrial research activities deal with intensive information and knowledge flows. The industrial researchers use existing information and knowledge in order to produce new research products. However, the new research products consist in fact of new knowledge: new conceptual models, validation knowledge and implementation knowledge.

Therefore, in chapter two we discuss the relevant aspects of industrial research in the context of an industrial research center. From a literature review, we propose a definition of industrial research. In order to clarify the structure of an industrial research center we discuss its customer, product, process, organizational and information and knowledge resource structure.

In our field study, we analyze the different activities and practices of the researchers. Furthermore, we have a closer look on the existing tool support and especially the handling of written information content. This analysis confirms that the exploitation of written information content plays a significant role for industrial research activities. We describe the results in chapter three. The analysis leads us to the description of the needs.

On a first more global level, we describe the needs with the help of a functional analysis. Based on this analysis we investigate the needs for a better handling and exploitation of written information content. We structure the investigation according to the knowledge management activities coming from the knowledge management models.

Based on the analysis of the knowledge management and industrial research literature and based on the structure of the research activities and the needs we propose in chapter four a general knowledge management framework for an industrial research center.

With part of the CIMOSA model we will propose a three-layer framework. The first layer constitutes a general objective oriented research process framework. The second layer constitutes a general activity management framework. The third layer constitutes the resource element content and research activity content structure framework which represents in fact a shared ontology.

This framework constitutes a central element of our work. It allows analyzing existing activities and tools in an industrial research context. This analysis shows that the actual operational tools are not able to support a performing management and exploitation of written information content. Moreover, we use this framework to structure the identified needs and the functions of the functional analysis in order to identify potential functions for a new prototype.

As there is the need for further development, we propose a prototype specification and realization in chapter five. We develop the A.N.I.T.A. tool which we realize in two main modules. The first module allows the structuring of written information content with points of views and the attribution of additional argumentations via annotations. The points of views are based on the shared ontology developed in chapter four.

A retrieval and visualization module gives the user access to written information content and allows the visualization according to the structure of the points of views. In order to handle written information content the A.N.I.T.A. tool works with documents and document zones. An experimentation of the A.N.I.T.A. tool with researcher gives some user feedback concerning the different modules but also concerning the general framework for industrial research.

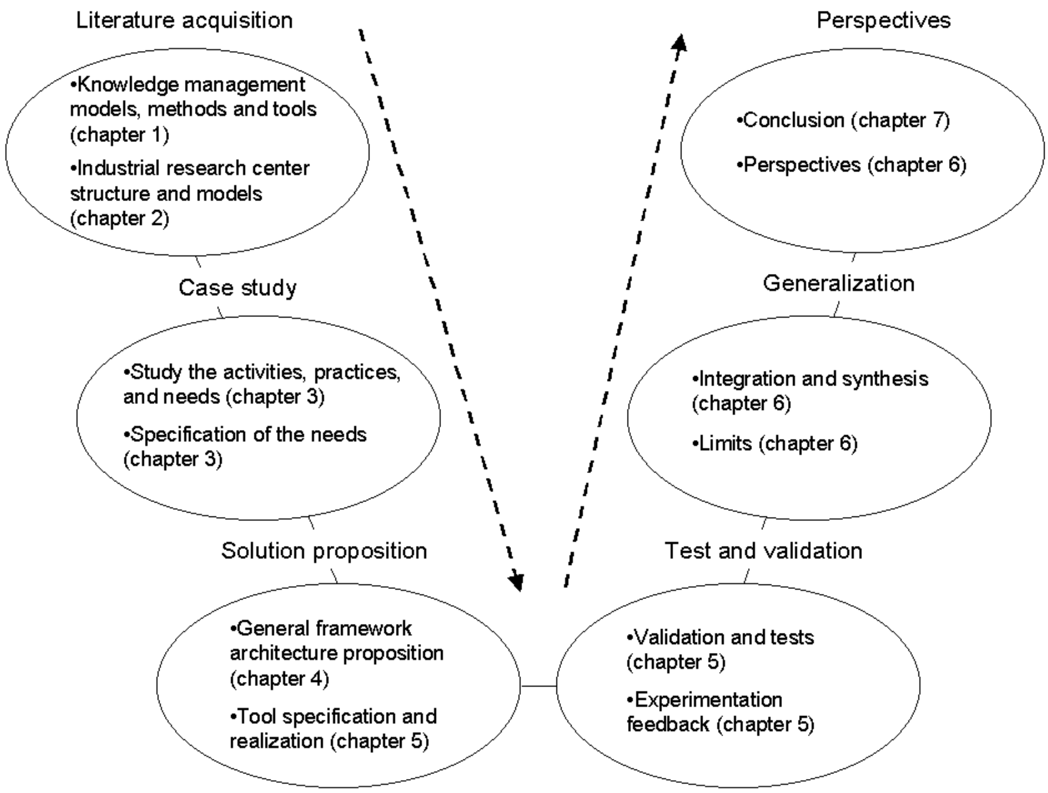
Chapter six synthesizes the results and discusses the results for a possible generalization for other industrial activities. We will discuss the cultural aspects of our study in order to compare our experiences to the literature. In perspectives, we discuss possible extensions of the general framework as well as of the A.N.I.T.A. tool proposition.

A general conclusion completes this work.

The following figure gives a synthetic overview of the different chapters. The V – structure of the figure represents the structure of this thesis document. On the left side we start with a literature acquisition in order to deepen the identified concepts with a real case study.

Based on the results of the literature review and the case study we make a solution proposition. This solution consists of new concepts, models and a tool realization.

The beginning of the right side consists of the test and experimentation of the new concepts and prototype. The tests show the limits and allow making conclusion for a generalization of the concepts. Perspectives give further research directions for future projects.



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ABSTRACT IN FRENCH

INTRODUCTION

Le partage des connaissances constitue une perspective stratégique au sein des entreprises (Grundstein, 2000). Si les connaissances ne sont pas maîtrisées, elles constituent un élément de fragilité. En effet, si elles sont peu partagées, elles sont en conséquence peu réutilisées. Par contre, si elles sont réutilisées, elles deviennent une source d'amélioration de la qualité des activités d'une entreprise et de ces produits (Prax, 2000). Le rôle d'un centre de recherche industrielle est de fournir de nouvelles connaissances à des clients opérationnels, en répondant rapidement aux problématiques posées et en effectuant une surveillance élargie des connaissances existantes à l'extérieur de l'entreprise (Frank et Gardoni, 2002b). Pour ce faire, le centre de recherche doit gérer des flux de connaissances et d'informations variées. Dans ce cadre, le chercheur en tant qu'individu et en tant qu'acteur dans une équipe de recherche a besoin de support pour une meilleure gestion des informations et connaissances disponibles (Frank et Gardoni, 2002c).

Dans ce travail de thèse au sein de deux centres de recherche du groupe EADS, nous proposons une analyse des activités de recherche industrielle et un cadre pour une gestion des connaissances pour un centre de recherche industrielle. Dans ce cadre, nous proposons l'outil A.N.I.T.A. (ANnotation tool for Industrial TeAms) pour une meilleure gestion et exploitation des contenus d'informations écrites au sein des équipes de recherche basé sur une ontologie partagée pour le domaine de la recherche industrielle, développée dans le cadre de cette thèse.

I GESTION DES CONNAISSANCES DANS UN CONTEXTE INDUSTRIEL

Un objectif des organisations industrielles est d'optimiser leurs processus et l'utilisation de leurs ressources. Selon plusieurs auteurs, la gestion des connaissances peut supporter cette optimisation en favorisant une amélioration des flux de connaissances et des processus de production de connaissances (Sveiby, 1997), (Grundstein, 2000), (Wiig, 1993). Nous décrivons ci-après certains des concepts et modèles de la gestion des connaissances supportant d'ores et déjà des technologies et des méthodes.

I.1 DES CONCEPTS POUR LA NOTION CONNAISSANCE

Il existe plusieurs définitions pour la notion de connaissance (Wiig, 1993), (Nonaka and Takeuchi, 1995), (Turban, 1992), (Davenport and Prusak, 1998). En synthétisant les différentes définitions, nous définissons la notion de connaissance comme suit : « la connaissance est le résultat d'une expérience et d'une réflexion basée sur un ensemble de croyances et résidant dans des objets fictifs dans le cerveau des personnes. »

Il existe un lien direct entre la connaissance et l'information : l'information interprétée par un être humain peut devenir connaissance (Beckman, 1997). Selon Terra et Angeloni (Terra et Angeloni, 2003), la différence entre la connaissance et l'information dépend du rôle joué par l'être humain. Dans le cas de la connaissance, les individus réalisent les fonctions de porteurs, créateurs, et utilisateurs. Dans le cas de l'information, ces mêmes fonctions peuvent exister « en dehors » des humains et sans leur influence directe. En effet, les informations peuvent être identifiées, organisées et distribuées avec des supports technologiques.

Dans ce contexte, certains auteurs font également la différence entre les connaissances tacites et les connaissances explicites (Nonaka et Takeuchi, 1995), (Barthes, 2000), (Kinghorn and Maasdorp, 1999). Dans le cadre de ces travaux, nous n'allons pas tenir compte de cette différence. Car selon notre définition, les connaissances son liées à l'esprit et le cerveau des personnes, elles sont donc par conséquence tacites. Donc, si elles sont explicites, nous les considérons comme étant des informations.

Pour créer de nouvelles connaissances, il faudrait soit gérer des personnes afin d'atteindre une meilleure communication, soit gérer des informations afin de permettre une meilleure exploitation de leur contenu. Dans ce cadre, des modèles de gestion des connaissances décrits ci-dessous proposent des activités de manipulation des connaissances et des informations.

I.2 DES MODELES DE GESTION DES CONNAISSANCES

La gestion des connaissances est liée à des activités qui ont été définies (voir appendix A.1 pour la description des modèles en détail) et en particulier dans les modèles de Rohmardt (Romhardt, 1998) et APQC (Arthur Andersen and APQC, 1996). Dans ce contexte, nous retenons comme principales les activités suivantes : identifier, acquérir, structurer, combiner, partager, distribuer, utiliser, préserver et évaluer (voir Tableau I.1).

Tableau I.1 - Description des activités de manipulation des connaissances

Activités de manipulation de connaissances	Description (avec quelques exemples d'illustrations)
Identifier	Identifier des informations de différentes ressources internes et externes. Ceci peut se traduire par des visites de conférences, etc.
Acquérir	Acquérir de nouvelles connaissances en intégrant des experts dans l'organisation industrielle.
Structurer	Structurer des connaissances en structurant des experts dans des groupes travaillant en synergie. La structuration peut aussi inclure la structuration des informations dans les bases de données.
Combiner	Combiner des connaissances dans les groupes de travail ou dans les projets partagés. Elaboration de nouveaux documents basés sur des informations existantes et combinées avec de nouvelles connaissances.
Partager	Partage des connaissances dans des communautés de pratiques lors des présentations. Partage aussi des informations dans des espaces de travail communs.
Distribuer	Distribuer concerne plus la distribution des objets d'informations. L'objectif est la distribution des « bonnes » informations aux « bonnes » personnes au « bon » moment, avec le « bon » niveau de synthèse.
Utiliser	Utiliser des informations pour une nouvelle combinaison dans des documents, etc.
Préserver	Préserver peut concerner l'enregistrement des informations sous différentes formes.
Evaluer	L'évaluation est liée à la prise de décision et peut se baser sur les informations disponibles et la maturité de connaissances des personnes.

Dans le chapitre suivant, nous allons discuter des différentes technologies et outils qui peuvent soutenir les activités de manipulation des informations et connaissances.

I.3 ASPECTS TECHNOLOGIQUES POUR LA GESTION DES CONNAISSANCES

Tiwana, (Tiwana, 2002) propose une liste de technologies et outils qui peuvent jouer un rôle important dans la construction d'une plate-forme d'outils de gestion des connaissances. Ces différentes technologies et outils peuvent supporter les différentes activités de manipulation des informations et connaissances décrites dans le Tableau I.1 (voir chapitre I.2 du résumé en français) :

- Intranet, pour un support à la distribution, la création de liens entre les personnes, et les publications des informations.
- Groupware, pour un support à la collaboration asynchrone et le partage des informations.
- Web / Video conférences pour un support aux dialogues et échanges d'images.
- Business intelligence pour un support à l'identification et à la capture de nouvelles informations externes.

- Data Warehousing avec les technologies de data mining et text mining pour un support à l'identification et à l'accès aux informations.
- Des pointeurs d'expertise pour un support à l'identification des experts.
- Des systèmes experts pour un support à la combinaison des connaissances et à la résolution de problèmes.
- Gestion des documents pour un support à l'organisation des documents.
- Gestion du contenu pour un support à la création et à l'exploitation du contenu des documents.

Nous pouvons constater que la plupart de ces différentes technologies gère des informations écrites dans des documents avec des formats variés. Un des objectifs de ces outils est de supporter la gestion, le partage et l'exploitation des informations pour favoriser un environnement de création de nouvelles connaissances. Selon Feldman (Feldman, 1998), 80% des connaissances explicites d'une entreprise se trouvent dans des documents textuels. Ceci montre l'importance d'une gestion et exploitation optimale des contenus d'informations écrites pour favoriser la création de nouvelles connaissances.

I.4 L'EXPLOITATION DU CONTENU DES INFORMATIONS ECRITES COMME UNE BASE POUR LA GESTION DES CONNAISSANCES – DES CONCEPTS ET TECHNOLOGIES SPECIFIQUES

Avec les nouvelles technologies, le nombre des informations sous forme d'informations écrites accessibles augmente rapidement. De ceci découlent différents problèmes : les personnes enregistrent leurs documents dans des structures inaccessibles ou incompréhensibles par d'autres personnes, les personnes interprètent le contenu dans des contextes différents et utilisent des informations identiques pour des objectifs différents ce qui peut créer une terminologie similaire pour des contenus différents, les personnes ne partagent pas des contenus de document à cause de contextes et de terminologies différents, etc.

Une meilleure exploitation du contenu passe par une meilleure structuration de ceux-ci. Une possibilité pour structurer le contenu est l'utilisation des concepts « of aboutness » et « of relevance » (Maron, 1977), (Froehlich, 1994), (Barry, 1998), (Tang, 1999). Le concept « of aboutness » caractérise de quoi parle une information. Le concept « of relevance » caractérise pourquoi une information représente un intérêt. En parallèle de ces deux concepts, un troisième peut permettre de donner des éléments d'interprétation supplémentaires à des contenus : les annotations. Le concept d'annotations, venant principalement du Web sémantique, permet d'ajouter des méta-données ou des informations sous forme de texte libre à des contenus existants (Kahan et al. 2001). Une annotation peut être une donnée informative jugée utile, des connaissances élémentaires interprétées, une trace de raisonnement ou une unité de sens qui peut être réutilisée et partagée (Montmain, 2001). Techniquement, les annotations sont surtout utilisées dans les technologies Web. En se basant sur le langage RDF et XML, il est ainsi possible de faire des annotations sur des parties de pages Web.

Afin de pouvoir mieux exploiter le contenu, surtout dans le contexte d'une équipe, il est utile de créer des cadres descriptifs de référence. Ceux-ci peuvent supporter la structuration des contenus et une interprétation commune. Une des possibilités pour construire un cadre descriptif de référence est d'utiliser le concept d'ontologie.

Une ontologie est une spécification explicite et formelle d'une conceptualisation partagée d'un domaine d'intérêt (Sure, 2003). Elle intègre les définitions qui donnent un vocabulaire conceptuel. Ceci permet de définir (a) les concepts utilisables pour décrire des connaissances, (b) les relations entre les concepts et (c) leurs contraintes d'utilisation (Dieng et al., 2000).

Selon cette définition, une ontologie peut aider à définir le sens du contenu d'un document. Comme l'ontologie est partagée et formelle, elle peut être utilisée comme un modèle de référence pour le cadre descriptif du contenu de l'information.

En assemblant les quatre concepts discutés dans ce chapitre : l'ontologie, les concepts « of aboutness » et « of relevance » permettant de donner des significations au contenu et les annotations permettant d'étayer ces significations, il est possible de mieux gérer les contenus d'informations écrites

Dans les chapitres suivants, nous allons discuter des spécificités de la recherche industrielle et surtout d'un centre de recherche industrielle : Centre Commun de Recherche de EADS. L'analyse de l'environnement d'un centre de recherche va montrer qu'une application des concepts et technologies de la gestion des connaissances peut supporter les flux de connaissances et d'informations ainsi que la création de nouvelles connaissances sous forme de résultats de recherche. L'analyse de besoins issue du terrain va montrer qu'un support supplémentaire d'exploitation du contenu d'informations écrites est nécessaire.

II LA RECHERCHE INDUSTRIELLE DANS LE CONTEXTE D'UN CENTRE DE RECHERCHE INDUSTRIELLE

Les centres de recherche industrielle intégrés dans un groupe industriel peuvent être considérés comme des moyens permettant de contrôler les développements de l'innovation et les évolutions des bases techniques de l'entreprise (Le Masson, 2001). L'exigence des industriels et des dirigeants d'entreprise est de contrôler non seulement les technologies existantes mais aussi l'émergence des nouvelles technologies conduisant à la maîtrise d'un flux d'innovation.

II.1 DEFINITIONS

Un centre de recherche industrielle se situe entre un système de fournisseurs d'informations externes (ex. fournisseurs de technologies, laboratoires académiques, etc.), et un système opérationnel du groupe (les unités opérationnelles comme le bureau d'étude, les usines d'assemblage, etc.). Le rôle de la recherche industrielle est d'expérimenter, de valider de nouvelles méthodes et technologies et de les combiner afin de proposer de nouvelles possibilités de solutions utilisables par le système opérationnel (Frank et Gardoni, 2003d).

Dans ce contexte et basé sur le Manuel de Frascati (OECD, 1993), nous proposons la définition suivante pour la recherche industrielle : « la recherche industrielle est une activité systématique, basée sur des connaissances existantes issues de la recherche fondamentale, des expériences pratiques et de la technologie existante. Elle est destinée à acquérir et à produire de nouvelles connaissances pour un objectif spécifique et pratique dans un contexte industriel. »

Cette définition décrit indirectement différents flux de connaissances et d'informations : la recherche utilise des connaissances et informations existantes, elle doit donc identifier, structurer et préserver des connaissances et informations, pour produire de nouvelles connaissances sous la forme de résultats de recherche. La production des nouveaux résultats est en fait une utilisation, combinaison, évaluation des connaissances existantes. Comme ces activités représentent en fait les activités de manipulation de connaissances (voir chapitre I.2), il est possible, de supporter des activités de recherche avec des approches de gestion des connaissances.

Afin de comprendre la structure des différents flux d'informations et de connaissances et leurs organisations, nous analysons un centre de recherche avec les points de vues : client et produit de recherche, processus de recherche, organisation des centres de compétences, projets et organisation des ressources.

II.2 LE POINT DE VUE CLIENT ET PRODUIT

Un des rôles majeurs d'un centre de recherche est de proposer de nouvelles solutions aux systèmes opérationnels du groupe, c'est-à-dire les clients du centre de recherche. Les clients fournissent des besoins de recherche et la description des produits et processus existants. Les chercheurs utilisent le terrain des clients pour expérimenter et valider les solutions de recherche. Il existe donc un échange important d'informations et de connaissances entre les unités opérationnelles et le centre de recherche.

Pour les résultats de recherche, on peut également parler de produits de recherche. Les produits de recherche constituent des modèles industriels, des « connaissances opératoires » et des « connaissances d'implémentation » (Figure II.1). (Dureigne, 2002).

Il existe deux aspects pour décrire le produit : un aspect intangible et un aspect tangible. L'aspect intangible concerne l'expertise du chercheur. Les nouvelles connaissances augmentent l'expertise du chercheur. Cette expertise peut être transférée à d'autres personnes via des présentations, discussions, etc. L'aspect tangible concerne des objets concrets comme des rapports, des comptes-rendus mais également des prototypes réalisés pendant les activités de recherche. Le prototype joue deux rôles : le premier rôle est de démontrer que le modèle industriel est valide et qu'il peut être transformé en une application, le deuxième rôle consiste en démontrer que le modèle répond à des besoins.

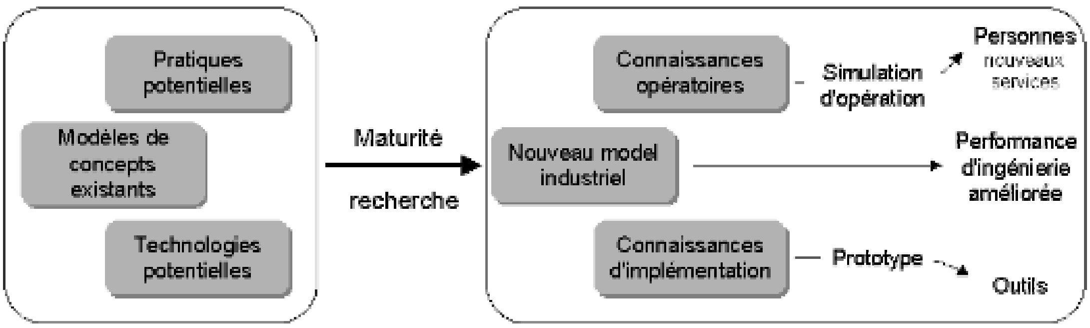

Figure II.1 – Modèle de produit de recherche d'un centre de recherche industrielle

Pour fournir des produits de recherche, les chercheurs conduisent un certain nombre d'activités. Dans le chapitre suivant, nous allons discuter d'un modèle de processus de recherche issu de la littérature.

II.3 LE POINT DE VUE PROCESSUS

Murray distingue trois niveaux pour caractériser le processus de recherche industrielle comme un processus de production de connaissances (Murray, 2001) :

- Selon le contexte, une stratégie peut être de conduire des activités de recherche pour avoir accès à la science des experts externes.
- Un deuxième niveau concerne des activités plus approfondies pour élaborer et acquérir des connaissances détaillées sur un domaine.
- Un troisième niveau concerne l'élaboration de connaissances très détaillées sur plusieurs domaines de telle manière que des experts internes puissent former d'autres experts.

Selon Murray, le processus de recherche peut être caractérisé par trois groupes d'activités : la recherche, l'assemblage et l'appropriation d'informations et de connaissances (Figure II.2).

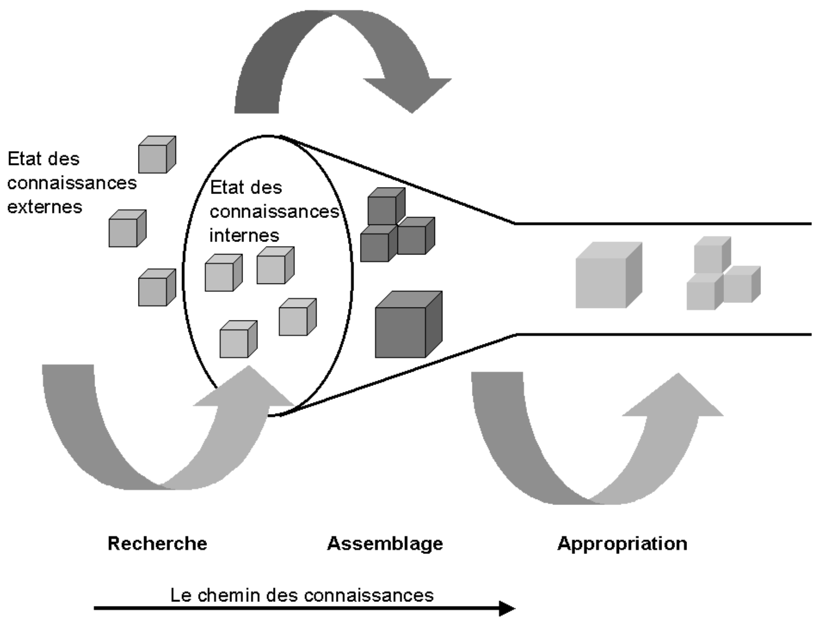

Figure II.2 – Modèle de processus de recherche selon Murray

Toutefois, selon notre recherche, le modèle de Murray représente seulement une partie des aspects d'un processus de recherche. Nous allons proposer un autre modèle de processus dans le chapitre IV.1 du résumé en français.

Selon le modèle ci-dessus, le processus de recherche utilise diverses ressources de connaissances afin de pouvoir assembler de nouveaux résultats. Dans le but de compléter les modèles pour décrire le fonctionnement d'un centre de recherche, nous allons approfondir les

les aspects organisationnels et les ressources décrivant les activités du groupe assemblage du modèle de Murray.

II.4 LE POINT DE VUE ORGANISATION ET ORGANISATION DES RESSOURCES

Différents départements et services élaborent des compétences spécifiques concernant des problèmes spécifiques. Alors les départements et services peuvent être considérés comme des « centres de compétences » (Dureigne, 2003). Ces centres de compétences sont structurés selon des domaines de recherche. Chaque chercheur est affecté à un centre de compétences car généralement il possède une expertise spécifique liée au domaine de recherche.

Les activités de recherche sont structurées en grande partie par des projets de recherche. Les projets ont pour objectif de répondre à une question précise de recherche. Certains projets peuvent impliquer des chercheurs venant de différents centres de compétences. Ceci mène à des équipes multidisciplinaires qui favorisent les échanges d'informations et de connaissances pour résoudre un problème.

Dans la structuration des activités au sein des projets, on peut, comme pour la structuration du processus de production des connaissances selon Murray, distinguer trois niveaux :

- Des projets ayant des objectifs d'acquisition et de pérennisation des connaissances en testant de nouvelles technologies, en faisant de la veille technologique, etc. Le chercheur identifie de nouveaux concepts et évalue leur faisabilité pour de nouveaux problèmes de recherche.
- Des projets qui ont pour objectif de transformer des progrès technologiques et des nouveaux concepts en des moyens opérationnels pour les besoins des unités opérationnelles (spécification des systèmes, développement des prototypes, etc.).
- Des projets dans lesquels les chercheurs interviennent directement et rapidement dans les unités opérationnelles. Les chercheurs donnent ainsi des supports techniques pour implémenter à court terme de nouvelles solutions.

Afin d'identifier des informations et connaissances utiles à la constitution des résultats, les chercheurs utilisent différentes ressources. Il est possible de distinguer trois catégories de ressources :

- L'environnement des unités opérationnelles comme ressource pour des informations concernant des besoins pour des problèmes industriels nouveaux.
- L'environnement externe incluant des fournisseurs de nouvelles technologies, des laboratoires industriels et académiques ou d'autres organisations industrielles externes comme ressources pour de nouveaux concepts, pratiques, technologies et applications.
- L'environnement interne qui concerne les activités de recherche internes au groupe avec des nouveaux concepts, méthodes, etc.

Afin d'avoir accès aux ressources, les chercheurs organisent des réseaux d'échanges d'informations et de connaissances.

Dans le prochain chapitre, nous analysons différentes activités et pratiques au sein des projets de recherche en montrant comment les chercheurs gèrent les flux d'informations et de connaissances. A partir de cette analyse, nous allons décrire et discuter des besoins pour un système de gestion des connaissances.

III ANALYSE DES BESOINS

Nous avons effectué une analyse de terrain au sein de deux centres de recherche du groupe EADS. Nous avons limité nos analyses aux domaines de recherche concernant les technologies d'informations et l'ingénierie des systèmes. Ces domaines de recherche possèdent des cycles de développements de solutions de recherche relativement courts. Ceci nous a permis de pouvoir observer les différentes activités et pratiques pendant plusieurs cycles.

Cette étude est basée sur une analyse des documents (comptes-rendus, rapports, présentations, mails, notes, etc.) de trois grands projets de recherche, des interviews ouverts auprès de dix chercheurs et des présentations des résultats avec retour d'expériences.

Lors de l'analyse, nous avons focalisé notre attention sur les points suivants :

- Les documents et informations utilisés dans les différents projets et en dehors des projets, les moyens d'accéder à de nouvelles informations, le réseau de personnes qui joue un rôle important dans les différentes activités, etc.
- L'interaction entre les personnes qui ont différentes fonctions, l'interaction entre des personnes et des systèmes d'informations, etc.
- Les rôles des différentes personnes dans les projets.

Cette analyse nous a aidé à clarifier et structurer les besoins des chercheurs.

III.1 ANALYSE DES ACTIVITES ET DES PRATIQUES DANS DES PROJETS DE RECHERCHE

Dans les projets de recherche, on peut distinguer quatre étapes : définition des besoins, conception des projets, réalisation des projets et transfert des résultats. Les trois premières étapes sont partiellement formalisées dans des procédures issues de la certification ISO. Ceci implique la constitution systématique d'un cadre documentaire : programmes de recherche, comptes-rendus après chaque réunion officielle, la constitution d'une fourniture de résultats officielle, etc. Les procédures ont une influence sur des pratiques communes et l'utilisation de modèles de document : lorsque les chercheurs utilisent les mêmes procédures, les pratiques concernant les tâches décrites dans les procédures peuvent graduellement se ressembler.

Selon les objectifs des projets, le chercheur définit lors de l'étape de définition des besoins, les besoins avec les unités opérationnelles ou avec les autres chercheurs et managers de recherche. Dans la conception du projet, le chercheur définit le programme du projet. Ceci est validé par la hiérarchie et par les clients.

Dans l'étape réalisation du projet, il est possible de distinguer cinq types d'activités de recherche :

- Constitution des états de l'art et des états de lieux : le chercheur décrit les nouveaux concepts, technologies, outils, etc. et les processus et activités existants.
- Elaboration de nouveaux concepts et modèles : le chercheur prend en compte les éléments identifiés lors des états de l'art pour les adapter aux besoins identifiés.
- Elaboration des nouvelles méthodes.

- Elaboration des prototypes pour supporter les méthodes et pour valider les concepts et modèles.
- Expérimentation et validation du prototype.

Lors de ces différentes activités dans les projets, les chercheurs identifient de nouvelles informations, les adaptent au contexte de recherche et produisent des nouvelles informations sous formes de rapports, présentations, etc. Lors des différentes étapes les chercheurs sont en contacts permanents avec d'autres chercheurs, les clients, des partenaires externes, etc. pour échanger et partager des informations.

L'étude de ces activités nous a conduit à l'analyse des pratiques de manipulation et d'exploitation des informations. Afin de structurer cette analyse, nous avons utilisé la structure des activités de manipulation des connaissances décrite dans le chapitre I.2 de ce résumé en français. Dans cette analyse nous avons fait la distinction entre des pratiques individuelles et collectives. Ces pratiques sont complexes et très diverses, cette analyse ne peut donc révéler que les points les plus saillants.

- Pratiques concernant l'identification et l'acquisition des informations : les chercheurs identifient des informations pendant la visite des conférences, expositions, etc. où ils peuvent discuter avec d'autres experts et où ils ont accès aux actes des conférences et diverses documentations. De plus, ils ont accès à des informations pendant des réunions, visites, etc. Néanmoins, une grande partie des informations est accessible en format écrit via Internet, mail, etc.
- Pratiques concernant la structuration des informations : des informations identifiées lors des conversations peuvent être partiellement structurées dans des documents (comptes-rendus, etc.). Ensuite, la structuration des informations se limite principalement à la structuration des documents dans des répertoires sur serveur et ordinateur pour des documents électroniques et dans des classeurs pour des documents papiers. Au niveau de la structuration des documents, on peut distinguer entre structuration partagée et non-partagée. La structuration partagée s'oriente selon la structuration des documents officiels des projets qui est définie dans les procédures ISO. Selon cette structure, il existe des répertoires pour des comptes-rendus, fournitures, présentations, etc. pour chaque projet. La structuration non-partagée concerne la structuration personnelle des documents.
- Pratiques concernant le partage et la distribution des informations : pour le partage des informations il est possible de distinguer entre le partage d'information orales et le partage des informations écrites. Le partage des informations écrites peut se faire via l'accès à des répertoires partagés. Cependant, ce partage est très limité, car les différentes personnes ne connaissent pas la structure des répertoires de chacun. Une autre forme de partage concerne les documents sous formats papier. Une personne peut marquer des parties importantes et ajouter des commentaires (sous forme de post-it, notes manuscrites, etc.) afin de communiquer une argumentation à d'autres personnes.
- Pratiques concernant la combinaison et l'utilisation des informations : les chercheurs utilisent des informations pour élaborer des résultats de recherche. Les pratiques sont très individuelles. Dans la réutilisation des informations, les personnes donnent parfois les références des documents originaux. Certaines personnes utilisent également les fonctions « copier – coller » pour insérer des informations existantes dans de nouveaux documents.
- Pratiques concernant la préservation et l'élimination des informations : la préservation des informations est liée à la structuration des informations. Des documents officiels sont à

préserver selon des règles précises. La préservation des informations personnelles et non-partagées dépend des pratiques individuelles.

Les différentes pratiques sont en interaction avec l'utilisation d'un système d'informations. Dans le système d'informations actuellement utilisé, nous pouvons également distinguer entre un espace partagé et un espace non-partagé. L'espace partagé concerne les répertoires communs, un forum, un agenda partagé et les possibilités de gestion électronique des documents. L'espace non-partagé concerne les répertoires privés, la messagerie, l'agenda privé et l'utilisation de l'Internet. Ce système d'informations se base sur des outils bureautiques. Cependant, l'utilisation de ce système au regard des pratiques identifiées ne permet pas une optimisation de la gestion et de l'exploitation des informations pour la production des résultats de recherche.

III.2 DESCRIPTION DES PROBLEMES AVEC LES PRATIQUES ET LES OUTILS DE SUPPORT EXISTANTS

Généralement, les chercheurs ont trop d'informations à gérer. Ils éprouvent des difficultés pour appréhender l'intégralité de ce qu'ils ont collecté, pour définir les raisons de ces collectes d'informations, pour les stocker et pour définir le sujet précis de ces informations.

Dans les documents, il est délicat de retenir les différentes sections intéressantes. En effet, les informations liées à l'étude du contenu des documents ne sont pas suffisamment conservées.

Pour l'instant, la préservation et la structuration des documents sont propres à chaque individu. Même dans des répertoires partagés, il n'existe pas de structuration fixe. Or, si les chercheurs ne savent pas où est l'information, il leur est donc difficile de l'identifier. Ainsi, l'exploitation du contenu des documents est difficilement possible. Les caractéristiques de la recherche industrielle ne sont pas prises en compte (structuration des différents thèmes, des différents stades de maturité de connaissances dans un projet, des différentes étapes dans un projet, etc.).

Ces aspects non exhaustifs des problèmes nous ont amenés à spécifier les besoins pour un système de management de connaissances. Cette spécification a été étayée par une analyse fonctionnelle.

III.3 ANALYSE FONCTIONNELLE POUR UN SYSTEME DE GESTION DES CONNAISSANCES ET BESOINS POUR UNE MEILLEURE GESTION DE CONTENUS D'INFORMATIONS ECRITES

Avec un groupe de chercheurs et de managers de recherche nous avons mené lors de plusieurs réunions une analyse fonctionnelle. Au cours de la première phase nous avons spécifié les milieux environnants du système. Nous avons défini cinq milieux environnants : les fournisseurs d'informations externes, les unités opérationnelles, les activités de recherche internes, les fournisseurs d'informations interne en tant que groupes et individus. L'objectif étant de supporter les flux d'informations et de connaissances venant des différentes sources d'informations et des chercheurs, les milieux environnants représentent les éléments du point de vue de l'organisation des ressources décrites dans le chapitre II.4 de ce résumé en français.

Les fonctions qui pourraient soutenir partiellement les interactions des éléments des milieux environnants du système de management des connaissances (Figure III.1) sont décrites ci-dessous.

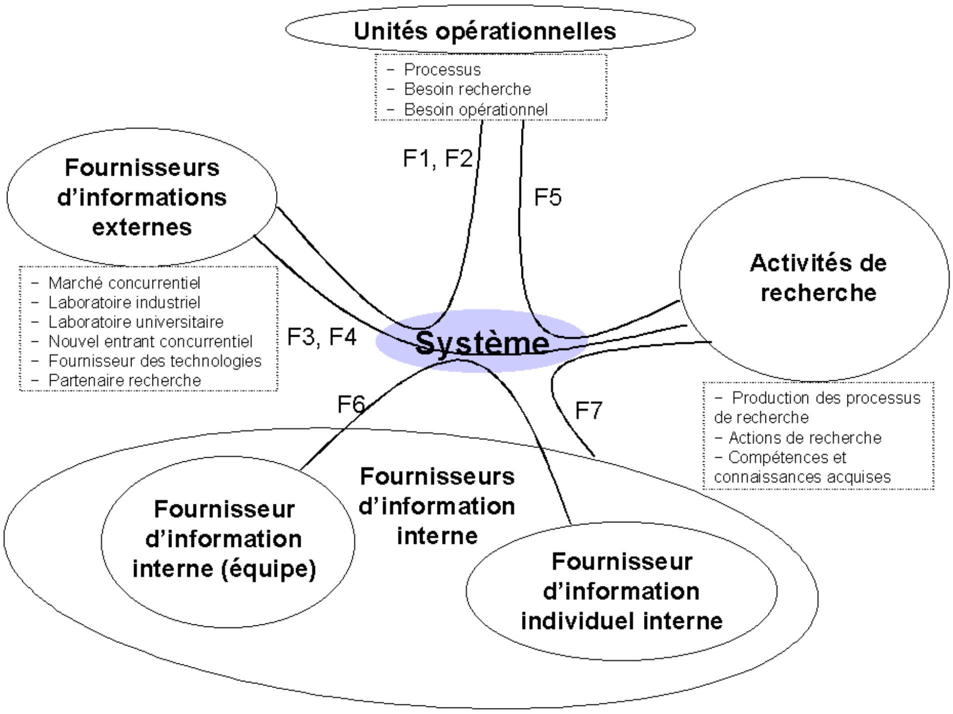

Figure III.1 – L'analyse fonctionnelle pour un système de management de connaissances pour un centre de recherche industrielle

- F1 : le système aiderait à identifier des problématiques industrielles externes des unités de recherche comparables aux problématiques des clients d'études de recherche. Certaines problématiques externes pourraient être des besoins clients internes implicites et non encore identifiés.
- F2 : le système aiderait également à la recherche des propositions des solutions (méthodes et technologies) externes pour les besoins des clients. Les solutions externes pourraient être prises en compte dans l'expérimentation des résultats de recherche dédiés à résoudre les problématiques des clients.
- F3 : le système rendrait visible l'écart entre les activités de recherche menée par des organisations externes et les activités de recherche interne.
- F4 : le système pourrait aider à identifier des éléments extérieurs (concepts, méthodes, technologies, outils et compétences) pour aider à réaliser des activités de recherche interne.
- F5 : le système montrerait à quel niveau les activités de recherche couvriraient les besoins des clients recherche. Cette différence pourrait donner des indications pour de futures activités de recherche à mener et pour l'approfondissement des activités de recherche existantes.
- F6 : le système pourrait soutenir une logique de partage entre chercheurs internes travaillant dans le même domaine de recherche. Cette fonction soutiendrait le partage des informations entre chercheurs travaillant dans un même domaine de recherche.

- F7 : le système aiderait à identifier des éléments internes (concepts, méthodes, technologies, outils et compétences) pour aider à réaliser des activités de recherche interne.

Les différentes fonctions montrent qu'un système doit supporter la gestion des informations. L'analyse des différentes pratiques a montré, qu'il est nécessaire de favoriser une meilleure gestion et exploitation du contenu des informations écrites. Les besoins concernent donc l'accès aux contenus des documents, pour favoriser un échange autour des contenus (voir Figure III.2).

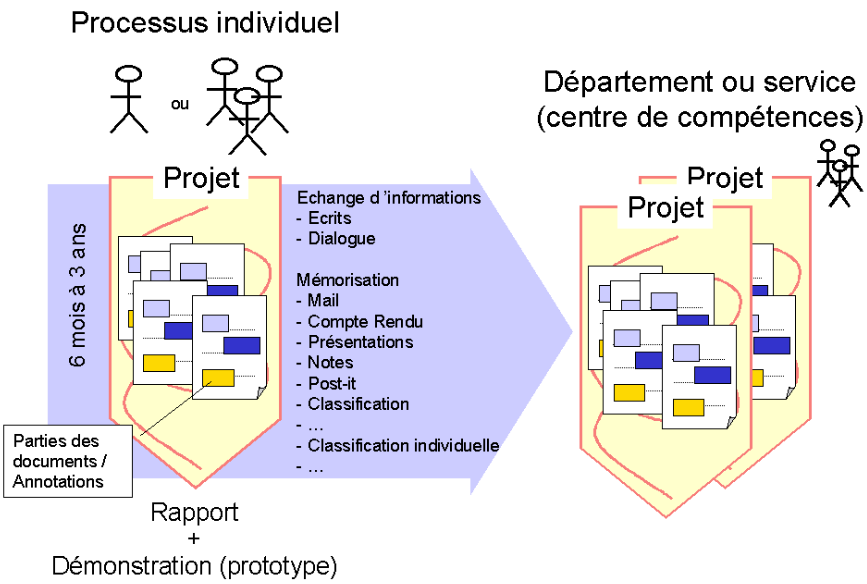

Figure III.2 – Exploitation des processus individuels pour un collectif appliqué aux contenus d'informations écrites

La gestion du contenu des informations écrites dans le contexte de la recherche industrielle pour l'individu et le groupe est un élément central pour notre proposition d'outil.

Afin d'intégrer ces propositions dans le contexte de la recherche, il est nécessaire d'élaborer un cadre global pour la gestion des connaissances dans le contexte d'un centre de recherche industrielle. Ceci est l'objectif du prochain chapitre.

IV UN CADRE POUR LA GESTION DES CONNAISSANCES POUR UN CENTRE DE RECHERCHE INDUSTRIELLE

En nous appuyant sur les travaux des précédents chapitres, dans ce chapitre, nous proposons un cadre pour la gestion des connaissances pour un centre de recherche industrielle. Selon le modèle de CIMOSA (Vernadat, 1996), ce cadre est composé de trois sous-modèles : modèle générique, modèle partiel et modèle particulier.

IV.1 LA CONSTRUCTION DU CADRE

Pour le modèle générique, nous proposons d'assembler, les différents éléments décrivant le contexte global d'un centre de recherche (voir chapitre II). Selon le principe du modèle générique, nous proposons de structurer ces aspects dans un modèle de processus de recherche (Figure IV.1). Dans ce modèle de processus, nous distinguons trois phases : investiguer, focaliser et déployer. Dans la phase investiguer, les activités concernent la réalisation d'états de l'art et d'états de lieux. Dans la phase focaliser, il s'agit d'expérimenter de nouveaux concepts, méthodes, technologies et outils pour acquérir de nouvelles compétences pour des besoins donnés. Dans la phase déployer, il s'agit de transférer des nouvelles solutions aux unités opérationnelles.

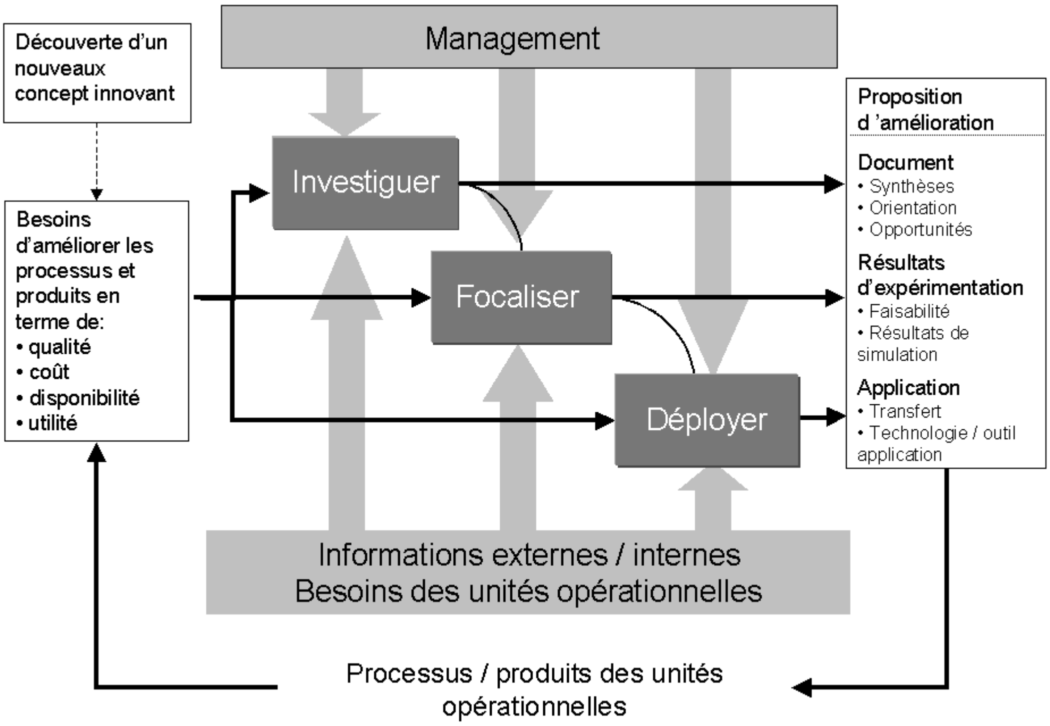

Figure IV.1 – Modèle de processus de recherche industrielle

Les différentes phases sont basées sur l'acquisition et l'utilisation des informations externes et internes ainsi que sur les informations concernant les besoins des unités opérationnelles. Donc dans chaque phase, les chercheurs gèrent des activités de manipulation d'informations et de connaissances. Nous rassemblons ces activités dans le modèle partiel.

Le modèle partiel représente les différentes activités de manipulation d'informations et de connaissances sur un cercle. Les activités se basent sur les activités de manipulation d'informations et de connaissances décrites dans le chapitre II.1. Les différentes activités sont liées car elles ne peuvent pas exister indépendamment (Figure IV.2).

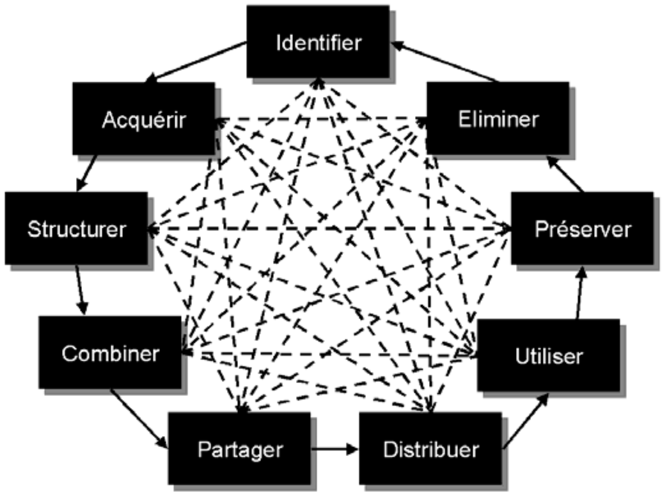

Figure IV.2 – Modèle de management des activités de manipulation d'informations et de connaissances

Afin de pouvoir proposer un cadre global, il est important de caractériser ces informations et connaissances plus en détail. Cette caractérisation fait l'objet du modèle particulier.

Pour le modèle particulier, nous proposons donc d'assembler les différents aspects qui influencent l'élaboration des résultats de recherche du point de vue du contenu. La structure orientée contenu est liée aux problèmes de recherche et aux objectifs des projets. Selon le principe du modèle particulier, nous proposons un modèle de structuration du contenu des éléments de ressources d'informations et un modèle de structuration de contenus des activités de recherche.

Le modèle de structuration du contenu des éléments de ressources représente une structure de contenus d'informations nécessaires pour élaborer les résultats. Nous avons élaboré ce modèle à partir des analyses des contenus de documents et de réunions de consolidations et il est orienté vers l'environnement des ressources d'informations préalablement décrit dans le chapitre II.4 avec le point de vue organisation des ressources. Pour chaque ressource (laboratoire externe, fournisseur externe, etc.), nous avons structuré et défini le contenu d'informations important pour l'élaboration des résultats de recherche (Tableau IV.1).

Tableau IV.1 - Modèle de structuration du contenu des éléments de ressources

Laboratoire externe	Fournisseur externe	Environnement industriel externe	Unités opérationnelles	Centre de recherche
Directions de recherche	Directions de recherche	Stratégie	Stratégie	Stratégie
Concepts innovant et modèles	Concepts innovant et modèles	Cas d'utilisations	Besoins / processus	Organisation / méthodes / outils / contraintes
Méthodes	Méthodes	Besoins	Objectifs de recherches	Exigences de recherche
Prototypes	Outils	Méthodes	Approche	Expérimentations
Moyens	Moyens	Outils	Concepts innovants et modèles	Processus
Expérimentations	Expérimentations et retour d'expérience	Solutions	Méthodes	Méthodes utilisées et expérimentations
			Prototypes	Outils utilisés et expérimentations
			Moyens	Retour d'expériences
			Expérimentations	

Le modèle de structuration de contenus des activités de recherche représente une structuration des problèmes et des objectifs de recherche. Basé sur l'organisation des activités de recherche décrit dans chapitre III, nous distinguons quatre niveaux (voir Figure IV.3):

- Un centre de compétences structurant un ensemble d'activités de recherche.
- Chaque centre de compétences peut être constitué de domaines de recherche.
- Ces domaines de recherche peuvent être eux-mêmes constitués de thèmes. Pour les thèmes, nous proposons de les caractériser selon : des thèmes partagés, des thèmes non-partagés et des thèmes émergents.
- Pour chaque thème, il peut exister des projets de recherche.

La différence entre domaine et thème concerne le degré de détail : un domaine couvre des intérêts de recherche plus globaux qu'un thème.

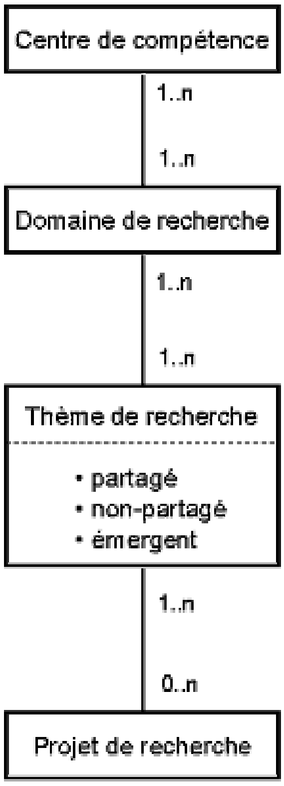

Figure IV.3 - Modèle de structuration de contenu des activités de recherche

Les éléments des modèles de structuration de contenus des éléments de ressources et de structuration de contenus des activités de recherche sont basés sur un consensus entre chercheurs. Ceci implique, que les éléments peuvent donner une structure d'un point de vue contenus d'information qui est commun pour la majorité des activités de recherche. Nous pouvons donc parler d'une structure d'ontologie partagée.

Les différents modèles du chapitre I.V.1 forment une architecture générale du cadre pour la gestion des connaissances pour un centre de recherche industrielle.

I.V.2 L'ARCHITECTURE GENERALE DU CADRE POUR LA GESTION DES CONNAISSANCES POUR UN CENTRE DE RECHERCHE INDUSTRIELLE

Selon la structure de CIMOSA et notre adaptation au contexte de la recherche industrielle, nous proposons une architecture générale structurée sur trois niveaux. Le premier niveau constitue le modèle de processus de recherche. Dans chacune de ces phases, nous proposons d'introduire ici notre modèle de management d'activités de manipulation d'informations et de connaissances

Afin de supporter les différentes activités du modèle de management d'activités, nous proposons une boite à outils pour chaque activité. Chacune des boites à outils possède une entrée et une sortie. Les entrés et sorties concernent les ressources et les résultats de chaque activité. Nous utilisons donc les modèles de structuration du contenu des éléments de ressources pour caractériser les entrées et le modèle de structuration de contenu des activités de recherche pour caractériser les sorties d'un point de vue contenu d'informations (Figure IV.4).

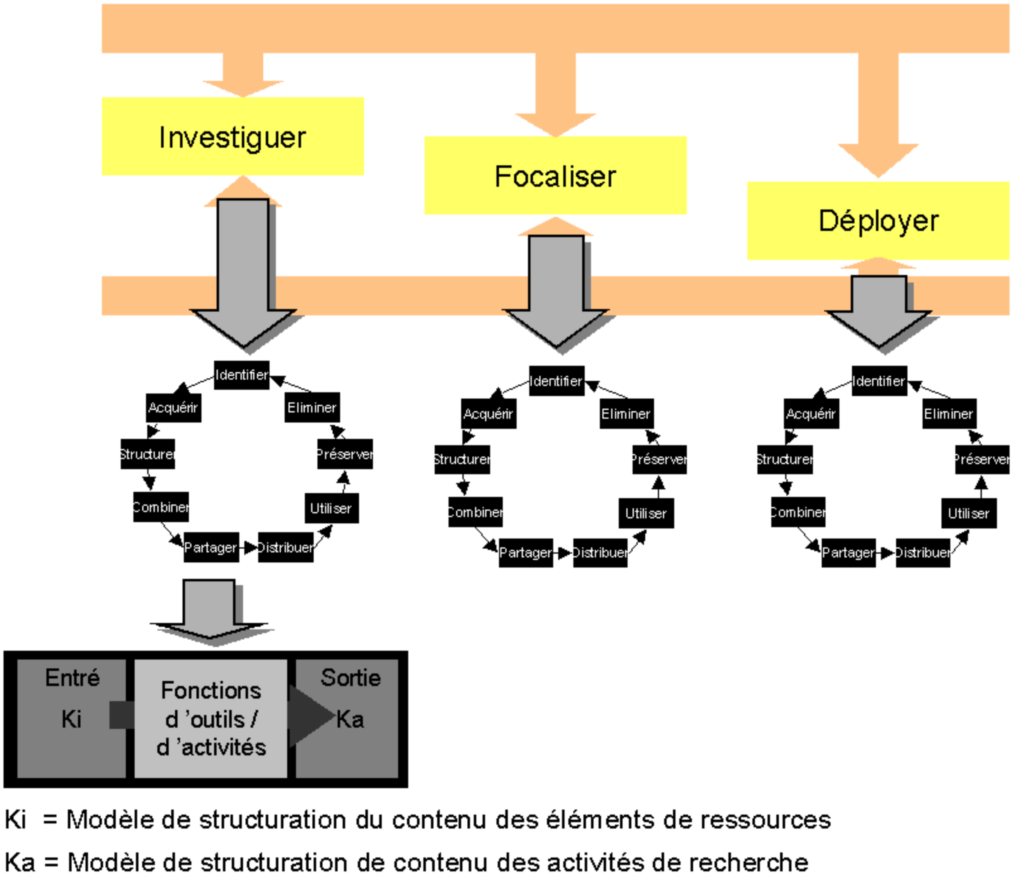

Figure IV.4 – Architecture générale du cadre pour la gestion des connaissances pour un centre de recherche industrielle

A partir de ce cadre nous avons construit un tableau (Tableau IV.2) pour décrire les différentes entrées et sorties ainsi que les différentes fonctions d'outils et d'activités nécessaires.

Tableau IV.2 – Tableau descriptif pour le cadre pour la gestion des connaissances pour un centre de recherche industrielle

	Investiguer	Focaliser	Déployer
Identifier	Identifier des nouvelles connaissances / informations externes pour des nouvelles questions de recherche. Identifier les besoins des unités opérationnelles	Identifier des cas d'utilisation dans les unités opérationnelles pour l'expérimentation des résultats.	Identifier un environnement d'application et de transfert pour des résultats de recherche.
Acquérir	Transférer des connaissances / informations externes et internes dans le milieu de recherche.	Acquérir des informations et de données de test pour des nouveaux résultats de recherche.	Acquérir des conditions de transfert et d'implémentation.
Structurer	Structurer des nouvelles connaissances / informations dans les milieux existants de structuration.	Structurer des informations d'unités opérationnelles selon le développement des nouveaux résultats.	Structurer l'information d'implémentation.
Combiner	Combiner des connaissances / informations externes et internes pour des conclusions.	Appliquer des connaissances internes et externes afin de produire de nouveaux modèles et leur simulation.	Combiner et adapter les résultats selon les conditions de transfert et d'implémentation.
Partager	Partager des nouvelles connaissances / informations externes avec d'autres chercheurs.	Partager des nouvelles connaissances / informations avec d'autres chercheurs et les unités opérationnelles.	Implémenter des résultats de recherche et forme leur utilisation aux unités opérationnelles.
Distribuer	Distribuer des conclusions concernant des connaissances externes et internes à des chercheurs et unités opérationnelles.	Distribuer des résultats de simulation et des produits de recherche à d'autres chercheurs et unités opérationnelles.	Distribuer des résultats de recherche et des retours d'expériences à d'autres chercheurs et unités opérationnelles.
Utiliser	Utiliser des informations / connaissances collectées pour l'élaboration des résultats de recherche.	Utiliser des résultats pour la proposition des nouveaux résultats et des nouveaux concepts.	Utiliser des informations importantes pour le transfert des résultats aux unités opérationnelles.
Préserver	Préserver des conclusions et des informations / connaissances externes importantes.	Préserver des conclusions sur des résultats de recherche et nouvelles idées.	Préserver retour d'expériences des implémentations des résultats de recherche pour d'autres activités futures.
Eliminer	Eliminer des informations externes si elles ne représentent pas de valeurs pour de futures activités.	Eliminer des informations non nécessaires pour des activités futures.	Eliminer des informations non nécessaires pour des activités futures.

Ce tableau permet de structurer les besoins des chercheurs et des propositions d'outils. Il s'agit donc d'un cadre d'analyse pour la gestion des connaissances et des informations pour la recherche industrielle.

IV.3 L'ANALYSE DES OUTILS DE GESTION DE CONNAISSANCES AVEC LE CADRE DEVELOPPE

L'architecture générale du cadre pour la gestion des connaissances pour un centre de recherche industrielle structuré sur trois niveaux met en lumière l'importance du contenu et du contexte qu'il est souhaitable de supporter avec des outils opérationnels. Cependant, après une analyse approfondie des outils existants, les outils actuels ne répondant pas à ces besoins. Les outils ne prennent pas en compte la structure du cadre pour la gestion des connaissances et des informations pour la recherche industrielle. Surtout pour les activités identifier, structurer, combiner, partager, utiliser et préserver, nous pensons qu'il est important de proposer des fonctionnalités supplémentaires basées sur les pratiques et besoins identifiés.

Puisque les informations écrites représentent un aspect important pour la recherche, nous proposons un support pour leur gestion et leur exploitation. Nous utilisons le Tableau IV.2 pour structurer nos propositions de fonctionnalités supplémentaires (Tableau IV.3).

Tableau IV.3 – Proposition de support de gestion d'informations écrites

	Investiguer	Focaliser	Déployer
Identifier		• Faciliter l'identification et l'accès à des contenus d'informations écrites déjà identifiées (document et parties de documents avec commentaires) selon un contexte multi-vue. Le contenu concerne des besoins des unités opérationnelles et des technologies et outils avec retour d'expériences. • Réaliser les fonctions F2, F4, F7.	• Faciliter l'identification et l'accès à des contenus d'informations écrites déjà identifiées (document et partie des documents avec commentaires) selon una approche multi-vue. Le contenu concerne des besoins des unités opérationnelles et des processus existants.
Acquérir			
Structurer	• Donner une structure multi-vue à des contenus écrits déjà identifiés (document et parties de documents) avec structuration des ontologies ressources et activités.	• Donner une structure multi-vue à des contenus écrits déjà identifiés (document et parties de documents) avec structuration des ontologies ressources et activités.	• Donner une structure multi-vue à des contenus écrits déjà identifiés (document et parties de documents) avec structuration des ontologies ressources et activités.
Combiner	• Faciliter la combinaison et l'assemblage des contenus écrits des ressources d'informations externes. • Combiner des contenus avec des idées.	• Combiner des contenus avec des idées. • Réaliser les fonctions F1, F5.	• Combiner des contenus avec des idées dans le contexte de transfert des résultats.
Partager	• Réalisation de la fonction F6 concernant des contenus d'informations externes et avec des commentaires annotés.	• Réalisation de la fonction F6 concernant des contenus externes combinés avec de nouvelles propositions et avec des commentaires annotés.	• Réalisation de la fonction F6 concernant des retours d'expériences et avec des commentaires annotés.
Distribuer			
Utiliser	• Assembler le contenu identifié avec des idées. • Réalisation de la fonction F3 avec des contenus d'informations écrits identifiés.	• Assembler le contenu identifié avec des idées pour élaborer des résultats de recherche.	• Assembler le contenu identifié avec des idées pour élaborer des résultats de recherche.
Préserver	• Préserver des contenus avec un contexte multi-vue.	• Préserver des contenus avec un contexte multi-vue.	• Préserver des contenus avec un contexte multi-vue.
Eliminer			

Afin de pouvoir concrétiser une part de nos propositions, nous avons spécifié, réalisé et testé un outil prototype avec de nouvelles fonctionnalités

V A.N.I.T.A. : POUR UNE MEILLEURE EXPLOITATION DU CONTENU DES DOCUMENTS POUR LA PRODUCTION DES CONNAISSANCES

L'objectif de notre proposition d'outil est une meilleure identification, structuration, combinaison, partage, utilisation et préservation des contenus des informations écrites. L'outil doit prendre en compte les modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenus des activités de recherche.

V.1 PRINCIPES DES SOLUTIONS

Afin de pouvoir exploiter le contenu des documents, nous donnons la possibilité de travailler avec des parties de documents (que nous appelons zones de document), sans division du document dans plusieurs sous-documents.

Selon le modèle de management d'activités de manipulation d'informations et de connaissances (voir chapitre IV, Figure IV.2), nous proposons les fonctionnalités suivantes :

- Structurer : pour structurer des zones de document, nous souhaitons les indexer avec les éléments des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenu des activités de recherche (voir chapitre IV, Tableau IV.1 et Figure IV.2). Comme les modèles représentent une ontologie partagée (voir fin chapitre IV), les différents utilisateurs manipulent les mêmes éléments d'indexation pour structurer le contenu (voir Figure V.1).
- Identifier : nous supportons la recherche et l'identification des informations préalablement structurées avec l'outil A.N.I.T.A.. L'identification se fait à partir des éléments d'indexation de la structuration. Des représentations variées et modifiables des contenus identifiés permettent un accès personnalisé.
- Combiner : nous proposons deux fonctionnalités de combinaison : la combinaison des zones de documents avec des argumentations sous forme de texte libre via des annotations texte libre et la combinaison des zones de document dans un nouveau document. En dehors, nous proposons également une combinaison via des représentations spécifiques des contenus.
- Partager : le partage des informations est possible via la structuration des informations avec l'ontologie partagée (les utilisateurs peuvent connaître la structuration des informations des autres et peuvent donc avoir accès à ces informations). De plus, nous proposons un partage via les annotations, avec lesquelles les chercheurs peuvent échanger des argumentations concernant une zone de document.
- Utiliser : l'utilisation est en fait possible via une identification, un partage, et combinaisons. L'utilisation rassemble donc les différentes fonctionnalités de ces trois activités.
- Préserver : la préservation est le résultat d'une évaluation sur l'utilité des informations structurées et disponibles. Cependant, une préservation peut être supportée avec la structuration via une indexation. La préservation des informations indexées permet une meilleure ré-identification.

L'indexation représente aussi une attribution de points de vues à des informations car le chercheur a la possibilité d'attribuer des combinaisons variées des différents éléments de l'ontologie partagée à une zone de document.

Comme cette proposition d'outil est basé sur des annotations fixes (indexation) et textes libres (annotation) ainsi que sur une notion d'accès aux contenus via une ontologie partagée, nous avons choisi de nommer notre proposition A.N.I.T.A. pour « ANnotation tool for Industrial TeAms » (outil d'annotation pour des équipes industrielles). L'utilisation de l'ontologie qui est spécifique à la recherche permet une application de A.N.I.T.A. au domaine de la recherche.

Du point de vue de son utilisation et de sa réalisation, l'outil est structuré en trois modules (voir Figure V.1) :

- Le module structuration et annotation (activités structurer et partager)
- Le module recherche et visualisation (activités identifier, combiner et partager)
- Le module d'assemblage d'informations (activités combiner, utiliser et préserver).

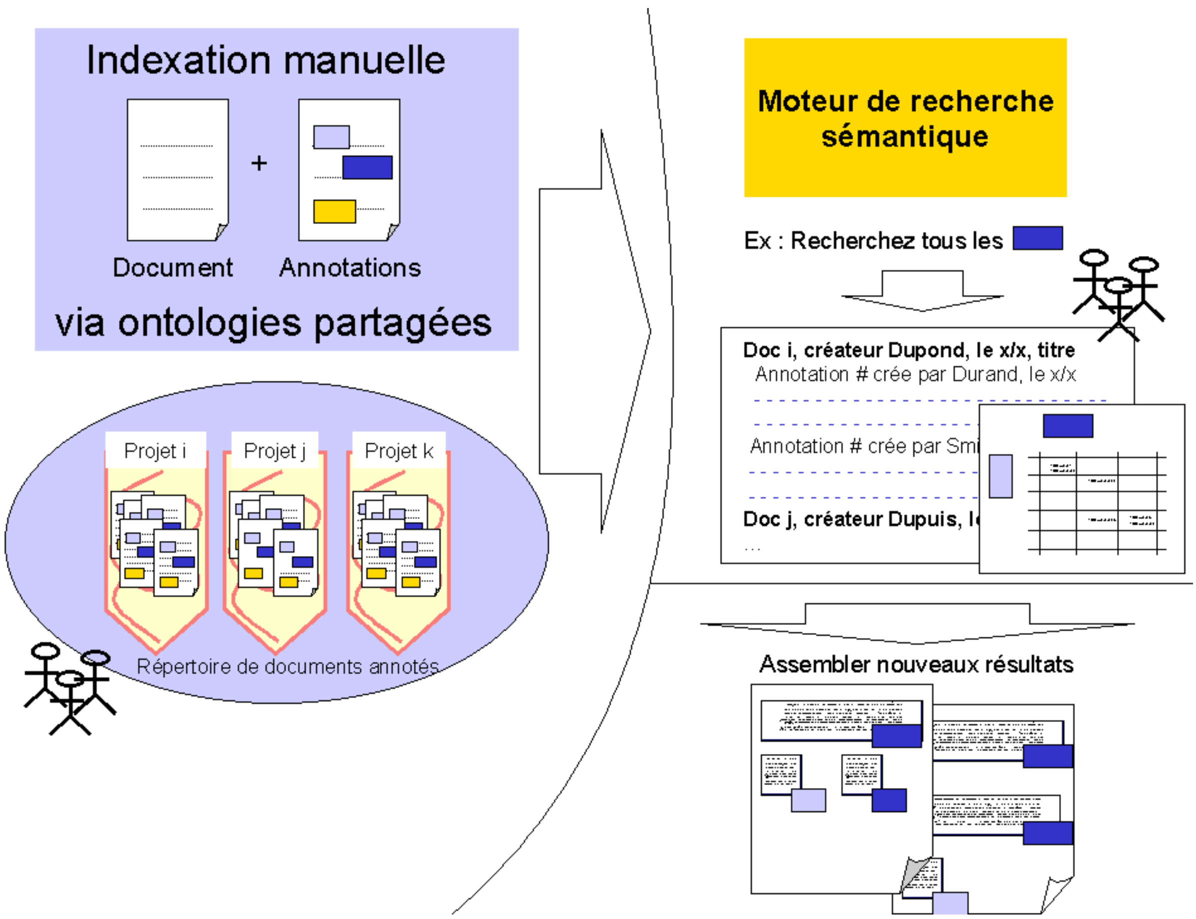

Figure V.1 – Principes de solution pour l'outil A.N.I.T.A.

Ces modules s'appliquent à des zones de documents mais également à des documents. Les documents peuvent être de formats variés. Par la suite, nous allons approfondir les différents modules.

V.1.1 LE MODULE STRUCTURATION ET ANNOTATION

La structuration du contenu d'informations est basée sur une indexation avec les éléments des modèles éléments des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenus des activités de recherche (voir chapitre IV, Tableau IV.1 et Figure IV.2). Pour donner une signification précise des différents éléments de ces modèles, nous utilisons les concepts « of aboutness » et « of relevance » (Frank et Gardoni, 2003b).

Les éléments du modèle de structuration du contenu des éléments de ressources d'informations sont liés au concept « of aboutness » via les expressions : de qui / de quelle organisation / de quoi il est question.

Les éléments du modèle de structuration de contenus des activités de recherche sont liés au concept « of relevance » via les expressions : Pour quoi et pour qui l'information représente un intérêt. Cette signification structure les contenus vis-à-vis des objectifs de recherche.

Les annotations en texte libre associées à des documents et à des zones de documents permettent d'associer une argumentation et de l'échanger avec d'autres personnes.

V.1.2 LE MODULE DE RECHERCHE ET DE VISUALISATION

L'utilisateur peut accéder aux contenus via les éléments des modèles de structuration du contenu, des éléments de ressources d'informations et de structuration de contenus des activités de recherche, utilisés pour l'indexation. Il a la possibilité de combiner les différents éléments pour créer des points de vues d'accès. La combinaison peut varier et permet donc un accès dynamique à des informations. L'utilisateur n'est pas obligé d'utiliser une structure fixe de structuration.

Cette possibilité de combiner les différents éléments permet aux personnes d'accéder aux informations indexées par d'autres personnes. Comme les index se basent sur des modèles en communs (ontologie partagée), les différentes personnes peuvent connaître les différents contenus enregistrés avec les index. La visualisation des résultats peut être affichée selon un croisement des différents éléments des modèles éléments des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenu des activités de recherche. Il est donc possible de croiser des éléments des concepts « of aboutness » et « of relevance » pour une analyse des informations et pour préparer leur assemblage.

V.1.3 LE MODULE D'ASSEMBLAGE

Nous n'avons pas encore implémenté le module d'assemblage à cause des contraintes de temps, nous le développerons par la suite.

Cependant, les fonctionnalités de base concernent la combinaison des zones de documents et des annotations de textes libres dans des nouveaux documents de recherche. Ceci supporterait l'assemblage des documents de recherche finaux.

Lors de l'assemblage, les références des zones de document et des annotations sont automatiquement transférées dans un nouveau document.

V.2 SPECIFICATION FONCTIONNELLE ET TECHNIQUE

Pour la spécification fonctionnelle, nous nous sommes basés sur le formalisme U.M.L.. Nous avons donc spécifié des cas d'utilisations ainsi que des diagrammes de classes. Pour les cas d'utilisations, nous distinguons entre trois types d'utilisateurs : le créateur, le lecteur et l'administrateur. Le créateur possède les cas d'utilisations suivants : attribuer des points de vues à des documents, attribuer des points de vues à des zones de document, attribuer des annotations, sélectionner des informations dans un document, créer un nouveau point de vue. Le lecteur possède les cas d'utilisations suivants : lister des informations selon des points de vues sélectionnés, afficher des informations sélectionnées. L'administrateur peut définir des points de vues et modifier des points de vues.

Pour les diagrammes de classe nous distinguons entre les classes : acteur, document, zone de document, annotation, et « aboutness » et « relevance ». Les classes « aboutness » et « relevance » représentent les différents éléments des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenu des activités de recherche.

Au niveau spécification technique, l'outil A.N.I.T.A. est basé sur des technologies de Adobe Acrobat et XML pour l'annotation des informations et sur du PHP et MySQL pour la représentation des résultats de recherche et de navigation dans des informations (Figure V.2).

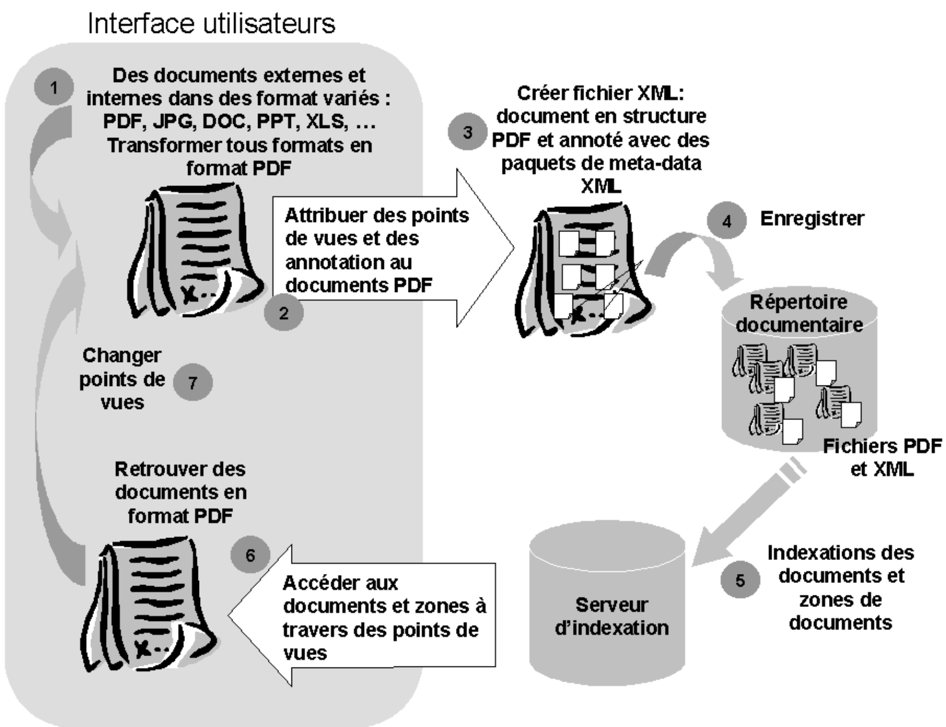

Figure V.2 – Spécification technique de l'outil A.N.I.T.A.

Dans (1) (Figure V.2) l'utilisateur choisit des documents qu'il veut introduire dans le système et les transforme en format PDF. Avec ces documents en PDF il peut choisir des zones de documents et attribuer des points de vues et des annotations sous forme de texte libre (2). Dans (3) le système crée un ficher XML pour le fichier PDF où il gère les différents points de vues et annotations sous forme de méta-données. Ensuite il enregistre les fichiers XML (4). Dans (5) un serveur d'indexation indexe les documents et zones de documents avec les différents métas-données. Dans (6) l'utilisateur accède aux contenus d'informations (documents et zones de documents) via les points de vues. Il peut modifier ces points de vues (7) et enregistrer à nouveaux le document. L'interface entre le module d'attribution des points de vues et des annotations et le module accéder et visualiser les informations est constituée par le fichier XML. Ce fichier est créé automatiquement lors de l'attribution des points de vues.

V.3 RETOUR D'EXPERIENCE

Nous avons testé et tenté de valider les principes de notre outil avec une petite équipe de chercheurs. Cette expérimentation a montré que l'outil peut contribuer à un support de gestion de flux de connaissances et d'informations et à l'élaboration des résultats de recherche. La Figure V.3 montre l'interface d'utilisation pour l'attribution des points de vues à une zone de document. La Figure V.4 montre comment accéder à des informations avec des points de vue attribués.

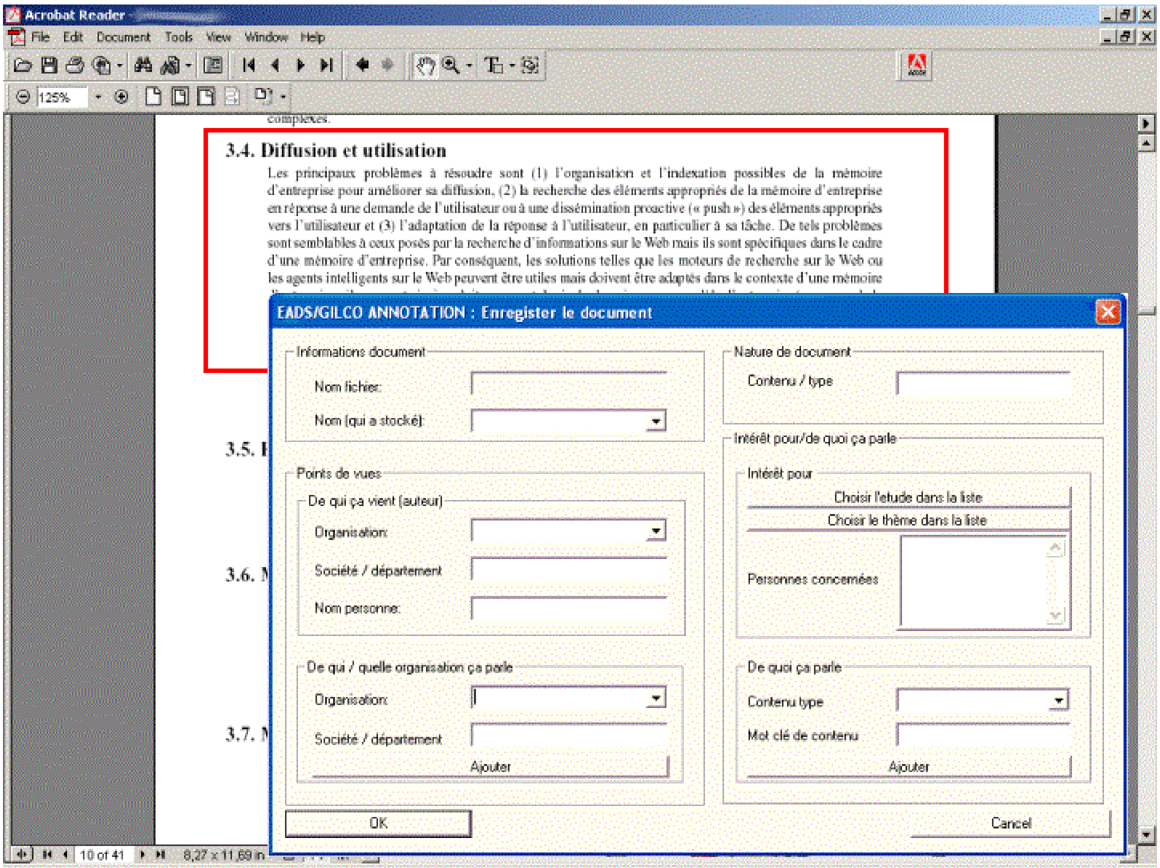

Figure V.3 - L'interface d'utilisation pour l'attribution des points de vues à une zone de document

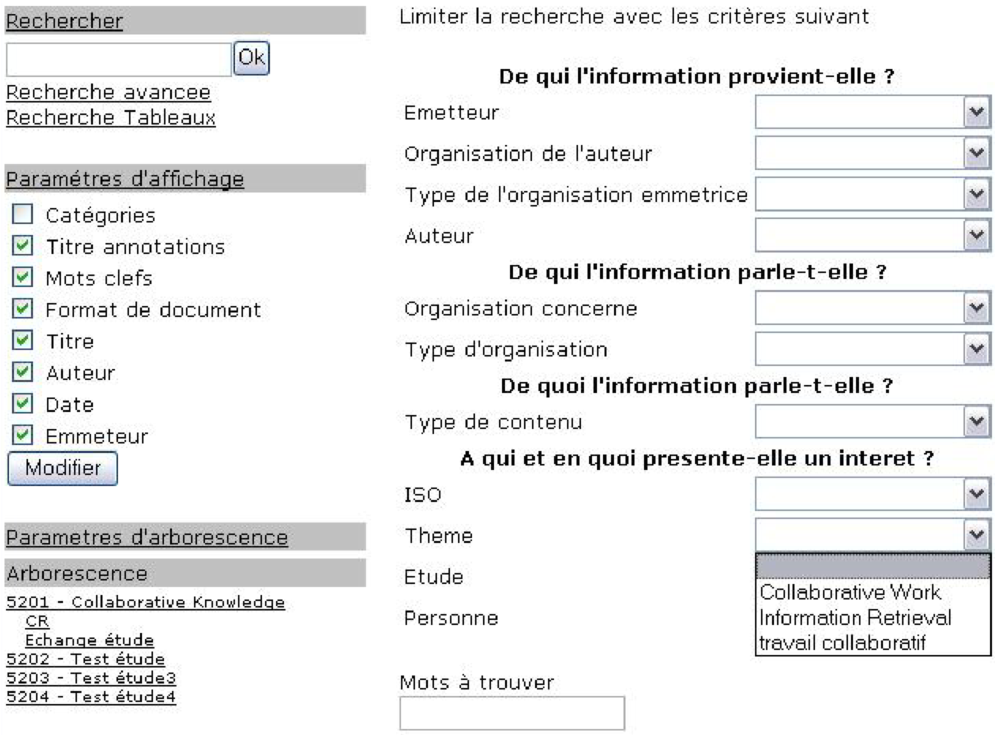

Figure V.4 – L'interface pour accéder à des informations avec des points de vue attribués

Concernant la validation, l'outil supporte les pratiques : identifier, structurer, combiner, partager, utiliser et préserver. Par le fait de pouvoir gérer des zones de documents, il est possible d'exploiter les contenus des grands documents.

La possibilité de faire des annotations sous format de texte libre, peut conduire à un transfert des annotations orales vers des annotations écrites pour la communication asynchrone. Cependant, les réticences exprimées par les utilisateurs ont trait au caractère écrit et donc non évolutif des annotations et de l'effort consacré au passage à l'écrit. Pourtant, une fois les annotations créées, les utilisateurs tendent à les réutiliser pour échanger plus d'informations ou pour les utiliser dans l'élaboration des résultats de recherche.

L'utilisation du modèle de structuration du contenu de ressources d'informations et du modèle de structuration de contenu des activités de recherche qui sont commun pour les chercheurs, permet un meilleur partage des contenus d'informations.

En conclusion, l'outil A.N.I.T.A. prend en compte une partie du cadre pour la gestion des connaissances et d'informations pour un centre de recherche industrielle.

CONCLUSION ET PERSPECTIVES

L'objectif de nos travaux est de structurer les activités de recherche d'un centre de recherche industrielle d'un point de vue flux d'informations et de connaissances et de favoriser la gestion et l'exploitation des contenus des informations écrites pour la production de nouveaux résultats de recherche.

Avec l'aide du modèle CIMOSA, nous proposons un cadre pour la gestion d'informations et des connaissances pour un centre de recherche industrielle. Ce cadre est basé sur trois modèles : un modèle processus de recherche, un modèle de management d'activités, et des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenus des activités de recherche, qui peuvent en effet représenter une ontologie partagée.

Ce cadre permet de structurer et d'analyser les besoins des chercheurs et les fonctions des outils existants pour un meilleur support dans le contexte de la recherche industrielle. Cette analyse a montré qu'il est nécessaire de proposer des fonctionnalités supplémentaires pour une meilleure gestion et exploitation des contenus de documents écrits.

Nous proposons donc un outil nommé A.N.I.T.A. que nous utilisons avec les éléments des modèles de structuration du contenu des éléments de ressources d'informations et de structuration de contenu des activités de recherche. Les chercheurs ont la possibilité de gérer, partager et exploiter des contenus d'informations avec des mécanismes d'annotations des points de vue fixes, des argumentations, des mécanismes d'accès, et de visualisation. Un module d'assemblage est prévu prochainement.

Pour les perspectives, six aspects nous semblent utiles pour de futures pistes de recherche :

- L'application du cadre pour la gestion d'informations et des connaissances pour les activités d'un centre de recherche industrielle et de l'outil A.N.I.T.A. à d'autres environnements. Ces environnements peuvent concerner d'autres domaines de recherche industrielle, l'environnement de la recherche académique, et d'autres environnements industriels en général.
- L'utilisation de l'outil A.N.I.T.A. dans des équipes de taille plus importante. Au sein de grandes équipes, il pourrait être difficile de définir des ontologies communes et de gérer des parties de documents.
- Intégration de l'outil A.N.I.T.A. dans d'autres systèmes d'informations, notamment dans des systèmes de gestion de documents et des portails de gestion de connaissances.
- L'utilisation des nouvelles technologies pour favoriser par exemple une attribution des points de vues en semi-automatique, via des annotations orales ou des écrans interactifs, etc.
- Adapter les fonctions de visualisation de contenus d'informations pour supporter la définition des stratégies.
- Appliquer des méthodes de ROI (Return On Investment) pour analyser la performance de l'outil.

Pour mener à bien ces travaux qui peuvent relever des domaines de l'informatique, de l'ergonomie des logiciels, des nouvelles technologies de l'information, des outils de veilles technologiques, de la psychologie du travail, etc., nous recommandons la mise en place d'une équipe de recherche pluridisciplinaire pour embrasser les différents domaines abordés. De plus, cette équipe pourrait mettre en pratique le cadre pour la gestion des connaissances pour un centre de recherche industrielle et l'appliquer à leur contexte. L'outil A.N.I.T.A. pourrait alors donner un support à cette équipe de recherche.

“Real knowledge is to know the extent of one’s ignorance.”

-*Confucius*

1 KNOWLEDGE MANAGEMENT IN INDUSTRIAL CONTEXT

1.1 INTRODUCTION

In this first chapter, we will discuss some basic concepts of knowledge management in the context of industrial organizations. We will discuss knowledge management with the three following aspects:

- Knowledge management from a concept and model point of view.
- Knowledge management from a practice point of view.
- Knowledge management from a support and especially technology and written information point of view.

From the concept point of view, we will first clarify the concept of knowledge and the link between knowledge and information. This will lead to our definition of knowledge for the context of this work.

We then will discuss different knowledge management models. In these models, we will clarify the knowledge resource aspects and the knowledge manipulation activities. These aspects play an important role for industrial processes and can therefore play an important role for industrial research processes.

As our study takes place in a multicultural environment, we will have also a closer look on cultural concepts which might play a role for knowledge management.

From the practice point of view, we describe some common practices for knowledge management in industrial organizations. Although the described practices are only some examples, they give a good overview, how the knowledge manipulation activities defined in the knowledge management models are realized in practices.

From the support point of view, we will see how the different practices, and therefore the different knowledge manipulation activities, are supported with organizational and technology aspects. As written information and documents can constitute a resource for new knowledge creation (North, 1999), we will have a closer look on document and document content structures. The exploitation of document content will then play an important role for our study.

At the end of this chapter, we will describe how knowledge management can be introduced in an industrial organization. We will use parts of the introduction framework for our own study as we propose knowledge management facilities for an industrial research center.

1.2 THE INDUSTRIAL CONTEXT

An industrial organization is not only a production unit or a service provider trying to produce new products and services in best conditions concerning costs, delays and quality, but also a knowledge production unit (Grundstein, 2000). We distinguish therefore between industrial processes producing products and services, and knowledge production processes.

Industrial processes assemble different resources in order to produce the products and services. The industrial processes involve people and machines which are responsible to assemble the resources. During the execution of industrial processes, the people can produce new knowledge. However, the human agents need also a certain level of knowledge in order to execute the industrial processes. Therefore, the knowledge produced supports the industrial processes (Grundstein, 2000).

One objective of industrial organizations is to optimize their industrial processes and resource consumption. This can be achieved by optimizing knowledge flows and the knowledge production process (Sveiby, 1997). Knowledge management can be one possibility to support the organization of knowledge and the knowledge production processes (Barthes, 2000).

The different possible motivating facets for knowledge management in an industrial organization can be diverse (Dieng, 2000):

- Avoid the loss of knowledge of an expert being near to his pension age or move to another organization.
- Exploit the experience of past projects and keep past lessons in order to avoid reproducing some errors.
- Improve the circulation of information and the communication.
- Improve learning processes of the employees.
- Integrate new possible information and knowledge existing outside the firm and exploit it to improve existing processes.
- Etc.

Ermine (Ermine, 1998) highlights that knowledge management in an industrial organization concerns several organizational levels: the research and development, the management (service, quality, etc.), the production (data management, document management, know-how) and the human resource management (competence management). Knowledge management can therefore be a support for various industrial processes. In this work, we will discuss the possible support of knowledge management for industrial research activities.

However, before going into deeper detail concerning knowledge management support for industrial research activities, we will clarify the concept of knowledge and knowledge management.

1.3 CONCEPTS OF KNOWLEDGE

There are several definitions of knowledge (non-exhaustive list of definitions):

- According to Wiig (Wiig, 1993) “knowledge consists of truths and beliefs, perspectives and concepts, judgements, expectations, methodologies and know-how”.

- Nonaka and Takeuchi's definition (Nonaka and Takeuchi, 1995): "Knowledge is true and justified belief."
- Turban (Turban, 1992) defines knowledge as an "… information that has been organized and analyzed to make it understandable and applicable to problem solving or decision making".
- Davenport and Prusak (Davenport and Prusak, 1998), define knowledge as a mix of fluid experiences, values, contextual information and intuition that provides a structure to evaluate and incorporate new experiences and information. It originates and is applied in the minds of individuals.

We can recognize from in the above definitions, that knowledge has something to do with aspects like "judgements", "expectations", "beliefs", "experiences", etc. (definitions of Wiig, Nonaka and Takeuchi, Davenport and Prusak) residing in the minds of individuals. On the other hand, there seems to be a link between knowledge and the notion of "information" (definitions of Turban, Davenport and Prusak).

As a synthesis of the above definition we propose the following definition for knowledge: "Knowledge is the result of human experience and reflection based on a set of beliefs and residing as fictive objects in people's mind".

The link between knowledge and information is presented in the following sections.

1.3.1 FROM DATA TO WISDOM PASSING BY KNOWLEDGE

In order to make knowledge accessible, it can be encoded through different forms. Beckman (Beckman, 1997) proposes a five-level knowledge hierarchy in which knowledge could be transformed from a lower level to a more valuable higher level (Table 1.1)

Table 1.1 – Five-level knowledge hierarchy according to Beckman (Beckman, 1997)

Form of "knowledge"	Description
Data	Text, fact, code, image, unstructured sound as abstracts without significant meaning.
Information	Organized, structured, interpreted, summarized data with a meaning to people.
Knowledge	Case, rules, procedures, ideas or thoughts that guide actions and decisions (this description of knowledge is in accordance to our definition).
Expertise	Expertise allows fast and accurate advice, explanation and justification of results, reasoning for decisions.
Capability	Organizational expertise: knowledge repository, integrated performance support system, core competence.

We notice the difference between knowledge and information. Information includes human participation in the purposeful organization of raw data (Terra and Angeloni, 2003).

According to Terra and Angeloni, the key difference can be summarized by the role played by the human beings. In the case of knowledge, individuals play a prominent role as creators, carriers, conveyors and users. In the case of information, these same functions can happen "outside" humans and without their direct influence. From a management perspective, the important difference between information and knowledge is that information is much more easily identified, organized and distributed with technological support. Knowledge, on the other hand, cannot directly be managed because it resides in one's mind.

In this document we will not go into deeper detail concerning the notions of expertise and capabilities. However, in the context concerning the difference between knowledge and information, some authors make the difference between tacit knowledge, explicit knowledge and information.

1.3.2 TACIT KNOWLEDGE – EXPLICIT KNOWLEDGE – INFORMATION

In the context of making the difference between knowledge and information, several authors introduce the concept of "tacit" and "explicit" knowledge (Nonaka and Takeuchi, 1995), (Barthes, 2000), (Kinghorn and Maasdorp, 1999). They make a distinction between "something" which could be called "tacit" and which is not accessible by other people without that the owner makes an effort to transmit, and something which could be called "explicit" and which is accessible for other people.

- Tacit knowledge refers to cognition that resides in people's mind, such as understanding, institutional knowledge, organizational lore, and basic orientations. It also includes personal knowledge embedded in individual experience in the form of rules of thumb, values, preferences, intuitions, and insights (Baker and Badamshina, 2003).
- Explicit knowledge refers to intellectual artifacts (books, documents, manuals, theories, tables, graphs, etc.). It encompasses all levels of cognition (including information and data) that can be put into visual presentations, words, or numbers (Baker and Badamshina, 2003).

In the context of our work, we will not take into account the difference between these two knowledge concepts. As knowledge is in peoples' mind, it is tacit. If it is explicit, we consider it as being information. Brohm (Brohm, 1999) argues that the notion of "explicit knowledge" is another expression for information which can be interpreted by receivers by using their expertise. We agree with this argumentation and therefore consider explicit knowledge as information as long as it possible to interpret this information.

1.3.3 INFORMATION / KNOWLEDGE TRANSFORMATION

Knowledge can be turned into information (in form of documents, best practices, etc.) via transformation process. During the process of speaking and writing people transform what they know into something that is materialized as records or symbols. These symbols resemble part of what these people know, but that is inherently different from what they exactly know (Von Krogh and Roos, 1995). Polany (Polany, 1997) said: "We know more than we can tell". The transformation process can therefore lead to the loss of certain knowledge.

The transformation from information into knowledge is linked to the expertise of the information consumer (for example reader of a document) and to the circumstances of the activity of the consumer. Considering this aspect, Prax (Prax, 2000) adds in a general manner a dynamic aspect to the transformation process. According to his opinion, knowledge exists only in action: knowledge exists when a rational agent (a machine or a human being) uses information in an intention.

These two processes play an important role for the knowledge management models and for knowledge creation processes based on information. However, in order to be able to transform information into knowledge, people need a certain expertise and need to know the context of the information. For each transformation, the human being brings in his own interpretation of the knowledge or information. Therefore, the information and knowledge can have different meanings for different human beings.

By interpreting knowledge or information, people can add a certain amount of context. This leads us to the aspects of context in information and knowledge transmission.

1.3.4 CONTEXT AND INFORMATION / KNOWLEDGE TRANSMISSION

In a general manner, context plays a crucial role for knowledge management (Ackerman and McDonald, 1996), (Giboin, 1999). The context aspect plays an important role for information and knowledge transmission if several people are involved. In order to be able to understand transmitted information, a certain context to the information is necessary (Prax, 2000).

If an owner of knowledge transforms part of his knowledge into accessible information and somebody else (the receiver) has access to this information, the receiver needs a certain context to understand the transmitted information (Prax, 2000). Therefore, part of the information produced by the owner is context relevant information to support its understanding by other people (Klemke, 1999). This means also that in order to be able to understand information and to transform it into new knowledge, people need context for this information (Figure 1.1).

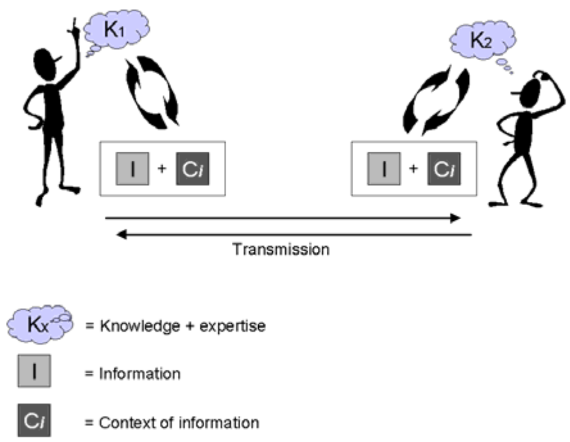

Figure 1.1 – Knowledge transmission

Additionally to the added context, the receiver needs a certain capacity and expertise in order to understand and interpret the information. Only with this expertise he is able to transform information into new knowledge.

Several people can access the same information and can create new knowledge. This knowledge can be different for each individual according to their understanding of the context. This leads us to the notions of individual and collective knowledge.

1.3.5 INDIVIDUAL AND COLLECTIVE KNOWLEDGE

Knowledge as an collective attribution is a concept that corresponds to the shared knowledge which persists independently of any individual within an organization (Walsh and Ungson, 1991),(Nonaka, 1994).

As examples for collective knowledge in an organization can be mentioned the knowledge about administrative processes, the knowledge about hierarchies and organizations, etc. (Grundstein, 2000).

However, as knowledge is linked to peoples' mind and therefore to individuals, collective knowledge describes in fact a shared understanding of certain aspects among a group of people. The basis of collective knowledge is therefore often based on a shared understanding of available information. Therefore, according to Barthes (Barthes, 2000), if the knowledge which was created during the interaction with other people stays non-formalized, it keeps an individual character: everybody has its own interpretation of the shared information.

This leads to the conclusion, that the notion of collective knowledge is relative. Collective knowledge is more based on a shared understanding of existing information. The information can be collective available for a group, but knowledge stays into a certain extent individual.

The notion of collective knowledge stays also relative between groups. For example, different teams in an industrial organization and working on different levels of a production process for the same product (for example design office and assembly line) have to a certain extent a shared knowledge about the product. However, as they work on different levels, they might have difficulties to communicate to each other.

The different concepts of knowledge can be assembled in a framework as shown in the next section.

1.3.6 AN ASSEMBLING FRAMEWORK FOR EXISTING KNOWLEDGE CONCEPTS

All the above discussed knowledge concepts are valid for knowledge intensive organizations (Prax, 2000). They do not exclude each other but they represent different points of views of the same concept.

Trying to represent the different points of views we can say the following: in an industrial organization, there are human beings representing a part of a knowledge basis which is necessary to execute industrial processes. This basis can be enlarged with organizational learning processes. These processes include processes of individual and collective knowledge transmission and the transformation of information into knowledge. We propose an overall framework (adapted from (Romhardt, 1998)) including the different concepts (Figure 1.2). This framework represents an organization from the different knowledge concepts points of view.

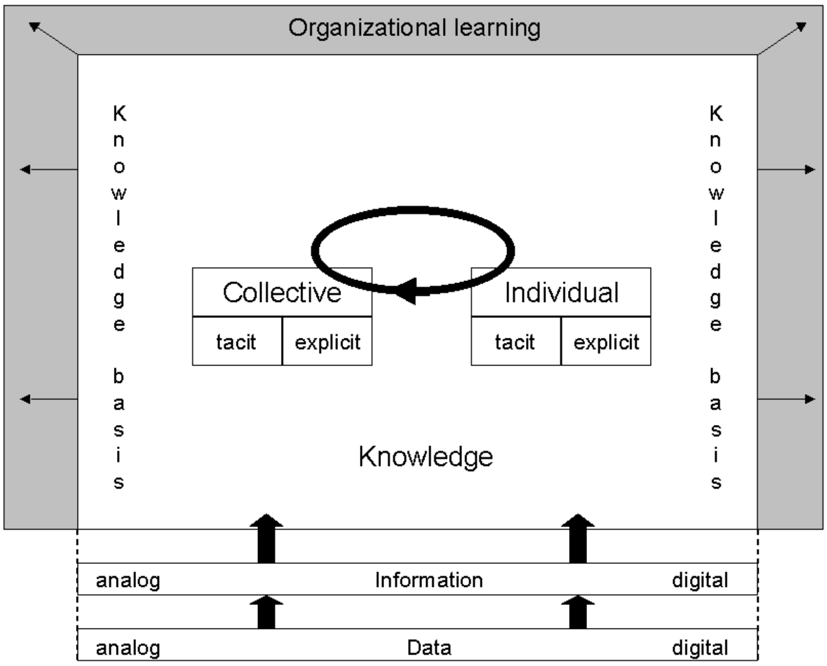

Figure 1.2 – Assembling framework for existing knowledge concepts adapted from Romhardt

Romhardt proposes to assemble the different knowledge concepts by introducing a certain dynamic between the concepts (represented with the different arrows). He introduces flows between the different representations of knowledge (ex. between collective – individual knowledge, data – information – knowledge).

The different flows can be stimulated via knowledge relevant activities (Prax, 2000). We already saw some examples of knowledge relevant activities: transforming information into knowledge, transmitting of knowledge, acquiring of knowledge, etc. The different flows represent the fact that knowledge exists only in action (Tiger and Weil, 2001): the creation of new knowledge depends on the activities and exchange among people, the transforming of information into knowledge and vice versa, etc.

These knowledge relevant activities are assembled in various knowledge management models. The following sections will give an overview about some relevant knowledge management models for the industrial context.

1.4 THE MANAGEMENT OF KNOWLEDGE

The following definitions show that the concept of knowledge management can be described from different perspectives. However, we can distinguish between two main perspectives: a process-centered perspective and a human-centered perspective.

For the process-centered perspective, there are the following definitions:

- "Knowledge management" is a multi-faceted, multi-layered concept which can be defined as: "any process or practice of creating, acquiring, capturing, sharing and using knowledge … to enhance learning and performance in organizations." (Scarborough at al., 1999).

- Lank (Lank, 1997) suggested that knowledge management involves "collecting, connecting, creating and applying knowledge for short term and long terms sustainability".
- In the same direction goes Wiig (Wiig, 1997) by defining knowledge management as "…the systematic, explicit, and deliberate building, renewal, and application of knowledge to maximize an enterprise's knowledge-related effectiveness and returns from its knowledge assets".
- Mackintosh et al. (Mackintosh et al., 1999) claim that knowledge management is concerned with managing both "knowledge assets" ("knowledge regarding markets, products, technologies and organizations") and the processes that act upon those assets.
- Myers on the other hand emphasis the capture and storage of knowledge in organizations' systems, processes, products, rules, and culture (Myers, 1996).

The following description emphasizes the human perspective of knowledge management.

- Lank (Lank, 1997) suggested that the knowledge management should facilitate connections between people, arguing that effective knowledge management ensures people with needs can find people who know within an organization.

The process-centered perspective describes knowledge management as a process of knowledge relevant activities, which allow managing the knowledge in an organization. The human-centered perspective describes knowledge management as an organizational issue of bringing people together.

From our point of view, the process-centered perspective includes the aspects concerning the transformation of information into knowledge and vice versa. If the concept of knowledge management should not be limited to the organization of people, as focused in the human-centered perspective, there is a need to take into account this transformation process. This allows supporting knowledge management with technical support as technologies can only act on information.

The difference between knowledge and information management can be illustrated with the following descriptions:

- Von Krogh, Ichijo and Nonaka (Von Krogh et al., 2000) propose that knowledge management is about supporting conversations and supporting a humanistic perspective of work. According to this work, information management is usually not concerned with knowledge creation processes.
- The objective of information management is to manage and make accessible to people the information content of information items like documents, presentations, etc. (Terra and Angeloni, 2003). The focus lies on the proposition of sophisticated technical systems which can support the objectives.

Knowledge management is, according to the above description, much more human-centric than information management. However, one starting point for knowledge management can be the management of information (Prax, 2000).

The concept of knowledge management is based on different theoretical models. These models describe in detail different knowledge relevant activities and their interaction to each other.

1.4.1 KNOWLEDGE MANAGEMENT MODEL FRAMEWORKS

For the knowledge management models we propose to take into account a distinction between holistic framework models and explanatory framework models (Studer et al., 1999):

- Holistic framework models provide a holistic description of knowledge management. They aim to describe and combine all major aspects of knowledge management and usually consider elements like organization, technology, humans, strategy, etc. and explain their particular role for knowledge management.

  The identified holistic knowledge management frameworks differ not only in their focus, but also in their depth in characterizing the nature of knowledge management phenomena.

  In the appendix section A.1, we give a detailed description of the following models:

  - The framework of knowledge management pillars from Wiig (Wiig, 1993),
  - The framework of core capabilities and knowledge building from Leonard-Barton (Leonard-Barton, 1995),
  - The model on organizational knowledge management from APQC (APQC and Arthur Andersen, 1996),
  - The framework of the knowing organization from Choo (Choo, 1996),
  - The knowledge management media reference model from Eppler and Sukowski (Eppler and Sukowski, 2001).

- Explanatory framework models aim to explain certain facets in knowledge management to emphasize a certain approach or message or to provide a small sub theory itself.

  In the appendix section A.1, we give a detailed description of the following models:

  - The framework of intangible assets from Sveiby (Sveiby, 1997),
  - The framework of knowledge conversion from Nonaka (Nonaka, 1994),
  - The knowledge management process cycle model from Romhardt (Romhardt, 1998).

The different models show different aspects of knowledge management. The following section will give a synthesis of the different models and we will discuss relevant aspects which might play a further role for our work.

1.4.2 A SYNTHESIS OF KNOWLEDGE MANAGEMENT MODELS

In this section, we will provide a comparative analysis of the different knowledge management models. This comparative analysis is based on an industrial context. As seen in section 1.2 an industrial organization needs access to information and knowledge resources as well as means to organize its knowledge to support industrial processes. In this context, we will highlight two aspects in this analysis:

- Knowledge resources identified in the models (Table 1.2): knowledge resources are the resources where industrial organizations gain the existing knowledge in order to acquire and produce new knowledge.
- Knowledge manipulation activities identified in the models (Table 1.3): knowledge manipulation activities concern the description of the knowledge relevant activities which might play a role in an industrial context.

Table 1.2 – The knowledge resources in the different knowledge management models

Author	Knowledge resources
Leonard-Barton, 1995	1. Employee knowledge 2. Knowledge embedded in physical systems
Sveiby, 1997	1. External structures 2. Internal structures 3. Employee competencies
Eppler, 2001	Community experience, insights, new concepts

Not many knowledge management models take into account the aspect concerning knowledge resources. They assume the resources as given. In the models describing the resources, it is possible to distinguish mainly between internal and external knowledge resources considering employee competencies as internal knowledge. Most of the models consider people as knowledge resources. This confirms the structure of knowledge as being fictive objects in peoples' mind. However, Leonard-Barton mentions also physical systems as knowledge resources. According to our distinction between knowledge and information, these physical systems are in fact information resources.

Table 1.3 – The knowledge manipulation activities in the different knowledge management models

Author	Knowledge manipulation activities
Leonard-Barton, 1995	1. Shared and creative problem solving 2. Importing and absorbing technological knowledge from the outside of the firm 3. Experimenting and prototyping 4. Implementing and integrating new methodologies and tools
APQC and Arthur Andersen, 1996	1. Share 2. Create 3. Identify 4. Collect 5. Adapt 6. Organize 7. Apply
Wiig, 1993	1. Creation 2. Manifestation 3. Use 4. Transfer
Choo, 1996	1. Sensemaking (includes "information interpretation") 2. Knowledge creation (includes "information transformation") 3. Decision making (includes "information processing")
Nonaka, 1995	1. Socialization (conversion of tacit to tacit knowledge) 2. Internalization (conversion of explicit to tacit knowledge) 3. Combination (conversion of explicit to explicit knowledge) 4. Externalization (conversion of tacit to explicit knowledge)
Szulanski, 1996	1. Initiation 2. Implementation 3. Ramp-up 4. Integration
Romhardt, 1998	1. Objective determination 2. Identification 3. Acquisition 4. Development 5. Distribution 6. Utilization 7. Preservation 8. Evaluation
Eppler, 2001	1. Identification 2. Evaluation 3. Allocation 4. Application

There is not a common standard way of characterizing knowledge manipulation activities. This is also due to the different knowledge concepts and levels.

Nonaka makes a difference between tacit and explicit knowledge for the knowledge manipulation and transformation activities. However, the SECI model does not give a precise description of these transformation processes. As we pointed out in section 1.3.2, we do not make the difference between tacit and explicit knowledge. Therefore, we see these transformation processes as knowledge into information transformation processes and vice versa.

The model of Choo takes into account the transformation process from information into knowledge. According to Choo, knowledge creation is based on information transformation. This implies that information could be a basis for knowledge creation processes. However, the model of Choo does not give any further detail, how this transformation from information into knowledge could be supported.

The models from APQC and Romhardt propose a relative detailed number of knowledge relevant activities. This gives a detailed view of possible activities to deal with knowledge in an industrial organization. Romhardt proposes besides the activities also a control process. This process controls the knowledge management relevant activities for the industrial context. The definition of knowledge objectives and the evaluation of knowledge, being the two elements of the control process, can be part of an industrial process. Therefore, the control process can constitute the direct link to the activities of an industrial process.

The knowledge manipulation activities described in the model of Wiig and Eppler are close to the manipulation activities to APQC and Romhardt. Therefore, we can say that the knowledge manipulation activities defined in the models of APQC and Romhardt represent the basic knowledge relevant activities which need to be supported in order to be able to have a knowledge management framework.

All the different models can be used to describe a knowledge management framework for an industrial context. However, we think, that the different transformation processes according to Choo or Nonaka and the different knowledge manipulation activities according to APQC and Romhardt are especially important for industrial contexts where innovative development takes place (Frank and Gardoni, 2003a). Therefore, we will synthesize the different knowledge manipulation activities of the APQC and Romhardt model for the of industrial research activities.

For this objective, we propose to merge the different manipulation activities of both models as following (the merger is possible as both models consider knowledge in general and do not make any distinction for internal, external, collective, individual, etc. knowledge):

- Identify: the activity is present in both models.
- Acquire: this activity is present in the Romhardt model. In the APQC model, this represents the "collect" activity. We consider that collecting of knowledge or information is part of the acquisition activity.
- Structure: this activity is not present in the Romhardt model. However, the APQC proposes an "organize" activity. Organize is often linked to the organization of people and activities. However, in order to be closer to the fictive object of knowledge and especially to related objects like information we prefer to use the notion "structure".
- Combine: this activity is not present in the two models. However, different activities can be integrated in the "combine" activity. For us, combining means, using existing

knowledge or information in order to adapt it to a new problem or to create and develop something new. Therefore, “combine” integrates the “adapt” and “create” activities from the APQC model and the “development” activity from the Romhardt model.

- Share: coming from the APQC model.
- Distribute: coming from the Romhardt model.
- Use: the activity is present in the Romhardt model and we propose to consider the “apply” activity from the APQC model as a use activity.
- Preserve: coming from the Romhardt model.
- Evaluate: coming from the Romhardt model.

However, besides the resource and knowledge manipulation aspects, some models propose other issues to take into account for knowledge management. The model from APQC takes into account a cultural aspect. This aspect plays also a role in our study context, as the industrial organization is a multinational industrial organization. Therefore, we will discuss possible cultural aspects of knowledge management in section 1.5. Eppler in his model mentions also the necessary implementation and infrastructure view of knowledge management. By infrastructure, he means organizational and technical infrastructure. In section 1.7.2 we will discuss in detail the technical aspect of knowledge management.

1.5 CULTURAL INFLUENCES ON KNOWLEDGE MANAGEMENT

Our study takes place in an international environment. We were working at the French and German industrial research center. The research centers belong to an international group which has facilities and management stuff located in France, Germany, Spain and which is deeply linked to companies in Great Britain.

As our study took place in different countries, the question was: does culture have an influence on knowledge management or knowledge management activities? Therefore, we conducted a bibliographic research on cultural aspects on knowledge management.

We can make a distinction between national cultural differences and enterprise cultural differences (Hofstede, 1998). For our study, we will focus more on national cultural differences. As the industrial group in our use case emerged from a merger of three national companies of three different countries which were already together for a certain period, we suppose, that enterprise cultural differences will slowly disappear with the new organizational form of international networks between the different units and the construction of a unique enterprise identity.

Cultural impacts on knowledge management relevant activities concern mainly knowledge identification, knowledge development and knowledge transfer (Hofstede, 1998). These activities are part of the knowledge manipulation activities in the models of APQC and Romhardt. Therefore, the cultural aspects can be integrated in these activities.

A general cultural problem for the different knowledge management relevant activities can be the language barrier. The exchange of complex information might be difficult when the different participants do not control a common language. Translation technologies might give a first support to avoid to language obstacle. However, when the exchange concerns complex subjects, these technologies are still limited or might be too expensive.

- Knowledge identification: knowledge identification is possible via expert location. This implies the transparency of the expertise of the employee who might be a part of an expertise location system. The transparency goes against the German sense of constant security (Hofstede, 1998). German unions have a critical viewpoint on the introduction of such systems. Their basic argumentation is that with the introduction of such systems, the employee becomes transparent and therefore can be easier replaced. On the other hand, expert location systems are well developed in Great Britain. In this country, the individualism is much more developed and the feeling of uncertainty does not play an important role.
- Knowledge development: the development of new knowledge can be an individual or collective process (Nonaka, 1994). The development of new knowledge implies the way to define a problem and how to look for a new solution. This implies the definition of what is an acceptable result and what is a relevant information which plays a role for the solution development (Pateau, 1998). In an international group, a knowledge development process can imply a multi-cultural teamwork environment. In this environment, different ways of thinking are confronted. These different ways of thinking have an impact on the solution development (Galtung, 1981). In our context, we can distinguish between the Teutonic, Gallic and the Anglo-Saxon way of thinking (Table 1.4).

Table 1.4 – Teutonic, Gallic and the Anglo-Saxon way of thinking (Galtung, 1981)

Teutonic	Gallic	Anglo-Saxon
• Theoretical arguments are essential • Precise and exact thinking processes lead to „perfect“ concepts • Solutions are considered as being absolute, non-exchangeable and individual	• Theories are less absolute • The truth is a relative and changeable construction : “... something fleeting and floating“ • Facts and numbers only serve for illustrating statements • Evaluation criteria are rhetoric style, elegance and good speeches	• Make great efforts looking for proofs for their statements • Preference for empiric reality • Not very strong in theory formation, and not that strong on paradigm awareness

Support for knowledge development processes need to take into account these different ways of thinking. The information which is manipulated by such systems can vary according to the cultural influence. This might cause impacts of means supporting the knowledge combination and assembling to new results.

- Knowledge transfer: According to Barmeyer (Barmeyer, 1998), the different cultures can have an impact on the context which accompanies the knowledge transfer (Table 1.5).

Table 1.5 – Knowledge transfer in cultural differences (Barmeyer, 1998)

Low-context knowledge transfer	High-context knowledge transfer
Ex. Germany	Ex. Spain, France, England
• Low information density • An important information needs always to be explicit • If possible, focus on written information • Need for more detailed additional information to understand the whole content of the communication	• High density of information • Important information are transferred in a indirect way • Preference for oral transfer • General implicit understanding and less need for additional information to understand the whole content

In our study we are confronted with a low-context and a high-context knowledge transfer environment. We will have to consider this for our solution proposition.

As we have seen with these three knowledge management relevant activities, the respective national culture might influence the conception of a knowledge and information management system. For a transnational use of such a system, the different cultural aspects need to be taken into account.

In this section describing the cultural aspects of some knowledge relevant manipulation activities, we started actually to describe the different practices, how the knowledge manipulation activities are realized in practice. In literature, we can find different ways of how the knowledge manipulation activities are realized. Therefore, we will describe in the next section some practices for the different main knowledge manipulation activities.

1.6 KNOWLEDGE MANAGEMENT PRACTICES

Different practices can support knowledge management in an industrial organization. The practices depend on the activity context of the people: if people are working in a development, administrative, manufacturing, etc. context, their knowledge management relevant practices might be different.

In this section, we will discuss some more general knowledge management practices in order to prepare the discussion and description of knowledge management practices in the context of industrial research activities.

We will orient the discussion of the practices according to the knowledge manipulation activities described in the merger of the APQC model and the Romhardt model of section 1.4.1.

According to these different activities, we describe the following practices as some examples (Table 1.6):

Table 1.6 – Knowledge manipulation activities and examples of relevant practices

Knowledge manipulation activities	Practices (some examples)
Identify	Identify information in dispersed resources inside and outside the industrial organization. Practices can concern visiting regularly other experts, industrial tradeshow events, etc.
Acquire	Acquiring new knowledge by introducing experts in industrial organizations (job offers to experts, etc.).
Structure	Structure knowledge by structure experts in synergic groups or competence centers. The structuring can also include the structuring of information for example in form of documents in a coherent way.
Combine	The combination of knowledge can be represented in various ways. Building working groups for specific problems. This is similar to shared project organization where people work commonly in the same project. But also the elaboration of a new document by an individual can be seen as a form of knowledge combination.
Share	Sharing can be done in communities. Therefore, organizations establish communities where people meet regularly to share their knowledge. People can share knowledge by preparing written documentation such as lessons learned, training manuals, good work practices, etc.
Distribute	Distribution concerns more information objects. Here the objective is to distribute the right information to the right people. Information objects can be documents, etc.
Use	Use is close to combine. In order to combine, people use knowledge or information. They can do that in various ways: read a document, assemble a new document with parts from existing documents, create new products from new ideas, etc.
Preserve	The practices for the preservation include the storage of information in form of documents in various formats. However, also the distribution of knowledge or information can be seen as a form of preservation: as more people know about something, as longer is it possible, that the knowledge or information can be retrieved.
Evaluate	For evaluation, there is no real practice. Evaluation is often linked to decisions. People could evaluate information or establish a knowledge map in order to evaluate the value of accessible knowledge. Other methods can concern the evaluation of intangible assets like presented in the model of Sveiby (Sveiby, 1997)

In these different practices we can distinguish between individual, team and organizational practices (North, 1999):

- Individual practices concern non-shared practices of an individual. This concerns the non-shared organization of information elements like documents, the personal channels to identify and acquire new knowledge or also personal networks to share knowledge with other people.
- Team practices concern shared practices among people working in a team organization. These practices concern mainly the way of exchanging information between the team

members (this includes that the team members know where to access to information of other team members, how to reach the different team members, etc.).

- Organization practices concern more administrative practices or official networks between organizations. The members of the industrial organization use these administrative practices or networks.

In order to facilitate the practices, they can be supported with organizational aspects and partly with technical support. We will discuss this knowledge management support in the next section by focusing on the technical support.

1.7 Supporting Knowledge Management

The description of the practices showed, that that managing of knowledge is mainly a question of organizing the communication among peoples and of accessing and organizing information items. Therefore, the knowledge management support concerns the introduction of facilities supporting the communication among people. On the other side, in the age of new information and communication technology facilities, it is possible to support communication among people and give access to new information with modern technologies and support the exploitation of available written information for new knowledge creation.

Written information content is mainly available in documents in various document formats. Therefore, a better handling and exploitation of written information content can be part of the management of knowledge.

We will focus on the three above-mentioned aspects in this section: supporting the human factor for knowledge management, technology support for knowledge management and the importance of written information and document content.

1.7.1 Supporting the Human Factor – The Community Support

We will only give a brief overview of literature concerning the community support as the focus of this study lies on technical support for knowledge management.

In literature, authors often discuss communities of interest or communities of practice as one appropriate support for the human factor (Savage, 1996), (Wenger, 1998), (Wenger and Snyder, 2000), (Steward, 1997). The difference between communities of interest and communities of practice is that, in the latter, the primary focus is on the conduct of some specific set of work practices, rather than on creating and sharing more generic knowledge that may have some potential future application. Communities of practice are directed at focal knowledge (an immediate concern), while the goal of communities of interests is to enhance knowledge that is more general.

The introduction of communities of practice or interest can imply organizational changes. People might belong to different communities. Regular exchange meetings support the communication among the people in these practices.

The different communities can be supported with information and communication technologies. These technologies can support the practices of the community, acting as a team, but also the individual.

1.7.2 TECHNOLOGICAL SUPPORT FOR KNOWLEDGE MANAGEMENT

For knowledge management, the technology can play the role of a “facilitator” by providing to individuals and groups the necessary means to communicate their knowledge and to have access to information for new knowledge creation (Balmise, 2003).

We will discuss some important technologies which can be part of a knowledge management platform. However, this discussion will not be exhaustive because many technologies and tools can contribute to basic knowledge management functions (Kühn and Abdecker, 1997).

Tiwana (Tiwana, 2002) proposes a list of some knowledge management relevant technologies which can contribute to the construction of a knowledge management platform. We think that this list is representative for the most relevant knowledge management technologies.

The description of the main functions is in fact a link to the merged knowledge management manipulation activities from the APQC and Romhardt model. This allows us to make a link between the knowledge management relevant manipulation activities, the practices and their technology support.

According to Tiwana, the knowledge management relevant technologies are the following:

- Intranet:

  Intranets are composed of services which are connected to a local network. This means, the different functions of an intranet are only accessible via a local network. An intranet uses the standards of the Internet in order to realize an internal information system. On this platform, an unlimited group of tools can be installed.

  The main functions of an Intranet application are: distribution, connectivity, publishing.

- Groupware:

  Groupware technologies describe the overall tool applications which facilitate the group work. The Groupware tools support the asynchrony exchange of information (Gardoni, 1999). According to Sandkuhl and Messer (Sandkuhl and Messer, 1998), Groupeware is based on seven main tools: messaging, publication, shared agenda, shared file, formula, workflow, and forum tool.

  The main functions of a Groupware application is: asynchrony collaboration and sharing.

- Web / Video conferencing:

  Web / Video conferencing technologies describe the applications which allow the synchronous exchange of information in form of conversations with image support. This technology makes distance a less important handicap to communicate with several people at the same time. These technologies can play an important role for a community support. However, if web / video conferencing technologies a really part of knowledge management technologies could be discussed.

  The main functions of a Web / Video conferencing application is: dialog.

- Business intelligence:

  Business intelligence technologies support the user to identify external information according to certain criteria or a certain profile. Business intelligence technologies are often used to make external technology monitoring. The technology allows searching in large internet areas and then filtering for relevant information. Once these internet areas are filtered they can be monitored for ongoing changes and updates. This allows focusing on a selective information flow from an external environment (the internet) to an internal environment (an intranet).

The main functions of business intelligence applications are: identifying and capture new external information.

- Data Warehousing:

  Date warehousing is an overall technology concept including data mining and text mining. Data mining is a technology allowing the tracking of data in large structured databases. The technology is based on data retrieval technologies where the user can introduce search criteria in order to find data. The principle of text mining is similar to the principle of data mining. Text mining focuses on unstructured documents.

  The main functions of data warehousing applications are: knowledge discovery.

- Expertise pointers:

  Expertise pointers are known under the tool description “yellow pages”. Based on a search demand, expertise pointers locate people having a certain expertise. The expertise is described in profiles of the people being in the expertise systems.

  The main functions of expertise pointer applications are: identification of peoples’ expertise.

- Expert systems:

  An expert system is regarded as the embodiment of a knowledge-based component from an expert skill in such a form that the system can offer intelligent advice or take intelligent decision about a processing function. Also know as knowledge based systems, they are computer programs, designed to simulate the problem-solving behavior of human experts within very narrow domains or scientific disciplines.

  The main functions of expert systems applications are: knowledge combination, problem solving.

- Document management:

  Document management is a support for a systematic organization of documents. The objective is to index the different documents in order to be able to structure and make them accessible for the users.

  The main functions of document management applications are: organize the documents in an organization.

- Content management:

  A description of content management is done by Koop (Koop, 2001): “A focused, systematic and general handling with information in order to create, administrate, distribute and use content.” Other propositions to describe content management focus on the elaboration and administration of digital content which is published on the internet or on internal intranets (Infoquelle, 2003). Sometimes, instead of using content management systems people use the term editing system or production system (Feldman, 1998).

  Other content management systems focus more on content interpretation technologies (Jones et al., 2003) or retrieval and sharing of digital content (Das and Banerjee, 2002). Starting from existing documents, they analyze the content in order to be able to extract automatically the essential context of a given piece of text. This extraction can be compared with other texts to test whether there is any overlap for a contextual relevance. This technology can be used for advanced search and retrieval, multi-dimensional text classification, auto-summarizing, etc.

The main functions of content management applications are: the creation and exploitation of document content (publishing / distribution).

The different technologies manage in fact information in different formats. Almost all technologies manage information in written format except of web / video conferencing. Technically, written information can be available in emails, databases, documents, presentations, etc.

According to Feldman (Feldman, 1998) up to 80 % of a company's explicit knowledge is typically stored in the form of text documents, rather then in formally structured databases. This implies the need to be able to explore the document contents. The corpus of documents within a company represents a valuable repository of knowledge (Dieng, 2000).

In order to favor the exploitation of documents or more in general, of written information, we need to have a closer look on the structure of written information and possible description frameworks for document contents.

1.7.3 The importance of written information and document content – relevant concepts and technologies

Documents are an important part of a firm's knowledge assets (Ginsburg, 2001). As the number of documents is growing inside an organization, the challenge to access and retrieve them effectively grows as well. Current systems are hampered by the fact that access is usually an ad-hoc process (Ginsburg, 2001). There is no coordination between readers as they search nor is there usually ontological assistance to help navigate search and retrieval. The situation is provoked by various socio-technical factors (some examples):

- Document islands: users store their documents in folders which are inaccessible for other users in the organization.
- Terminology difficulties: users interpret content in different contexts and apply documents in different use cases. This causes the development of different terminological use contexts for different users of the same content.
- Adoption barriers: users do not share document contents because of the different work context and different terminology representations of the content.

This means, ineffective access implies mismanagement of the authors' expertise. Authors' expertise can contribute significantly to the knowledge production process for new research results. The exploitation of the document content resources means therefore supporting the industrial research activities.

Many schemes for registering shared resources and providing structured descriptions originator on the crucial 'capture bottleneck' – the envisaged users of the system simply do not have the motivation or time to invest in sharing resources to reach a critical mass of useful material (Buckingham-Shum et al., 1999). This conclusion can be drawn from an analysis of the computer supported argumentation literature (Buckingham-Shum and Hammond, 1994), confirmed by indications relating to groupware (Grudin, 1994), design rationale support (Buckingham-Shum et al., 1997), organizational memory systems (Buckingham-Shum, 1997b), (Selvin, 1999), and indeed, for many CSCW systems that require users to formalize information (Shipman and Marshall, 1999). These technologies often provide schemas of semantic node-link types. However, rich taxonomies of node and link types very often overwhelm users. The effective use of semantic hypertext links may depend on finding the right mix of target domain, context of use and user community.

Some people consider that information content management technologies play an important role for knowledge management technologies (Jones et al, 2003) (Beckman, 2000). The central assumption is that explicit knowledge is represented in form of text documents. Many workers of a company spend considerable amounts of time writing documents directly related to their work experience, in which they record items like (Jones et al, 2003):

- Raw data gathered by experimentation, hands-on experience, and / or observation,
- Description of a particular event or specific case,
- Interpretation of data,
- Beliefs, guesses written in documents,
- Ideas, theories, opinions written in documents,
- Conclusions, summaries, recommendations, judgements, proposed actions.

The assumption considers that such documents are able to communicate an explicit representation of at least some of the knowledge and expertise of their authors. The representation of the knowledge is encoded in the document content.

Therefore, a knowledge management tool should be able to support the exploitation of the content of documents. Before going into deeper detail about the content of documents we will discuss the deferent documents types in an industrial organization. The different types can have an influence on the content.

1.7.3.1 Document types

In industrial organization, there are various types of documents (Dieng et al., 2000):

- Personnel documents: notes, personnel archives,
- Documents linked to a project: minutes of project meetings, product specification documents, design documents, test documents, contractual documents like the requirement or functional specification, technical contractual reports,
- Internal norms and standards, rules and procedures,
- Reference bibles on a professions,
- Expertise sheets,
- Product catalogues and sell argumentations,
- Quality documents,
- Image documents like photos, scanned plans,
- Technical reports, scientific and technical articles,
- Books, theses,
- Online documents, reference manuals, user manuals,
- Press reviews useful for business intelligence,
- Exchanges via electronic mail.

These documents can have different statuses: they can be confidential, confirmed, being documents of reference or in contrary, working documents (for example during a project), being obsolete, or being part of archives (Fondin, 1998).

The text in these documents can be non-structured, semi-structured (the text contains some markers which allow to identify a certain structure for the document), and structured (like in a document database) (Gardoni, 1999). The structure of a document and its text format allows supporting the retrieval of information content. For electronic documents which might be managed by an information system, identification structures like "tags" help to guide the information system to find the relevant information content. SGML, XML and ODA/ODIF are languages which help to describe the structure of a document (for a detailed description of XML see appendix A.2).

Each document has a certain structure. We can distinguish between a physical structure and a logical structure (Brugger, 1998), (Taghva et al., 1998). The logical structure describes the organization of the document content before it is represented in the physical structure (Brugger, 1998). The following figure describes the different possible elements of the logical document structure (Figure 1.3).

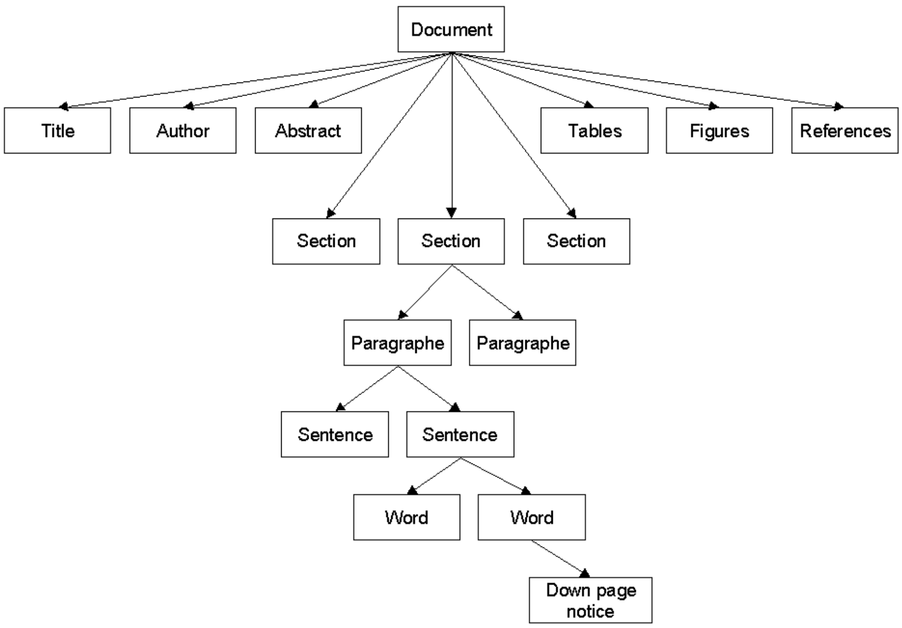

Figure 1.3 – Logical structure of a document (Taghva et al., 1998)

Each document type has its characteristic logical elements, how they are assembled, and how they are represented in a layout (Brugger, 1998). The different characteristics of a type constitute a logical document model.

The type of the document has an influence of the document content. For example, personal documents contain a different content than official documents. For official documents, we can for example distinguish between technical reports describing mainly technical data, and quality documents, describing quality procedures.

Therefore, the document type can guide the reader about the probable content of a document. However, in order to characterize the document content, we will use additional concepts to support knowledge creation from written information.

1.7.3.2 Characterisation of document content – concept of aboutness and relevance

A document's content can be divided into 'facts' (axiomatic 'truths' that the author(s) copied and pasted from other data sources that are believed reliable), author assertions regarding these facts, and structural information (Ginsburg, 2001). These different aspects can be described partly with the addition of document meta-data to the document content.

In information retrieval literature, authors discussed several concepts to describe the content of a document (Maron 1977), (Froehlich, 1994), (Barry, 1998), (Tang, 1999).

The "concept of aboutness" describes of what a document is about. However, the definition of aboutness depends of the reader of the document: there can be made a difference between aboutness and meaning (Tang, 1999). Maron (Maron, 1977), suggests three forms of aboutness: objective about, subjective about, and retrieval about. The objective about is "obtained by considering an external or observer's point of view". The subjective about, on the other hand, is related to an individual's inner experience of what a document is about as the person reads the document. The retrieval about refers to "the information searching behavior of a class of individuals" as reflected by the retrieval results. Beghol (Beghol, 1986) transforms the concepts of objective and subjective about into the concepts of aboutness and meaning.

Beghol proposes that the notion "aboutness" shows that "a document has an intrinsic subject, an 'aboutness', that is at least to some extent independent of the temporary usage to which an individual might put one or more of its meanings". Beghol argues furthermore that a document or a text may have only one aboutness, but an unlimited number of meanings, differing according to the exact use a particular person may find for the document's aboutness at a certain time.

Froehlich (Froehlich, 1994) and Barry (Barry, 1998) make the link between aboutness and relevance. For them, different meanings of a document can be derived from the different readers at different times. The different meanings may be extended to imply that users have different perceptions of the relevance of the content of a document.

Mizzaro (Mizzaro, 1997) developed a simple structure in defining relevance. He specifies that relevance is a relation between the entities of two groups: the first group contains either "Document," "Surrogate," or "Information," the second group includes either "Problem," "Information Need," or "Query". With this structure, relevance can be operationally defined either as a relation between surrogate and a query, or a relation between a document and an information need, and so forth.

In the study of relevance, the terms "usefulness" or "utility" often occur simultaneously with the term "relevance". Cuadra and Katter (Cuadra and Katter, 1967) suggest that usefulness refers to the use orientation of the information, in other words, usefulness is reflected by the intended use of the documents. Cooper (Cooper, 1971) uses the term "relevance" to describe topical relevance and links it with the concept of "utility". For him relevance has to do with whether or not a piece of information is on a subject which has some topical relation on the information need in question and utility, which has to do with the ultimate usefulness of the piece of information to the user.

According to Saracevic (Saracevic, 1997) an information system has to provide information that has utility. This means, information that helps to directly resolve given problems, that directly aim on given actions, and / or that directly fits into given concerns and interests.

The concept of aboutness describes the information content of a document according to a certain domain description. The concept of relevance describes the information content of a document according to a certain problem environment description (an information is relevant for a certain problem – concepts of relevance).

However, according to Schamber, Eisenberg and Nilan (Schamber et al., 1990), there are three aspects to take into account for the aboutness and relevance of information:

1. Aboutness and relevance are multidimensional cognitive concepts whose meanings are largely dependent on users' perceptions of information and their own information need situations.
2. Relevance is a dynamic concept that depends on users' judgements of the quality of the relationship between information and information need at a certain point in time.
3. Relevance is a complex but systematic and measurable concept of approached conceptually and operationally from the user's perspective

These three aspects stress a multidimensional concept of relevance and aboutness. For Tang (Tang, 1999) the concept of relevance is dynamic and situational.

Another important issue for the use of the above concepts is the possibility to add context to information: "contextualizing information is a powerful way to increase both the interest of an audience and the audience's propensity to act on information in a certain way (Davenport and Prusak, 1998).

Besides the description with these two concepts, it is possible to attribute additional argumentations on document content. These additional argumentations can be seen as a form of capitalizing the knowledge of the reader. This leads us to the concept and tool support for annotations on documents.

1.7.3.3 Argumentation on document content – annotations

The idea of annotations is not new. They exist primarily for the semantic Web environment. There are three types of annotations for the semantic Web: simple meta-data (modification dates, authors, etc.), annotations exploiting the resource of existing programs (Bremer and Gertz, 2001) and cognitive semantic annotations designated for reader who can get an actor (author) in the Web environment (Kahan et al., 2001). For this third type, the reader gets an author and introduces supplementary argumentations to existing written information content.

Argumentations concerning given information content are part of any new knowledge production activity (Martin et al., 2001). A support of these argumentation activities, generally transmitted via hand notes on documents or via electronic messages, is important in the context of any "long" development cycle (Zacklad et al. 2003). Long development cycles can concern research activities and research programs covering a problem environment for several years. This support is also important to be able to "capitalize knowledge" from one project to another in order to be able to reuse already existing argumentations (Zacklad and Grundstein, 2001) but can also support the sharing of information among researchers.

Annotations can be of personal character but can also be designated to other people working on similar problem environments. In the second case, the annotation plays a role in the context of a knowledge management process: the cooperative management of knowledge (Lewkowicz, 2000). The cooperative management of knowledge focuses on functions supporting organizational learning processes in providing tools and methods which are integrated in the daily work processes and which support the documentation and formalization processes.

The annotation can be defined as being (Montmain, 2001):

- An informative data which is judged as being useful,
- An interpreted elementary knowledge,
- A reasoning track,
- A sense unit which is shareable and reusable.

There exist technologies allowing the annotation of documents or documents zones. Annotations are especially used for semantic Web applications. These sorts of annotations give the reader of the Web page the possibility to add information to parts of the page. For indexing and annotating a document, the W3C developed a further language: the RDF (Resource Description Framework). The combination of XML and RDF leads partly to what is nowadays called the "Semantic Web". RDF allows annotating documents via a formalism which allows to reference the document via terminological knowledge in form of ontologies. This supports information retrieval mechanisms by using the defined ontologies as meta-index for documents.

Among the different solutions available today, here two technical solutions to store the context and the content of an annotation in this environment as examples:

- For the first solution, the annotations are stored and integrated in a document via a proxy server. In order to see the annotated document, the users link the address of the Web page with the address of the proxy (for example Annotator (Ovsiannikov et al. 1999), CritLink (Yee, 1998)).
- The second solution is based on the implementation of additional functions in the Internet navigator vie plug-ins or external application. These plug-ins or applications allow to integrate the annotations stored on one or several servers when the pages is displayed (for example Commentor (Röscheisen et al. 1994)).

Both solutions need a Web application environment. In addition, the first solutions allow only annotations in HTML.

The standard Annotea developed by the W3C (Kahan et al., 2001) is based on a RDF description for the annotations. The annotation server stores the annotations in a RDF database and the user can access the server for searching an annotation, create a new one, or delete one. An annotation is represented as an ensemble of meta-data (its attributes) and a corpus (its text). The meta-data are integrated in the RDF schema.

However, the different domain or problem environment descriptions need certain reference descriptions. These reference descriptions are shared concepts among a group of people working in the same domain and understanding the concepts. The reference descriptions lead us to the field of ontologies.

1.7.3.4 Ontology as a concept to approach document content

One definition of what an ontology is, is given by Sure (Sure, 2003): "An ontology is an explicit, formal specification of a shared conceptualization of a domain of interest." Formal refers to the fact that an ontology should be machine readable (which excludes for instance natural language). Shared reflects the notion that an ontology captures consensual knowledge, that is it is not private to some individual, but accepted as a group. The reference to a domain of interest indicates that for domain ontologies one is not interested in modeling the whole world, but rather in modeling just the parts which are relevant to the task at hand.

In order to represent a given domain, it is necessary to restrain the description of the domain in a certain number of significant concepts sufficient to interpret this domain (Valente and Breuker, 1996). An ontology integrates the definitions which give the conceptual vocabulary which allows to communicate of a certain subject inside the domain. This allows to define (a) the usable concepts to describe knowledge, (b) the relations between the concepts and (c) their usage constraints (Dieng, et al., 2000). An ontology is interesting when it describes the consensual knowledge shared by a community. It supports the reduction of conceptual ambiguities and confusions and assures a shared comprehension for a community.

In order to share information in an organization, it is necessary that the people in this organization share the same vocabulary and that the terms mean the same thing for everybody. In order to achieve this, the role of a terminology is to establish the vocabulary (the terms) of a domain or activity sector. The complementary role of an ontology is to define the concepts (sense for the terms) of this domain or activity sector. In practice, different types of documents (glossary, index, terminological ontology) associate terms to their semantic content.

According to this definition, an ontology can play the role of defining the meaning of the content of documents. As the ontology is shared among user and formal, it can be used as a reference model for information content. According to this reference model, the concept of aboutness and relevance give a signification for people being aware of the ontology used by these concepts. It makes possible for people to communicate on an information content with a common understanding of the reference model being behind the information content.

After having discussed the different supporting aspects for knowledge management, we will discuss in the next section a systematic way to introduce knowledge management in an organization.

1.8 MODEL TYPE FOR KNOWLEDGE MANAGEMENT INTRODUCTION IN AN ORGANIZATION

As our objective is to introduce aspects of knowledge management for industrial research activities, we need to discuss a basic knowledge management introduction framework. We will orient this discussion based on the knowledge management introduction framework proposed by Tiwana (Tiwana, 2002). From our point of view, this framework is relatively complete neutral compared to other frameworks in literature. Neutral because many other frameworks depend on the knowledge they focus on or some specific knowledge management relevant activity. This framework addresses a general knowledge management introduction.

According to Tiwana, the knowledge management introduction process can be divided into four phases: the infrastructure evaluation phase, the knowledge management system analysis, design, and development phase, the deployment phase and the evaluation phase. Each phase contains further steps which we will discuss in the following sections.

- Phase 1: infrastructure evaluation:

  The first phase involves two steps. The first step concerns to analyze the existing infrastructure. The objective on this step is to identify the existing structure on which it would be possible to build new knowledge management functions. On the other side this step helps to identify the gaps which might exist to a new knowledge management system.

The second step consists of aligning knowledge management and business strategy. As knowledge management can have an impact on the business strategy, it is important to take the strategy into account and vice versa. Knowledge management very often concerns the operational level of an organization. Nevertheless, in order to be able to introduce a new knowledge management system in the operational level, business strategy support is necessary.

- Phase 2: knowledge management analysis, design and development

  The second phase involves five different steps. Counting from the first two steps in the first phase, the third step concerns knowledge management architecture and design. In this step the selection of the infrastructure components that constitute the knowledge management system architecture takes place.

  A knowledge audit and analysis is conducted during the fourth step. The knowledge audit identifies the already existing knowledge in an organization. This is an important step because it determines knowledge sources and potential knowledge gaps.

  The objective of the fifth step is the design of the knowledge management team which will design, build, implement, and deploy the knowledge management system for the company. We see this step more flexible. In our point of view, a first team definition takes already place at the beginning of each knowledge management initiative. Moving further on in the knowledge management introduction process, the team members might change or be less involved for certain steps. Strategic team members will be certainly involved at the beginning of the project, whereas technical team members will be involved in the middle until the end.

  The sixth step concerns the creation of the knowledge management system blueprint. This blueprint provides a plan for building and incrementally improving a knowledge management system. Having such a blueprint, future technologies can be implemented in the already existing knowledge management architecture.

  Step seven then concerns the knowledge management system development.

- Phase 3: deployment

  The third phase involves the process of deploying the knowledge management system and the introduction of reward structures.

  Step eight concerns therefore a pilot deployment in order to examine the adoption of the new system by the users. This pilot allows to undertake improvements before releasing the system for the whole organization.

  The objective of step nine is to think about leadership and reward structures. Very often in order to get to run a new knowledge management system, reward structures need to be introduced. This supports the motivation of the employees of an organization to use such systems. This step concerns also the management of cultural changes coming along with the introduction.

- Phase 4: evaluation

  The evaluation phase contains the last step of the introduction framework. The objective of this last step is to introduce performance measurements. Measures like ROI (Return on investment) can give indications about the performance of the system. This evaluation phase helps also to identify improvement potentials for the existing system. These improvement potentials can be implemented in a next introduction round of new features for the knowledge management system.

1.9 CONCLUSION

In order to improve the performance of industrial processes or to improve the products and services produced by these processes, people involved in these processes need access to new knowledge.

As knowledge resides only as fictive objects in people's mind (according to our definition), people need to be brought together in order to communicate and exchange to have access to knowledge. However, as it is difficult to bring always people together, another possibility to have access to people's knowledge is having access to written information.

From the knowledge management models, we saw that there are several information and knowledge resources. In the next chapter, we will discuss the main knowledge and information resources for an industrial researcher center.

The knowledge models provided also a set of knowledge manipulation activities which we synthesized in the nine main activities: identify, acquire, structure, combine, share, distribute, use, preserve and evaluate. These manipulation activities are realized in knowledge management practices and technical tool support. We will use these knowledge manipulation activities for a basic structure to analyze the practices of industrial researchers and to structure a tool proposition in the context of industrial research processes.

As our work will focus on a more technical solution proposition for industrial research activities and here in specific focusing on the exploitation of document content, we needed to have a closer look on the different documents and their content structure. With the concept of aboutness and relevance we have the possibility to describe written information content for an industrial context and therefore should be able to adapt these concepts to the industrial research context. The concept of ontology should here support to describe the industrial context.

In a later section (section 3.4) we will therefore discuss and analyze the different knowledge management relevant practices of an industrial researcher with a tool support acting on the exploitation and manipulation of written information content in the context of industrial research activities.

For this, we have to clarify the notion of industrial research and describe the context of an industrial research center which is the objective of chapter two.

2 INDUSTRIAL RESEARCH IN THE CONTEXT OF AN INDUSTRIAL RESEARCH CENTER

2.1 INTRODUCTION

In this second chapter, we will define the notions industrial research and clarify the role of an industrial research center. In this context, we will describe the role from three points of views:

- The industrial research center customer: we will describe, how the customers and their needs direct the roles of an industrial research center.
- The product of an industrial research center: we will describe the different aspects and specifications of the product (or research results) of an industrial research center. In this context, we will show the difference between industrial research and academic research.
- The industrial research process: we will describe the different main activities in the industrial research process from a literature point of view.

The description of these three points of views is driven from a literature analysis. However, some of the literature description and models are extended with own description and specifications. This was necessary, as we tried to describe the role of an industrial research center from a knowledge point of view. Literature does not provide exhaustive descriptions of this aspect.

In order to generate research products for industrial research customers, the industrial researcher uses knowledge and information coming from various resources. We will discuss the different resource networks of an industrial research center in further detail.

2.2 INTERACTION BETWEEN SCIENCE AND INDUSTRY – THE HISTORICAL AND ECONOMICAL CONTEXT

Today, technological progress is partly based on new scientific achievements and their realization and distribution via industrial companies. Technology progress is therefore partly based on the interaction between the world of science and the world of industry.

From a historical perspective, this interaction followed a certain development. During 1826 Wilhelm von Humbold founded the University of Berlin and the first chemical laboratory. These new research areas lead to new industrial sectors trying to apply the scientific research as it can be shown with the appearance of the German chemistry industry. Two scientists initially working at the laboratory of Liebig at the University of Berlin founded Hoechst, becoming rapidly one of the leaders in the industry of chemistry during the 19th century, in

1863. New scientific results to produce artificial colors lead to this foundation. During the same time the two competitors of Hoechst, Bayer and BASF, founded their activities on the results of the laboratory of Liebig. The relation between this new industry sector and the academic laboratories got new dimensions.

A constant exchange between the two environments, the one of science and the one of industry, started to take place (Locke, 1984). This constant exchange was one reason for the acceleration of technological progress in the industrial environment (Lefebvre, 1998)

Today's companies, being in an environment of competitive advantage, need to follow and control the acceleration of technology progress in order to be able to maintain their product and service market position. Not controlling technology progress represents a risk for the activity of a company from a mid-term and long-term point of view in terms of market share loss.

One possibility of controlling technology progress was and is the control of some scientific activities. These argumentations conducted industrial enterprises to establish facilities which allowed this control: for the first time during the years 1900 – 1920, industrial central research laboratories or centers appeared with examples from Bell-ATT, GE, DuPont and Alcoa. These industrial research centers leaded industrial research activities to support the development of new activities and products of the industrial group they were belonging to.

The argument for establishing and maintaining and industrial research center is thus an economic one: the industrial research center is a means to acquire monopolies based on technology control (Le Masson, 2001). They help to achieve new technology standards important for further developments. Therefore, an industrial research center can be seen as a means to control innovation and the evolutions of the technical bases in industrial enterprises. This control of innovation can be seen from two points of views: it is important to control further developments on existing technologies but also new developments on new technologies and new requirements. The control of innovation can lead to market leader positions.

the industrial research center leading industrial research activities is therefore one means to assure the interaction between science and industry.

2.3 A DEFINITION FRAMEWORK FOR INDUSTRIAL RESEARCH

The OECD (Organization for Economic Co-operation and Development) proposes a description framework for scientific technical activities which leads to the definitions of the terms research and experimental development. This framework and the definitions are appropriate to describe and define the terms of "industrial research" for our case.

According to the "Frascati Manual" (OECD, 1993), "scientific technical activities" contain all "systematic activities which are directly linked to the production, the improvement, the promotion, the diffusion and the application of scientific and technical knowledge in all scientific and technical domains".

The scientific and technical activities include the following categories (OECD, 1993):

- Research,
- Experimental development,
- Scientific and technical support activities.

For our purpose, we will have a closer look on the definitions of the notions research and experimental development in order to make the link with the notion of industrial research. According to the “Frascati Manual” (OECD, 1993), research and experimental development correspond to R&D (Research and Development) activities.

2.3.1 DEFINITIONS FOR “R&D”

In the “Frascati Manual” research and experimental development (R&D) are defined as following:

“Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge including knowledge of man, culture and society, and the use of this knowledge to devise new application”.

According to the Frascati Manual, R&D is a term covering three activities: basic research, applied research, and experimental development:

- “Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.” Basic research analyses properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws. The result of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues.
- “Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.” The results of applied research are intended primarily to be valid for a single or limited number of products, operations, methods, or systems. Applied research develops ideas into operational form. The result derived from it may be patented or be kept secret.
- “Experimental development is systematic work, drawing on existing knowledge gained from research and practical experience, that is directed to producing new material, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.”

Scientific and technical support activities support the completion of R&D activities. However, they need to be distinguished from the R&D activities. They contribute to the production, the improvement, the promotion, the diffusion and the application of scientific and technical knowledge. The basic criterion for distinguishing R&D from related activities is the presence in R&D of an substantial element of novelty and the resolution of scientific and/or technological uncertainty (OECD, 1993).

In this set of definitions and descriptions, we retain the definition of applied research, experimental development and the description of the scientific and technical support activities to describe the notion of “industrial research”.

2.3.2 DEFINITION FOR “INDUSTRIAL RESEARCH”

According to the description of Mees and Leermakers (Mees and Leermakers, 1950), industrial research concerns the conception of new or improved methods based on existing scientific knowledge and existing technology. Fundamental or basic research supports industrial research. The applied research, part of the industrial research, leads to new technical methods. The development activity is an activity apart from the industrial research. Industrial research is a step before development. The research results provide part of the input of the development process of the industrial group (Figure 2.1).

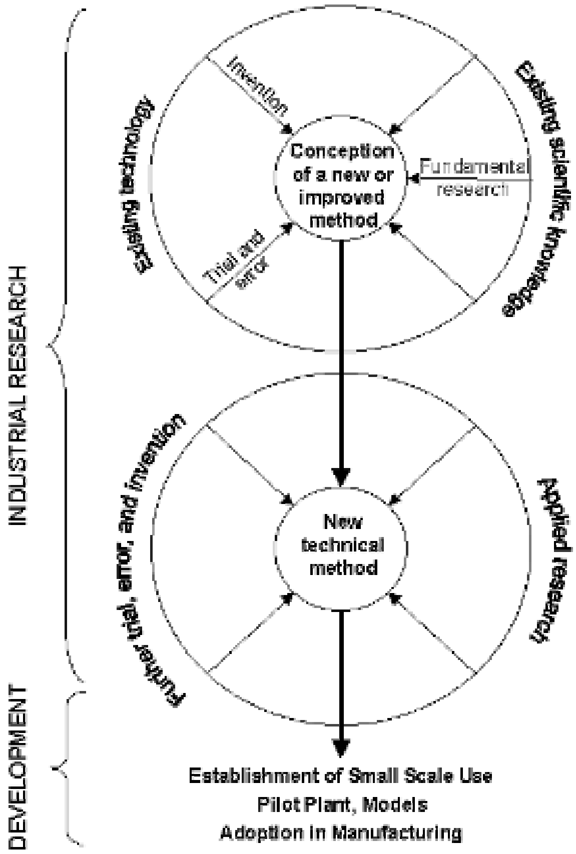

Figure 2.1 – Industrial research according to Mees and Leermakers (Mees and Leermakers, 1950)

Mees and Leermakers make a clear distinction between industrial research and development. However, the Frascati Manual proposes to take into account "experimental development" for R&D activities. We propose to make a distinction between the notions "development" and "experimental development": development includes the activities leading to an operational product, service, etc.. Experimental development includes the activities which use the knowledge gained from research activities in order to experiment it on a real product, service, etc. environment. Experimental development can lead to development when the experimental development results are validated and show interesting results for operational use.

The different above definitions give different viewpoints for the notion of "industrial research". As a synthesis from the above descriptions and definitions we propose the following definition for industrial research:

"Industrial research is systematic work, drawing on existing knowledge gained from basic research, practical experience and existing technology, that is directed to acquire and produce new knowledge for a specific practical aim or objective in an industrial context. Existing knowledge is gained by using scientific and technical support activities in a systematic way".

The Frascati Manual uses the concept of "knowledge" in the context of research. According to the Frascati Manual, the objective of research is to acquire new knowledge. We propose therefore to consider the new knowledge as "the product" of research activities (we will specify the notion "product" in the context of industrial research in section 2.7). In this context, Le Masson (Le Masson, 2001) proposes to describe the industrial research activity as being a rationalization activity of the knowledge production: it is a controlled knowledge production process. This description is in accordance to our definition.

2.3.3 Industrial research and innovation

Very often, when people talk about industrial research, they bring into discussion the notion of "innovation". However, there is a clear distinction between innovation and industrial research or R&D in general.

The industrial research or R&D activities are part of the innovation process. However, as the Frascati Manual and other authors show (Le Masson, 2001), (Schulze, 2001), (Hatchuel, 1994) (Ruggles and Little, 1997), the innovation process concerns a larger variety of activities than just industrial research or R&D.

According to the Frascati Manual, "the scientific and technological innovation can be considered as the transformation of an idea into a sellable new or improved product, or an operational process in the industry, or the commerce, or into a new method of social services. Furthermore, it covers all scientific, technical, commercial and financial activities to assure the success of the new or improved manufactured products, to assure the commercial use of new or improved processes and materials or to introduce a new social service method."

According to this definition, the R&D activities are only a part of the innovation. In order to bring new R&D results to market, commercial activities like marketing, advertising, etc. are necessary.

Before going into deeper detail concerning the knowledge aspect for industrial research, we will discuss some organizational characteristics of industrial research.

2.4 Organizational forms for industrial research

Le Masson (Le Masson, 2001), characterizes three frameworks of interaction between science and industry. These three frameworks can constitute an environment for industrial research or lead to industrial research activities:

- The partnering:

  Professors are employed as half-time industry researchers. The partnering is a mean to purchase scientific expertise in a specific research domain for the industrial environment. It is used for short term research projects and holds the industrial enterprise free from any longer dependence on research commitments.

- The internal analysis laboratories:

  Internal analysis laboratories in general use new scientific research results, tests and simulations. Results of the tests and simulations can show new unexpected phenomena which could stimulate further research activities. However, usually analysis laboratories do not conduct industrial research on their own. Results are often transferred to academic or industrial research laboratories via collaborative relationships.

- The innovation laboratories:

  Innovation laboratories are independent research laboratories. These laboratories do not belong to industrial groups. However, very often they depend on industrial funding and contracts to maintain their research activities. They propose new patterns and innovations for exploitation for industrial enterprises.

The three forms do not represent a full integration of industrial research in an industrial group. In order to integrate industrial research activities, industrial groups have the possibility to create separate research units among the operational units. These research units can be integrated in an industrial research center. In this work, we will focus on an industrial research center as the organizational framework for industrial research.

2.5 CLARIFICATION OF THE ROLE OF AN INDUSTRIAL RESEARCH CENTER

An industrial research center stands between an external information provider system (e.g. technology suppliers, academic laboratories, etc), and an industrial operational system, (operational units like the design office, the assembly factories, etc) (Frank and Gardoni, 2002a). The industrial operational system represents the one important final user of the industrial research results and thus can be considered as the industrial research customer. An information exchange process takes place between the operational system and the external information provider system with the industrial research center in the middle of this process (Figure 2.2).

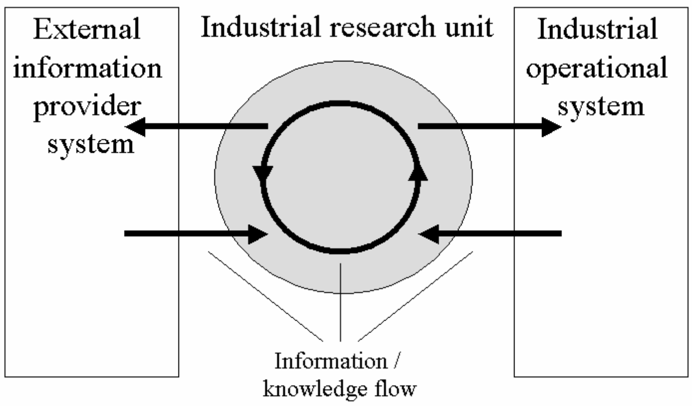

Figure 2.2 – Industrial research processes – a macroscopic description

The industrial research activities in an industrial research center are oriented towards the problem environment of the operational units.

In this environment, the industrial research center has to assure some crucial functions. From our point of view, there are three main functions (Frank and Gardoni, 2002a):

- The industrial research center has to answer the needs of the operational units. For this purpose, the industrial research center produces new knowledge for the requirements of the operational units. This new knowledge needs to be for the benefit of a better functioning of the operational unit system. The operational units use the research results to improve their processes.

The needs of the operational units can concern long-term and short-term needs:

- The long-term needs concern long-term improvements of global technology domains. The requirements are often not clear and the industrial research center is more in the position of making feasibility propositions for the implementation of new technologies and methods.
- The short-term needs concern immediate improvements of identified problems. The requirements are often clear and the industrial research center has to provide clear solutions for the identified problems.

- Based on the analysis of the needs, the industrial research center has to anticipate future needs of the operational units. By analyzing the external industrial environment and trends, the industrial research center needs to be able to propose new solutions when the operational units express their needs.
- The realizations of innovations in the industrial groups based on research results are possible if the industrial research center guarantees the distribution and promotion of new knowledge. Therefore, the industrial research center plays an important role to provide the new knowledge where it is needed and where it creates the greatest value added for the activities of the operational units.
- The industrial research center has to assure a constant knowledge flow from the external information provider environment into the internal industrial organization environment. Cooperations with other research partners or other industrial organizations based on common projects assure this constant knowledge and information flow. The operational units do not have the means to observe external innovation activities. Therefore, the industrial research centers fulfill the role of technology monitoring.

In our case, the industrial research center does not focus on innovative product improvement. The focus lies more on providing support to the operational units in order to improve their processes and systems around the product creation and development.

In order to understand the different information and knowledge flows and how they are organized, we need to have a closer look on the organizational framework including further descriptions of the notion of "customer" and "research product" in the context of the industrial research center.

These details are necessary to understand how knowledge management support can be adapted to the framework of an industrial research center in order to support the acquisition and production of new knowledge.

2.6 THE "CUSTOMERS" OF AN INDUSTRIAL RESEARCH CENTER

According to the classical quality certification approach, the customer-supplier relation implies a real customer and a precise process identified a priori (AFNOR, 2001). This relation description is not easy to apply for the research environment in general.

For academic research, the customer can be various. He can come from the external or internal environment. Sometimes he can be clearly identified as a buyer of research results, as someone responsible of a research program or a department, an expert needing research expertise, etc. However, sometimes the customer cannot be clearly identified. He does not have a formal existence for the academic research environment.

Nevertheless, contrary to academic research activities, industrial researcher centers usually have “research customers” for every research project. These customers are real or virtual organizations (defined bellow) ordering research “products” from the industrial research center (for the notion of “product”, we will go into deeper detail in section 2.7) .

- The research customers representing the real organizations are usually situated among the operational units or the corporate level. The operational units have the objective to develop new products and services for consumers. The operational units represent therefore the link between the research environment and the final consumer. This link is important for the activity of an industrial research center: the research center has not only to take into account the needs from the direct research customer (the operational units) but also to some extent the needs from the consumer of the product of the operational units (Figure 2.3). The needs of the final consumer can give an indication for the needs for capability for the operational units. This leads to the role of the industrial research center to anticipate the needs of the operational units.

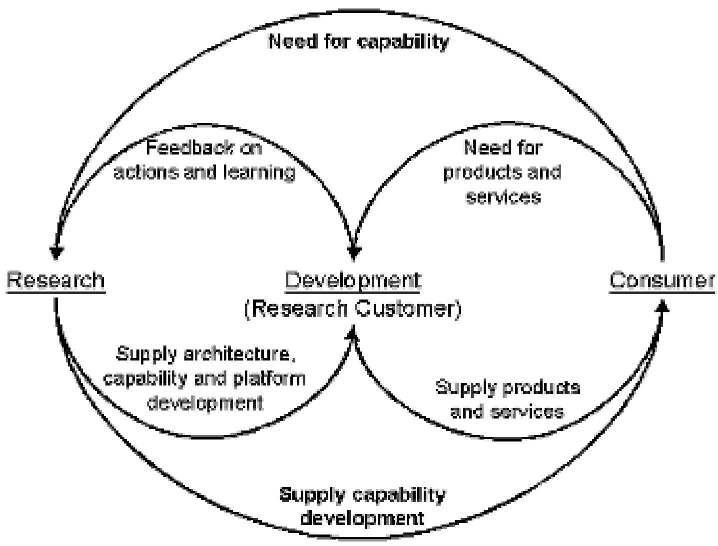

Figure 2.3 – The customers for an industrial research center (adapted from Miller and Morris, 1999)

- Virtual organizations are fictive organizational representations which have the function to represent an environment requiring new research results in a new domain which does not yet have any concrete operational unit need. Internal groups, mostly research managers, represent these virtual organizations. In this case, the industrial researcher has to present their research program and following results to the research managers. This sort of organization is usually used for the exploration of new research themes or new concepts.

In an industrial research center, each research domain serves a specific customer problem environment. This implies the understanding of the industrial operational processes and product and/or service production systems. Understanding the processes and systems helps to clarify the actual needs and to identify future potential needs.

As an example, for the IT industrial research, the problem environment of the operational units concerns the engineering processes (Figure 2.4).

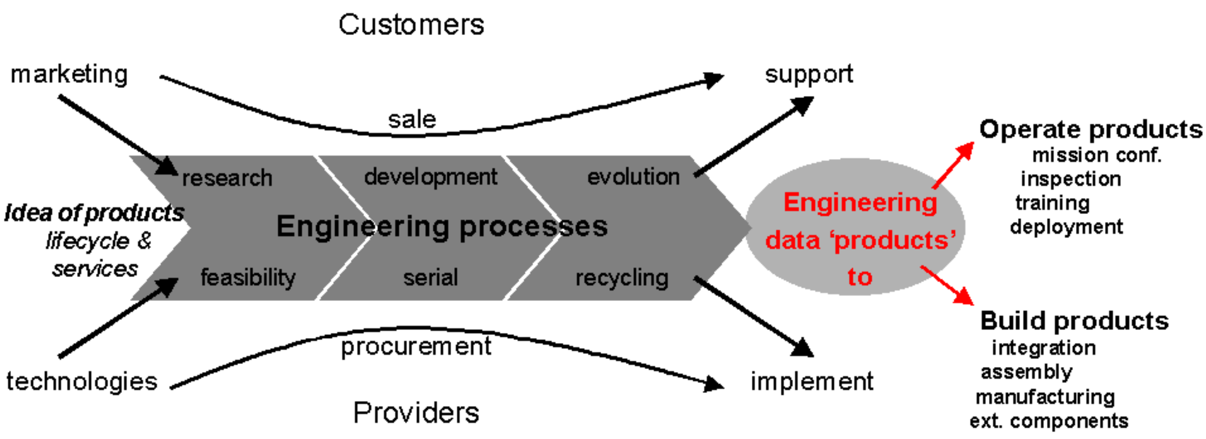

Figure 2.4 – Engineering process description of EADS operational units (adapted from Dureigne, 2002)

The purpose of the engineering processes of the operational units is to produce new engineering data. The data represents models (geometric 2D, 3D design models, rules, mathematics laws, etc), specifications, descriptions, instructions, etc. It constitutes the referential support for the real product development in two aspects: support of the building of products and support of the operation of products (see Figure 2.4).

The engineering process of the operational units, producing the engineering data, interacts with three environments: the customer, the producer and the provider of the engineering process.[1]

- The customer gives indications about new needs for the product (marketing).
- The provider provides new technologies and methods to improve the functioning of the engineering processes.
- The engineering process itself is coordinated by the producer. He is responsible for the production of new engineering data.

The process includes different activities: research, feasibility, development, serial, evolution, recycling. The different activities divide the process in three main phases. A first phase deals with the examination of diverse alternatives in order to get the best possible solution. A second phase deals with the development of the basic product data. The third phase deals with the adaptation of the basic product data to the specific customer needs and its implementation. New ideas of products activate new engineering processes to produce new data for the new products.

[1] This representation is abstract in order to simplify the description of the interactions of the engineering processes in the operational units. The customer, producer and provider are internal or external elements towards the operational units.

The objective for the industrial research activities can be to support the improvement of the engineering processes including their support system of the operational units with new concepts (in the case of IT research, with new IT co ncepts).

The industrial research center realizes this support with the production and transfer of new knowledge as we can derive form the definition of industrial research (section 2.3.12). This leads us to the clarification of the characterization of the industrial research product.

2.7 THE "PRODUCT" OF AN INDUSTRIAL RESEARCH CENTER

As the industrial research activity is leaded by concrete industrial operational needs, the form and character of the research results are often defined in advance. Therefore, we can talk about products for industrial research results.

The product constitutes of a new knowledge models for the given problem environment (Dureigne, 2003). Our definition for the industrial research product in this context is therefore: a research product is an entirety of industrial knowledge models, accompanied with procedures explaining their implementation based on acquired external resources and instructions guiding their operational use.

There are two aspects to describe the industrial research product as new knowledge: an intangible aspect and a tangible aspect.

- The intangible aspect concerns the expertise of the industrial researchers. The new knowledge produced increases the expertise of the industrial researchers. He can transfer this knowledge to other people and especially to people from the operational units for whom the industrial researcher was working for.
- The tangible aspect of the research product concerns the real objects the industrial researcher produced during his research activities. This can concern reports, minutes but also prototypes, pieces of test material, etc.

The prototype plays two roles in this context (especially for IT research activities): the first role consists of showing that the industrial model or concept can be transformed into something real which can demonstrate the feasibility of the model or concept. The second role consists of showing, with the help of simulations, which the model responds to the needs of the clients.

With these two roles of the prototype, the industrial research product does not only consist of the new industrial knowledge models but includes also "implementation knowledge" and "operating knowledge" which is necessary to realize the new industrial model. The implementation knowledge concerns the knowledge needed to implement the new model in form of the prototype in an existing process and technology environment. The operating knowledge concerns the use of the new industrial model or concept and therefore the use of the prototype application.

The following figure illustrates the research product model adapted from Dureigne (Dureigne, 2002) (Figure 2.5). The figure is divided into two main representations: the right side represents the research product model. The left side represents the elements which help to constitute the research product.

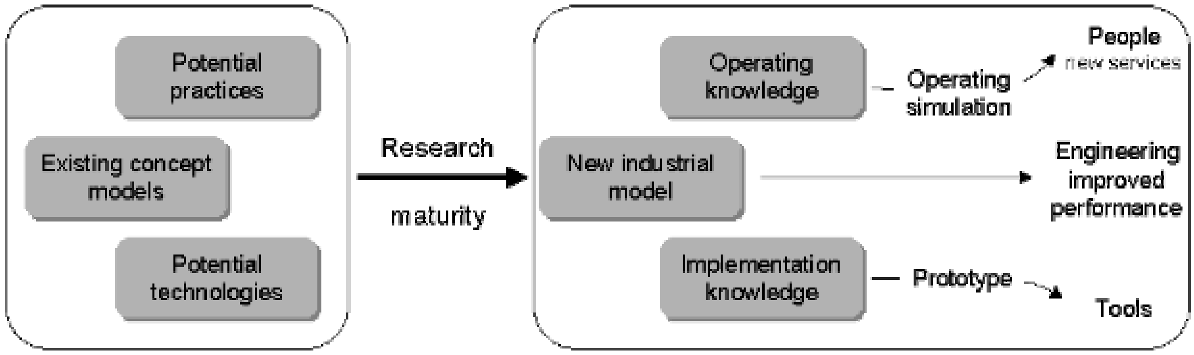

Figure 2.5 – Industrial research product model adapted from Dureigne (Dureigne, 2002)

In order to constitute the industrial research result, the industrial researcher transforms potential practices, new concept models and potential technologies into his new results. These different items are coming form his external, internal and operational unit environment through various information and knowledge resources.

The research result document (or research report) plays a significant role. In this document, the researcher describes the results and the approach which leaded to the results. However, the document includes also other important elements.

2.7.1 INDUSTRIAL RESEARCH DOCUMENT STRUCTURE ANALYSIS

The objective of the industrial research activities is to support the operational units and therefore a closed community. The objectives of the industrial research are given by the concrete requirements of the operational units. Therefore, industrial research activities have to create new means for operational use.

This finalized research influences the structure of the documents: definition of the audience, references of applicable documents (for example procedures), description of the needs, further necessary actions to take, etc. Bibliographic resources are not essential. However, the references which allow to arrive to an application of the results are important (example: suppliers, etc.). Therefore, the document can play the role for a finalized network support.

2.7.2 A COMPARATIVE ANALYSIS – ELEMENTS OF ACADEMIC RESEARCH DOCUMENT STRUCTURES

The objective of academic research activities is to contribute to the research progress of a research community. The focus lies on congresses, the exchange among people, the animation of networks, etc. The document plays a fundamental role to support these networks. It contains the following elements:

- Abstract and keywords in order to have the possibility to get a quick overview of the content,
- Identification of the authors (name, laboratory, etc.),
- Precise texts,

- Management of reader relations: bibliographic references (sharing of the resources), glossary (sharing of the concepts),
- Nomenclature of included objects (figure, equations, etc.).

The community has to have the possibility to re-appropriate the content for further research by mentioning the original author (necessity to cite the resources). For the nomenclature of the included objects, certain play the role of reference objects. These reference objects constitute the center of the research product. They can be tables, equations, algorithms, etc.

The differences between industrial and academic research documents reflect in fact the difference between the two research forms. The customer environment is different, the product is different and the knowledge and information resources are different. This will probably play a role for the management of knowledge and information. As the products are different, the exploitation of the resources is probably different.

However, we will not go into deeper detail of an analysis of the differences. It is important to keep in mind, that the following sections concern the industrial research environment.

In order to produce the research products, the industrial researcher follows certain activities. In the next section, we will discuss the industrial research process leading to the production of new research products.

2.8 THE INDUSTRIAL RESEARCH PROCESS – A PROCESS OF PRODUCTION

The knowledge production process according to an approach based on the principles of the economies of scale takes into account technological changes in a competitive environment (Barnes, 1985). The likely determinants of business influences on the knowledge production are the increasingly intertwined needs of competitors, suppliers and customers (Von Hippel, 1990), (Hatchuel et al., 2001).

In this context Murray distinguishes three ways to characterize the industrial research process as a knowledge production process (Murray, 2001):

- In some occasions, an appropriate strategy may be to do only enough research to gain access to the science of external experts.
- Alternatively, it may be more effective to build deep, well-focused knowledge of one discipline.
- A third possibility is to develop a broad knowledge base that includes a number of disciplines in such a way that internal experts from one discipline can inform other internal people – techniques are transferred or internal experts combined to develop more efficient processes or effective products.

We will see in our research model of the case study that these different ways to produce new knowledge can correspond to different research activities within the industrial research process (see section 4.2.1). However, the industrial research process as knowledge production process is based on certain basic activities allowing to transform existing concepts to new industrial knowledge models. These activities are described in the next section.

2.8.1 ACTIVITY DESCRIPTION FOR INDUSTRIAL RESEARCH PROCESSES

The knowledge assets are transformed by different combinations of knowledge-searching and assembly processes within and outside the industrial research center (Murray, 2001). These search and assembling activities might constitute the main activities to produce new knowledge in the context of industrial research.

- Searching is central to knowledge change because it is the mechanism by means of which new knowledge is identified and developed. From the perspective of the organization, the most critical dimension in setting the direction of the search is whether the relevant knowledge is internal or external. External knowledge may be sought from other firms – via relationships such as alliances, joint ventures or common projects (Chesbrough and Teece, 1996). Today, with problem environments and technologies getting increasingly complex, the industrial research centers need to integrate external knowledge in their research activities.
- The process of assembling knowledge involves combining new knowledge with existing knowledge in novel ways to exploit the industrial research center's resources (Lenoir, 1995). To be more concrete for the assembly process, it is helpful to think about knowledge assembly as either adding understanding from within a given discipline or providing understanding from outside that discipline (Brown and Duguid, 1998). When assembly occurs within a given area of knowledge, experts remain within their typical boundaries. Assembly is harder to achieve outside disciplinary boundaries, because the methods and problem environments are less clear. Because an established scientific discipline is frequently inaccessible to those in other areas, the ideas from that discipline are rarely applied elsewhere (Allen et al., 1979). Therefore, of the two dimensions of assembly – within and outside the discipline – the integration of knowledge from outside is more difficult.

The next figure (Figure 2.6) demonstrates the knowledge production process according to the two principles searching and assembling.

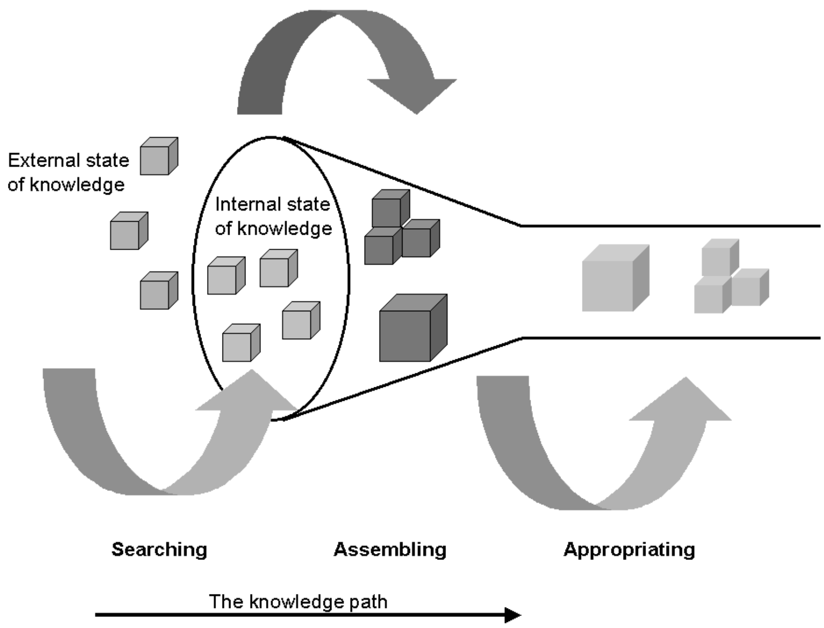

Figure 2.6 – The knowledge production process according to Murray (2001)

The notion of appropriating constitutes the direct interface to the operational use of the research product. The research results are deployed for the operational unit needs. This implies that the industrial research takes into account the needs during the searching and assembling process activity.

Besides the official research products, there might exist secondary research results. These results might appear during the research activity without that they were expected at the beginning. The secondary research results might be of value for the research customer and can therefore constitute a part of the research product (AFNOR, 2001).

The secondary research results play a role for the continuity of research activities. The discussion of secondary research results leads us to the concept of lineage.

2.8.2 SECONDARY RESEARCH RESULTS OR THE CREATION OF LINEAGE KNOWLEDGE

Secondary research results might constitute new opportunities for new research activities. In this context we can refer to the concept of lineage introduced by Vincent Chapel (Chapel, 1997) for the industrial design environment. According to Chapel, the lineage constitutes a way to exploit the learning processes from one project to another based on the same conceptual roots. A product can be used in a certain way. For the usage in another context, the product needs to be adapted to this new context. This adaptation creates a lineage of the product and new knowledge about the use of this product.

During the production process for industrial research results, the concept of lineage can occur during knowledge assembling. During assembling, he can find new concepts to problem environments which are similar to his main problem he is working on. These new concepts can lead to new activities because they constitute a certain value and they can be linked to competencies (Le Masson, 2001).

There is a need to explore and validate the new concepts in order to start working on new problem environments. Therefore, there is a need to capitalize this "lineage knowledge" in order to assure the possible exploitation of new knowledge linked to new conceptual findings.

In order to coordinate the production of new research results, an industrial research center is organized in competence centers including the different researchers working on coherent research projects. In the next section, we will have a closer look on organizational aspects of an industrial research center.

2.9 THE ORGANIZATION OF INDUSTRIAL RESEARCH ACTIVITIES IN COMPETENCE CENTERS AND RESEARCH PROJECTS

The organization of the research activities is oriented according to the customer problem environment. Therefore, each department and the different services of the departments develop special competencies for the customer research environment. The departments and services can be considered as "competence centers" (Dureigne, 2002). From the point of view of the industrial research center, each competence center provides the necessary resources to progress on its research domains and to answer the needs of the operational units.

The different researchers are affected to a competence center. However, each researcher has a certain expertise inside his competence center and represents therefore an expert for certain research problems.

Each competence center covers one or several research domains. A research domain represents specific and coherent research problems and activities. The research domain can cover one or several research themes which represent a certain research interest of the industrial researchers. For the research themes, the industrial researcher can conduct research projects.

2.9.1 THE RESEARCH PROJECTS IN COMPETENCE CENTERS

If there are precise objectives for a research problem, the researchers of a competence centers manage defined research projects in order to respond to the precise objectives.

Besides the structure in competence centers, certain research problems or operational unit requirements can lead to a multi-disciplinary team working. The resulting projects can concern researchers from different competence centers. In these projects, the researchers share their knowledge across the different competence centers in order to be able to produce new research products in a common sense.

The organization of the activities in competence centers and the multi-disciplinary project structure represents in fact a matrix organization (Figure 2.7).

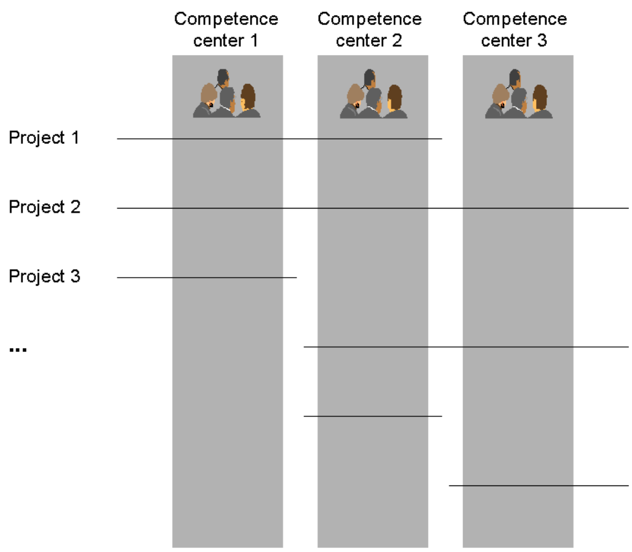

Figure 2.7 – Organisation of research activities in competence centers and research projects

In these research projects, the industrial research organizes and uses information and knowledge in order to produce new results. The structure of the research activity in projects has mainly administrative reasons. As the industrial research center is an industrial unit of an industrial enterprise, the activities are linked to the compilation of balance sheets. The annual financial statement leads to an annual project oriented organization of the activity. Besides this, the funding structure for research activities lays on financial funding coming from the operation units. As the operational units have to organize their budgets conform to the annual financial statement, they need a regular project oriented organization with a year-based cost and benefit calculation.

Even if the activity is based on a yearly project structure, it takes often more time to work on a specific research question. Therefore, the progress on a specific research question can involve several projects over several years.

The project organization in our case is partly based on an ISO 9000 certification. This certification describes in procedures among other things the project structure with its different tasks to realize and the relevant documents to produce. We will have a closer look on the ISO 9000 certification and its impact on the organization of information in section 3.4.6.

2.9.2 TYPES OF RESEARCH PROJECTS

According to the CRC France procedure derived from the ISO framework, the research projects can be structured according to three different types:

- The projects which have the objectives to acquire and deepen knowledge, to maintain competencies, to test new technologies, to evaluate the feasibility (business intelligence, technology scanning, state of the arts, demonstration of a feasibility, etc.). The industrial researcher identifies new concepts and technologies and conducts a first evaluation of their feasibility for given research requirements.
- The projects which transform in medium-term technological progresses into operational means for the industrial units requirements (transfer of technologies and know-how, specifications of systems, prototype development, etc.). Based on a panel of possible concepts and identified technologies the researcher identifies via specifications and prototype development, solutions for given research requirements. With experiments in the operational unit environment, he starts transferring new know-how.
- The projects which intervene directly and in a short-term on the domain of the operational units (technical support, consultancy, service, expertise, etc.). The industrial researcher intervenes on the operational unit environment as technical support in order to make operational the research results to implement them into the industrial units' processes.

In order to perform the research activities, the industrial researcher might include aspects of the different project types in one single project. In one project he can conduct a state-of-the-art and continuing focusing on prototype development with first demonstration in operational unit environment. Nevertheless, for a research project we distinguish three main steps (CRC France procedure derived from the ISO framework):

- Definition of the needs,
- Conception of the project,
- Realization of the project.

In chapter three, we will describe the different steps of the research projects and the different observed practices of an industrial researcher during the activities of the research project. This observation will lead us to the description of the knowledge management needs for an industrial research center.

In the different research projects, the industrial researcher uses information from various resources. In the next section, we will describe the different knowledge and information resources for an industrial research center and their organization. A clarification of the information resources is relevant as they might play an important aspect concerning information and knowledge flow optimization.

2.10 THE ORGANIZATION OF THE KNOWLEDGE AND INFORMATION RESOURCES FOR AN INDUSTRIAL RESEARCH CENTER

For the organization of the knowledge and information resources for the industrial knowledge production process, we will highlight the organizational framework, the network organization around the industrial research center.

Therefore, there are three major information and knowledge resources the industrial researcher uses to produce new research results:

- The operational unit environment as the major resource for information and knowledge concerning the needs for new industrial research problems,
- The external environment including information technology suppliers, academic and industrial research laboratories and other external industrial organizations as resources for new potential practices, IT concepts, and technologies,
- The internal environment concerning the group internal research activities with its new developed concepts and eventual similar problems.

In order to have access to these different resources, the industrial researcher is involved in different formal and informal networks. These networks constitute a means to access relevant information and knowledge for the research activities. We can distinguish between external and internal networks.

2.10.1 THE EXTERNAL NETWORK QUESTION – COLLABORATIVE WORK BETWEEN INDUSTRIAL RESEARCHERS AND THEIR EXTERNAL ENVIRONMENT – A KNOWLEDGE RESOURCE

For industrial research activities, the external knowledge can be in form of new technologies, concepts, methods, potential needs, etc. Although the availability of external technology may substitute own research investments, recent literature suggests to stress the "complementarity" between in-house research activities and external knowledge (Arora and Gambardella, 1994), (Cockbrun and Henderson, 1998). Own research activities allow the industrial enterprise to scan better the environment for existing external knowledge and information. The notion of "absorptive capacity" introduced by Cohen and Levinthal (Cohen and Levinthal, 1989) and further developed by Kamien and Zang (Kamien and Zang, 2000), stresses the importance of a certain level of prior internal knowledge to effectively absorb external knowledge. Once a suitable knowledge and information is located, the industrial research center with the in-house research activity capabilities is better able to evaluate the technology.

The acquisition of external knowledge is complement to the internal knowledge production. Teece (Teece et al., 1997) talks in this context about the theory of complementarity for the innovation processes. Cassiman and Veugelers (Cassiman and Veugelers, 2002), (Veugelers, 1997) show a positive effect on research results by purchasing new external technologies or by focusing on cooperations with external research partners in order to acquire external knowledge for internal activities.

The external knowledge acquisition is therefore based on the optimal exploitation of "external knowledge resources" (Grant and Baden-Fuller, 2000). The theory of resources based view of an enterprise relates the profitability of the enterprise to the resources of the enterprise that are exploited through the activities of the enterprise (Ghemawat and Pisano, 1999), (Teece et al., 1997).

Another network can be established with the final consumer of the industrial group. These networks allow getting to know the needs for new capabilities concerning the products of the industrial group. The needs for new capabilities are often tacit and difficult to articulate. Therefore, industrial researchers need the contact with the end consumer in order to be able to do research to supply a capability development (Miller and Morris, 1999).

The contact to final consumer of the operational units allows analyzing their needs in order to propose and supply new architectures, capabilities and development platforms to the operational units of the industrial group.

However, there are three main groups of external organizations representing an interest for the industrial researcher: technology suppliers, other research laboratories (academic and industrial), and other industrial groups dealing with similar problem environments. Each group plays a different role as a knowledge resource:

- The main role of technology suppliers is to provide new information and knowledge about new technologies or tools. It is possible to experiment them for a given problem environment in order to simulate the feasibility of technological solutions. If the simulation results are positive, the industrial researcher might decide to adapt this new technology for the problem environment and deploy it furthermore for the operational units. However, technology suppliers can also play an information resource for new models, concepts, etc.
- The main role of academic research laboratories is to provide new methodological and technological concepts and their simulation results with the help of prototypes. These new concepts can be integrated for the research activities of the industrial researcher in order to explore new possibilities. The role of industrial research laboratories is similar to the role of academic research laboratories. However, the industrial research laboratories are more prototype oriented and can therefore transmit these particular experiences. Besides this, they can also provide similar industrial research problem environments which can help to clarify own problem environments.
- The main role of other industrial groups is to provide experiences concerning similar problem environments of their operational units. This concerns experiences about the needs and the technological or methodological solution applications. With this experience feedback, the industrial researcher is able to compare his problem environment and possible solutions with already existing knowledge. The experience of the other industrial groups helps him to accelerate his own solution development because he avoids making similar mistakes or simulations which have already been realized.

The practical realization of the external network framework can have different organizational forms:

- International (for example European) or national projects allow being in contact with all three main groups of external organizations. These projects allow to work together on a common problem environment based on a contract for a limited timeframe. Therefore, these projects constitute an important organizational form of a knowledge resource.

- Using the academic laboratories as knowledge resource is often realized via the integration of doctoral students in the industrial researcher environment. The doctoral students represent a knowledge transfer facility from the academic laboratories to the industrial research environment by using the methodological or technological concepts developed in the academic laboratories for their doctoral project. They also transfer part of the expertise of the people working at the academic laboratory by discussing the research problem with these people. Besides this, doctoral students play also an important role for external unknown knowledge acquisition. This is done via publications and the visiting of national and international conferences, workshops, working groups, etc.

  Another form of using the expertise of an academic laboratory is to subcontract certain precise research activities. This concerns often the realization of state-of-the-arts and prototypes. The objective here is to use the expertise of the academic laboratory by considering that the people working at the laboratory are experts concerning the given problem environment.

- Using technology suppliers as knowledge resources passes very often by the definition of precise subcontracting contracts. In these contracts, the participants define the use of the expertise of the technology supplier and their technological realizations. This is therefore a direct support for prototype development and simulation.

The information and knowledge exchange with the external organizations depends on the contractual framework and the personal relation with other experts. In contracted frameworks, very often the knowledge exchange takes place during formal meetings and via the transmission of information in text format or product format. In case of a good relation with other experts, the information and knowledge exchange is very often informal. During these informal exchanges, the industrial researcher sometimes gets important information for his research activities which he probably would not get without this personal relationship.

In contrast to the external network there exists the internal network.

2.10.2 The internal network – sources for internal knowledge

In an industrial organization, there are three internal networks which concern the industrial researcher of an industrial research center:

- A first internal network concerns the connections between the industrial researchers inside the industrial research center. Industrial researchers work together on similar research problem environments or combine their research findings to an overall solution. By exchanging their experience and their knowledge, these internal networks constitute another knowledge resource for the industrial research activities.

- A second internal network inside the industrial organization concerns the connections between the industrial researcher of the research center and the research departments of the operational units inside the industrial group. This network constitutes a sort of a marketplace, where new research findings and research needs are exchanged. The research needs, coming from the operational unit research departments are very oriented towards the needs of the operational units. Therefore, these networks constitute an important resource for the industrial research center. The relation to the research departments of the operational units helps also to define new research activities which concern more explorative research.

- The third network concerns the relation between the industrial researcher and the operational units on an operational level. We consider this for the internal network because the operational units are part of the industrial group. It would also be possible to talk about the operational unit network. This relation concerns very often concrete research projects and their implementation on the operational environment. The relation helps to identify new operational needs for new research projects.

The different informal networks can be organized as official networks but exist also as unofficial networks depending on the researcher. The network with the operational unit plays a relative important role. It allows maintaining a certain technological identity for the industrial group. It constitutes an organized mechanism for knowledge and information exchange. For the industrial researchers, this network provides the possibility to keep a constant contact to the research requirements of the operational units. By working together with the people from the operational units, the industrial researcher has also the opportunity to promote new research results. This mechanism of collecting new requirements and promoting new research results leads to a certain continuity of new knowledge production in the industrial research units.

2.11 CONCLUSION

The objective of research activities in an industrial research center is to elaborate innovative improvements for the problem environment of the operational units of an industrial organization. The operational units constitute the customers for the industrial research products and thus for new knowledge.

The knowledge production process can be characterized with the three activities: searching, assembling and appropriating. In fact, these activities organize internal and external knowledge and information coming from various resources to new products. Some knowledge manipulation activities of the APQC and Romhardt knowledge management models (see section 1.4.2) are similar to these activities: searching can be included in the identification and acquisition manipulation activites, assembling and appropriate in combine and use. This means, that the activities describing the research production process could be supported with knowledge management relevant manipulation activities.

With the role of the industrial research center, the research result production can be characterized with several information and knowledge flows:

- Identifying and acquiring information and knowledge from external and internal resources,
- Combine and use information to produce new research results or
- Share the new acquired information with other people, and then
- Transfer and distribute the research results to the operational units.

The industrial researchers have individual and shared practices supporting these different activities. A potential knowledge management system should support these practices and therefore need to be adapted to the context of the industrial research center.

In order to introduce support, it is therefore necessary to analyze the different practices of the industrial researcher acting as an individual and in a group. The analysis of the practices and the used actual system gives a clearer view of the needs for a knowledge management system. In the next chapter we will discuss a deeper analysis of the practices as well as the description of the needs. Chapter four assembles certain concepts of knowledge management described in chapter one with the industrial research models of this chapter (chapter two) in order to support the practices and the needs described in chapter three.

3 THE ANALYSIS OF THE NEEDS FOR AN INDUSTRIAL RESEARCH CENTER

3.1 INTRODUCTION

One of the industrial research centers of our case study (the French research center) introduced an ISO 9000 certification program. This helped to structure part of the activities of the industrial research process. The ISO 9000 certification leaded to the introduction of reference documents describing the practices to adopt for certain activities and structured the format of certain official documents. For the certification, the research center used the ISO 9000, version 1994 (ISO, 1994). Via the description of procedures in the reference documents, the research center adapted the ISO 9000 framework for industrial research activities.

The implementation of a quality certification lead to a deeper reflection of how the performance of the industrial research production process could be improved. This reflection concerned essentially the organization of the information flows and knowledge production. The introduction of ISO 9000 played therefore facilitator role to the release of the need to optimize the knowledge production process.

In this first chapter, we first present the context of our application field. We will discuss the EADS context and the specifications of IT research activities.

In order to analyze the practical realization of research products (based on research customer needs by integrating different information and knowledge coming from different resources), we conducted a research activity analysis. We analyzed the structure of the research projects, the used and produced information, and the activities of the researchers. In this analysis, we focused particularly on the analysis of the different knowledge and information management practices. For this analysis, we structured the practices according to the knowledge manipulation activities identify, acquire, structure, combine, share, use, distribute, preserve and evaluate as proposed in section 1.4.2.

Besides the analysis of the activities and practices, we analyzed the use of the existing tool support and discussed the different problems for the researcher as individual and as acting in a team.

The analysis of the activities, practices, tool support and problem description leaded to the analysis of the needs. In a functional analysis, we specified with a group of researchers the potential functions of a knowledge and information management system for the industrial research context. We deepened this need description with specific needs concerning a better management and exploitation of information content structured according to the knowledge manipulation activities.

3.2 The context of the EADS industrial research center and the IT research activities

The application of the research activities of this thesis takes place at the EADS corporate research center. We worked in the French and German part of the research center in order to investigate the different practices for the different research activities and processes. This investigation allowed to structure the different practices and to analyze the needs to support the research activities.

In the following sections, we will first give some organizational elements of EADS before going into deeper detail for the EADS corporate research center and the IT activities.

3.2.1 The EADS industrial research centers

The creation of the new industrial group EADS in the year 2000 leaded to the organization of the corporate research center into three research centers in each country. Two of these research centers were already existing structures coming from the merging companies. A third research center needed to be created.

The different research centers are structured in different research departments. Every research department covers a specific research domain. There are for example research departments working on material research, electronic research, optical research, information technology research, etc.

In order to favor the common development of new research results and the creation of a corporate technology identity, the industrial group organized several networks between the different research centers but also between the research centers and the operational units.

The operational units produce new products and/or services. One objective is to optimize the product and/or services in terms of quality, cost, risk, etc. In order to constantly improve the performance of the different units another objective is to optimize the production system itself. For the optimization or the improvement of the products and/or services or the production system itself, the operational units ask support from the EADS industrial research center.

3.2.2 The IT research activity – the application domain of the thesis

The research activities of the different research departments and their product lifecycles are different according to their research domain. For example, material research deals with longer product life cycles then information technologies research where new products come to market rapidly. This has a direct impact on the activities of the industrial researcher and the research product lifecycle. For short lifecycles as in the information technology research, the industrial researcher needs constant orientation in this dynamic environment in order to be able to react on new needs and on new emerging technologies. An argumentation for the research results could be different according to the different research activities of the research departments.

As main application domain the research work of this thesis, we choose the Information Technology (IT) department (of the French research center). The reason for this choice was that the IT research domain represents a certain dynamic aspect with a constant appearance of new technological and methodological solutions.

As a second validation domain we choose the Systems Engineering department (of the German research Center) in order to have a comparative experimentation field. The research domains of the Systems Engineering department have several links to the research domains of the IT department. This leaded us also to include cultural aspects into our work.

The dynamic environment influences the information and knowledge flows necessary to produce new research products. The shortness of the research product lifecycle and the accompanying technology and the dynamic of the industrial research environment seemed to be particularly interesting as a basis for our research questions. With short lifecycles, there is a greater chance to validate the research propositions. The validated research propositions could then be adapted to other research domains in order to integrate the overall activities of an industrial research center.

The following sections have to be seen in the context of the IT and Systems Engineering research domain. However, we think that a general transcription of a large part of the analyzed practices and needs to other industrial research domains in the context of an industrial research center is possible.

3.3 ACTIVITY ANALYSIS OF INDUSTRIAL RESEARCH PROJECT WORK

As we have seen in section 2.9.1, the industrial research activity is structured in a project framework. In order to clarify the needs, it was necessary to conduct a deeper activity analysis for industrial research project work. We tried to describe the main activities of the industrial researcher in order to organize existing information and knowledge to produce new research results.

In order to perform this analysis, we worked on four major projects: three research projects on the French research side and one research project on the German research side. This allowed also to examine, whether there are cultural and practice relevant differences between the two sites. During the analysis, we hold fifteen interviews with the involved researchers and research managers. Furthermore, we analyzed the different documents and other information received, exchanged or produced during the research projects. We focused on the following aspects (Frank and Gardoni, 2002b):

- The principle documents and information objects used, the means to get new necessary information, the network which plays an important role for each step, etc.
- The interaction between people with different functions or people and information systems, etc. and therefore the different elements describing the activities.
- The roles of different people during the different steps.

In the next sections we will present and discuss the results of the analysis. However, before we will discuss certain elements of the ISO 9000 quality certification for the French research part, which helped to give a certain structure to the different projects and therefore a certain structure to the activity analysis.

3.3.1 RESEARCH PROJECT STRUCTURE ACCORDING TO QUALITY CERTIFICATION

The project as administrative unit is based on annual programs. This is linked to the annual finance plans for the different studies. Some research projects have a longer duration (for example European research projects). In order to cover these long-term research projects, several studies are necessary. The last study for the long-term research project needs therefore to produce the expected and defined results.

According to the procedure descriptions of the quality certification, research projects are structured according to two main steps: the step "definition of the needs" and the step "conception of the project".

- According to the CRC France procedure derived from the ISO framework, the analysis of the needs leads to a proposition more or less detailed according to the type of the study. This proposition is based on concrete documents: a technical and financial proposition. If necessary, other documents (functional specifications, technical specifications of the needs, etc.) join the technical and financial proposition. This proposition needs to be validated by the hierarchy of the industrial researcher. It is then sent to the research customer (operational unit, corporate entity, etc.) who commands the research project. The definition step ends with the acceptance of the proposition by the research customer. The research project can start as soon the research center hierarchy has accepted the previous exchanges and the contract between the researchers and the research customers.
- According to the CRC France procedure derived from the ISO framework the conception of the project is to deepen the technical proposition with a detailed project program. This program goes into deeper detail for the task descriptions, the schedule and details the resources to use. In detail, the document contains the following information:
  - The description of the activities: tasks, responsibilities, incoming data, expected results according to the type of the project.
  - The description of the activities which will be subcontracted.
  - A description of a detailed plan describing the deliveries, the delivery dates and the decision milestones.

The procedures derived from the ISO framework do not describe in detail the project realization. However, according to the description in the procedures, the responsible for the research project has to assure the correct proceeding of the different tasks and the overall project. During the project, there might be reviews with the operational units or the hierarchy concerning the progress of the intermediate research results. These review meetings need to be documented with minutes. If there is a risk for a delay for the deliverables, the industrial researcher has to renegotiate new deadlines for the research results.

The quality certification gives a certain structure for some of the activities of the industrial researcher. However, the analysis showed, that the industrial researcher has also other activities in order to conduct industrial research projects.

3.3.2 ACTIVITIES IN INDUSTRIAL RESEARCH PROJECTS

In order to analyze the different activities, we structured the industrial research projects in the following steps:

- Definition of the needs,
- Conception of the project,

- Realization of the project,
- Project transfer.

For each step, we describe the different activities of the industrial researcher.

3.3.2.1 Step “definition of the needs”

For this step, a formalized “idea generation process” characterizes the activities. In this idea generation process the industrial researcher collects new ideas and customer needs for new research propositions. The two most important aspects initiating an idea generation process are new customer problems and new ideas coming from internal industrial researchers for existing problems.

The different activities during this step depend on the type of project. This is also relevant for the information necessary to elaborate the propositions. The information content is different according to the type of the project.

- For projects having the objective to find solutions for operational unit needs it is important to clarify and precise the needs. Furthermore, it is important to discuss the existence of the competencies of the industrial researchers which can help to solve the problems. During discussions in planed meetings (with minutes of meetings) or spontaneous discussions (without minutes) with the responsibles of the operational units but also with the research responsibles, the industrial researcher tries to analyze the problem environment and to understand the functioning of operational units’ processes.
- For projects, which focus more on the development of new research domains the objective is to clarify the research needs. The needs come directly form the industrial researchers or research managers. Often, there is a need to work on new internal interests concerning new innovative concepts or new research domains. One objective is also to identify new research activities which might provoke future operational unit needs. During discussions with members of university laboratories, presentations of technology suppliers, visits of congresses and trade fares, or information research on the Internet, the industrial researcher has access to information concerning new research activities leaded by other organizations. This information can initiate interests for new research activities.

We can see that the step “definition of the needs” contains elements which support the observation, consultation and clarification of activities. The industrial researcher takes into account external information (university laboratories, technology suppliers, etc.) information coming from the operational units, information coming from other internal research units and information coming form the research center environment.

3.3.2.2 Step “conception of the project”

The objective of this step is to clarify the research needs, to define the context, to assure the necessary resources, to clarify the constraints, establish a contact network and start scanning the external environment for possible concepts, technologies or methods to use.

The following figure (Figure 3.1) illustrates the different activities and interactions as well as the document elaboration for the steps “definitions of the needs” and “conception of the project”.

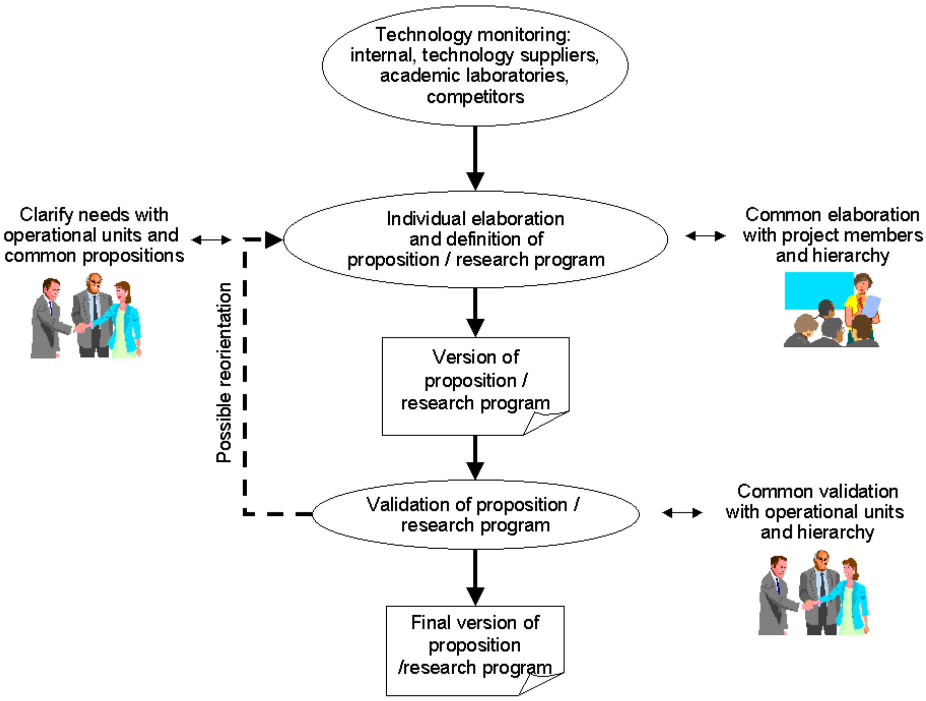

Figure 3.1 – Definition of the needs and conception of a research project program

In order to elaborate the research program document, the industrial researcher includes first elements, as result of the external environment scanning, for the research project. With the operational units and his hierarchy, he clarifies the needs and elaborates a first version of a program proposition. This activity is based on intensive interactions between the industrial researcher and other people. The first version of the proposition goes then through a validation process. The validation process involves again other people from the operational units as well as the hierarchy of the industrial researcher.

We can see that the process to elaborate the research project proposition is based on individual and collaborative activities. The researcher constantly exchanges information with the external environment, the operational unit environment, other industrial researchers, and research managers. During the research program elaboration, the industrial researcher tries to include a maximum of external and internal information in order to have an exhaustive proposition basis for the further research activities.

3.3.2.3 Step "realization of the project"

The objective in this step is to realize the defined research program and to find solutions for the defined needs and problems. Depending on the research program and the maturity of internal knowledge the industrial researcher works on different tasks. The different tasks can be:

- Task state-of-the-art and/or audit of existing processes (doing a state-of-the-art for new technological possibilities or innovative concepts and methods and/or investigate on existing processes and needs).
- Task concepts (elaboration of new concepts according to the given problem). The external integrated concepts are mostly not directly applicable to the problem environment of the operational units.

- Task methodology (elaborate new methods according to given problems and the new concepts).
- Task prototypes (elaborate specification of architecture for prototype and develop prototype functions according to the specifications and the given problem).
- Task experimentation and validation (experimentation and validation of new concepts and methodologies with prototypes or methods in a given experimentation).

According to the research project program, not all the tasks are realized during the realization step. The realization depends on the already existing available information and knowledge. If the researcher for example has information about existing technologies, tools and methods which is formulated in already existing documents, he will not do the tasks of the state-of-the art but focus probably more on a realization for the operational unit needs. He will therefore probably focus more on the prototype task.

The progress from one task to another depends on the common decision of the researcher, his hierarchy and the members of the operational units. They judge whether the achieved new concepts, experiences and therefore the achieved knowledge are sufficient to move forward on the research activity. The judgement represents in fact a judgement about the maturity of the achieved knowledge. If they decide to move forward, they consider the achieved knowledge as mature for application in further research activities.

During the project realization step, the industrial researcher constitutes intermediate research results. These intermediate research results are documented in short reports, minutes or presentations. The research customer and the hierarchy validate these results. The validation meetings help to give feedback necessary to continue the research activities. At the end of the realization step, the industrial researcher constitutes the final research result which is formulated in a research report, presentations and sometimes prototypes.

During the activities of the project realization step, the industrial researchers continue their technology monitoring. This activity helps him to be constantly aware of new technology development and new requirements.

The following figure (Figure 3.2) illustrates the different activities and interactions as well as the document elaboration of the industrial researchers for the step “realization of the project”.

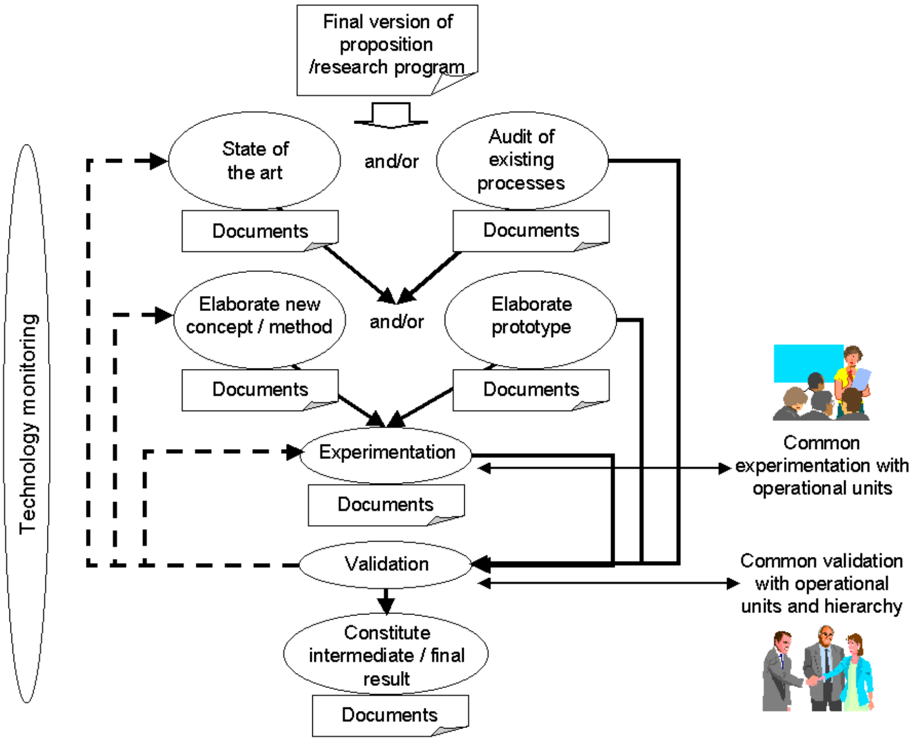

Figure 3.2 – The realisation of a research project

3.3.2.4 Project transfer step

The transfer step is not officially described in any procedure. The way research results are transferred depends on the research solution. If the research problem concerns changes on operational unit processes, there is a need of constant information exchange and review meetings. This means that the operational unit is constantly aware of the research results so that the transfer is a constant process accompanying the realization phase. In this case, the industrial research participates actively on the implementation process of the research solutions.

If the research problem concerns more finding a solution for a given problem which is not process oriented, the transfer can be the demonstration of a prototype or a simple presentation of the solutions. In this case, the industrial researcher might not be actively involved in the implementation process.

In the different steps of the industrial research projects, the industrial researcher assembles information and knowledge from the different resources in order to create new research products. In order to identify the needs for a potential knowledge management support, we observed and analyzed the different practices of the researcher which are related to the management of information and knowledge.

3.4 THE ANALYSIS OF INFORMATION AND KNOWLEDGE MANAGEMENT RELEVANT PRACTICES OF THE INDUSTRIAL RESEARCHERS

For analyzing the different practices, we distinguish between individual and collective or shared practices. This analysis helps to add relevant aspects to the description of the organizational aspects and existing processes for industrial research activities in order to have an almost complete picture for these activities.

We structured the practices according to the description framework of the knowledge manipulation activities from the knowledge management models (section 1.4.2): identify, acquire, structure, share, distribute, combine, use, preserve and eliminate. We did not specify practices for the evaluation activity, as evaluation is a cognitive process (Frank and Gardoni, 2002b). Although this structure helps to give a structured overview, practices often concern several manipulation activities at the same time. This means that the structure of certain practices according to the manipulation activities could be discussed.

Practices can be very individual and very complex. We synthesized the observed practices to more general descriptions.

3.4.1 PRACTICES TO IDENTIFY AND ACQUIRE NEW INFORMATION

In order to conduct research projects and to progress on research themes, the industrial researcher has to identify and acquire new information. For this purpose, he uses the information resources and their organizational networks as well as open information resources like the Internet or external data-bases.

As identification is related to search, the industrial researcher has several possibilities to identify new information:

- Identification of new relevant information during visits of conferences, trade-shows, etc.. During these events the researcher assists on presentations, on conversations with other participants and has access to the event proceedings and other support material like test versions of tool programs, etc.
- Identification of new information during meetings with external organizations like academic laboratories, technology suppliers, etc. Meetings can also take place with operational units or internal units. During the meetings, the researcher has access to oral discussions, presentations and sometimes written support, tool applications or prototypes.
- Identification of new information in written format via searching in Intranets, the Internet, various document databases (for example libraries, official document databases, etc.).

The information can be available in different representation forms and formats. The identified information can provide new resources for supplementary information (for example references in documents, addresses of authors in documents, oral communication of other information, etc.).

We have seen in section 1.3 that information is available in three major forms: oral form, written form in various document formats, and as tool or real object form. The industrial researcher has therefore three possibilities to acquire new information: by talking with other people, by reading written information or by testing and manipulating tools or real objects. These three possibilities can occur simultaneously.

3.4.2 PRACTICES TO STRUCTURE IDENTIFIED AND ACQUIRED INFORMATION

By structuring, we mean in fact the logical organized preservation (storage) of identified information. The structuring of identified information is linked to the evaluation of the identified information. Before structuring, the industrial researcher judges the information as useful to keep or to skip. If he judges the information as relevant to preserve, he structures the information according to the organization of his research expertise domain.

The industrial researcher can have access to information via the communication and dialogues with other people. In official meetings, the industrial researcher writes minutes of meeting documents in order to transcribe the exchanged information. This refers to the transformation of knowledge into information as discussed in section 1.3.3. The industrial researcher transforms only a part of the exchanged information into written information. If the exchanged communication is informal, the research can transform the oral information in all sorts of document (notes, presentations, emails, etc.). In official minutes of meetings, the industrial researcher has the possibility to structure the information according a shared standard document. These documents contain the list of the participants, a short synthesis, and sometimes a conclusion. In personnel notes, the researcher structures the information as individual and according to his own preference.

Written information in various electronic documents formats or tool applications are structured and stored on servers and computers. On the servers and computers we can distinguish between a personal folder structure and a shared folder structure:

- For the personal structure, each researcher has his private structure where he keeps information which is not accessible for other researchers. In the personnel folder structure, the industrial researcher structures private information which are linked to his private research interests. This structure includes usually the web favorites and the email folders. In the email folders, the researcher can store the different emails but also emails with attached documents.
- For the shared structure every research project has a folder structure where the industrial researcher can keep information relevant for the research project. Several projects have different work-packages (WP). Are these work-packages very big, they can have the same folder structure as the project (Figure 3.3).

The project folder structure (minutes, mail, client data, presentations, research program, exchange for study, results for transfer, other) is based on the ISO certification framework. This framework implies structuring the information describing the objective and plan of the research activity (research program) the progress of the research activities (minutes), and the results (results for transfer). Additional folders in the project folder give the researcher a coherent working space to structure the information relevant for the result of the study and its communication.

The folder structure for the projects does not only structure identified or acquired information. The industrial researcher preserves also the produced research results as well as the accompanying produced intermediate information like minutes, presentations, etc.

A third folder structure concerns relevant information for the research activities of the competence center (department / service). Here, researchers can structure general information for certain research themes or keep other relevant information for research activities.

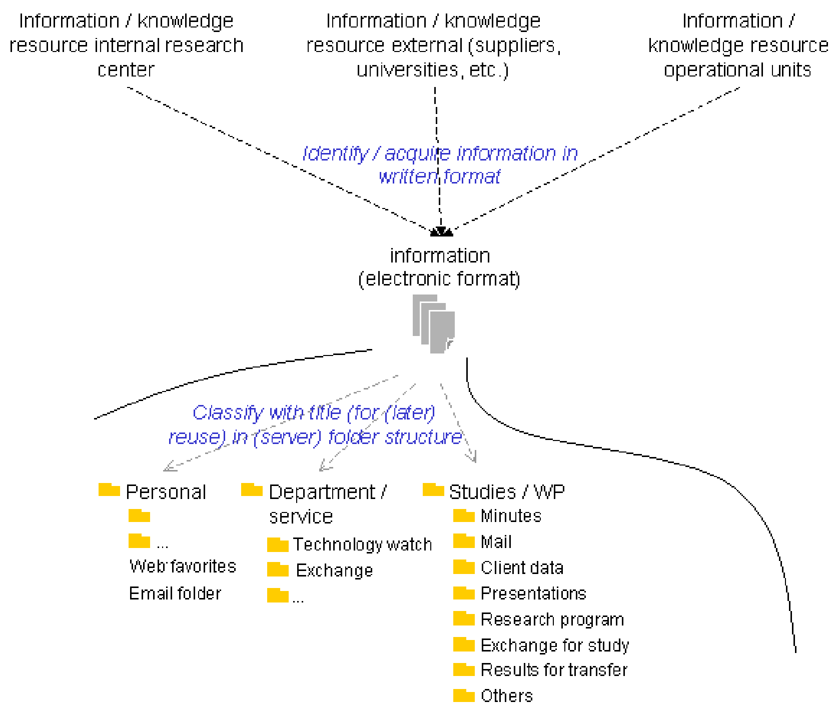

Figure 3.3 – Folder structure for structuring electronic written information

In the personnel and shared folder structure we can distinguish between shared research themes, non-shared research themes and emergent research themes.

- A shared research theme can cover several official research projects, private research interests, and group interests. The structure in themes allows that the different researchers can classify and identify their work in similar research objectives.
- The industrial researcher has personal research interests which he does not share with other researchers. These interests can be directly linked to his official research studies or are free general interests. Non-shared research interests can influence official research activities. New ideas, based on non-shared research interests can emerge as new shared research activities.
- Emergent research themes can concern information and knowledge for new and emergent research questions and/or technologies. Emergent research themes can be shared or non-shared. The industrial researcher collects information concerning these emergent research themes in order to prepare solutions for future needs. Projects can emerge from emergent research themes in order to clarify the new research questions and technologies.

The structure in themes gives an organizational framework in order to favor a structured progress on the research problems of the research domains of the competence centers. The themes can be supported by the research activities of the projects. In fact, each project usually contributes with its research activity to new information and knowledge for a theme.

This structure of the research in research themes helps to conduct other activities, besides the official projects, allowing to enrich the information and knowledge base of the competence centers. The industrial researcher collects therefore various information for which he admits an interest or supposes that it might be interesting for other researchers.

Written information in various paper document formats are structured similar to the electronic format. Project boxes or folders contain official documents like minutes, results, etc. Other documents are often structured in non-shared folders according to different themes.

3.4.3 PRACTICES TO SHARE AND DISTRIBUTE INFORMATION

Once the researcher identified and acquired useful information, he has the possibility to share it with other researchers. We can distinguish between two forms of information sharing. The two forms depend on the structure and format of the identified and acquired information:

- The first form concerns the sharing of identified and acquired information in dialogues and experiences by testing existing tool applications, etc.
- The second form concerns the sharing of written information.

For oral information, the industrial researcher shares in the following ways:

- Oral sharing: via formal or informal discussions and oral presentations, the researcher can share his new information.

Besides this, he has the possibility to transform the information into written information:

- Minutes: if the researcher attended an official event like a conference, trade-show, etc. he constitutes minutes describing his acquired information and experience during these events. The minutes are distributed according to a distribution list on the minutes (established by the industrial researcher). The hierarchy of the industrial researcher validates the minutes. Therefore, the hierarchy is always aware about the activities of the researchers and his new identified information and contacts.
- Presentations: the researcher can hold formal presentations in order to communicate his acquired information. These presentations can be then available in written format for the other researchers.
- Other written communication: the researcher can communicate acquired information via email and/or informal new documents in which he writes down his information and experiences.

For identified and acquired written information the researchers the industrial researcher shares the information with or without supplementary comments. These comments can be in written or oral format. The industrial researchers use the following ways to share them with other researchers:

- Sending by email: the industrial researcher shares written information by sending it via email with attached documents to other researchers. In the mail he can add additional information concerning the attached document. This additional information can be a personal argumentation concerning the content of the document.
- Printed document with hand written comments: the industrial researcher transmits printed documents with hand written comments in order to communicate additional argumentation for the document content.
- Written document with oral comments: the researcher can transmit documents with oral comments in order to point out additional argumentations for the document content.

The sharing of information plays an important role when researchers work together on research projects or they are attached on the same competence center and therefore working on similar research themes. By sharing information, the researchers support each other in the elaboration of new research results and support a shared and common progress of the knowledge and understanding in a research domain.

By sharing written information, researchers indicate the whole document or parts of the document as being interesting. In the later case, it can happen that researchers indicate different parts of one document as being interesting for different research activities. One part could be interesting for a research study and another part could be interesting for a research theme in general (Figure 3.4).

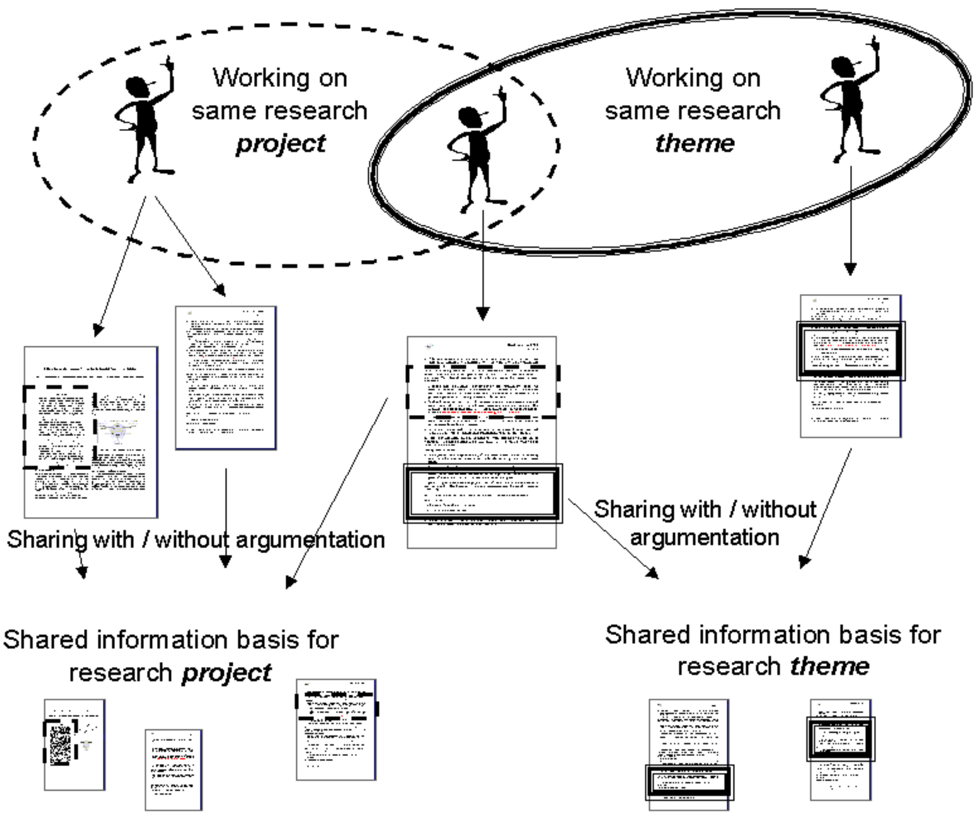

Figure 3.4 – Some practices to share written information content

Concerning the indication of parts of documents, the researcher adds hand-written comments or added coloring. If the document is in an electronic format, an additional explanation in form of an email, electronic note or others indicates other researchers which part of the document is interesting. A separate note in an email or other electronic notes can also describe an argumentation of interest of the document part and discussing for which particular research problem it is interesting and why. However, most of the time, the document part selection and commenting are manual (on paper) activities.

If one document is interesting for different research activities or has parts of documents interesting for different research activities, the industrial researcher stores the document in different folders which are linked to the research activities. This can lead to the fact that the same document is stored in different folders.

3.4.4 Practices to combine and use information for new research result production

The researcher uses information for his projects in order to constitute the research program, to develop new concepts and technical prototypes and to experiment the solutions with information coming from the operational units. In order to formulate new results, he sometimes takes into account parts of existing documents in order to constitute new research documents. He can assemble different concepts, methods and/or application descriptions from different documents in a new document by adapting the descriptions to the new context. This practice can represent the assembling of new documents based on existing document parts.

Some researchers elaborate the final research result descriptions (final research reports), and give the reference of the intermediate research documents (minutes, external documents, etc.). This allows to observe the progress of the development of the research results. The reference allows getting access to the original information which contributed to the research results. However, this is not a general practice shared by every researcher.

The elaboration of the results is very often an individual practice. However, it happens that researchers work together in preparing presentations, writing minutes of meetings or research reports. In this case, each researcher writes a different part of a document and they discuss the common elaboration.

For using information to prepare presentations, communications or uses it for information sharing (see section 3.4.3) the researcher can quote the information from existing documents by adding or not supplementary argumentations or uses the existing information in reformulation combined with his own argumentation.

The reuse of existing information is often accompanied with an additional argumentation or description, for what and why this information is considered as useful for the research objective. This description is often on paper format and constitutes a memorization for what and why the information is relevant for the results.

3.4.5 Practices to preserve and eliminate information

According to the importance of the documents, they are kept differently. Final research result documents (research reports) are preserved during a longer period then researcher research results like minutes or presentations. The preservation duration of the different elements is described in the ISO certification.

At the end of the year and at the end of each research project, the researcher decides which document should be preserved and which document can be eliminated.

The different information in form of documents are often preserved according to the information structure of the research projects or research activities of the competence centers. Besides this, the researcher preserves information in his private folder structure for an eventual later use for new research activities.

The preservation of the different documents depends if the researcher estimates that the documents might play an important role for later researcher activities or if he considers the documents as important key documents for a certain research domain.

3.4.6 THE ROLE OF THE ISO CERTIFICATION FOR THE PRACTICES

The ISO certification which concerns the French research center showed some impacts on the practices. It proposes procedures describing the different tasks concerning the definition of a research program, the regular review meetings for the research results with the customers of the project and the quality control of the research results.

A second important issue concerns the regular elaboration of documents during the project describing the progress of the project and describing important meetings with customers or external partners. At the end of the project, the results are described in a research report addressed to the research customer. The customer evaluates the quality of the report. As the regular elaboration of documents is linked to the procedure of the ISO certification, there are defined document types to use for the different events (formulas for minutes, formulas for reports, etc.).

The ISO certification leaded to a certain structure for the content of "official" documents (standard documents) like minutes or research reports. This concerns for example the elaboration of conclusions and abstracts for the different documents.

Furthermore, a large part of official documents are structured and stored in electronic format on the server according to their document type (folder for minutes, folder for research results, folder for presentations, etc.). This structure concerns the different projects and work packages.

Some consequences for the practices concern therefore the organization of part of information contents in official documents and the storage of these documents. These consequences concern all researchers and have therefore a collective impact on the practices. This can have an impact on the identification and reuse of information. As documents are stored in defined folders and structure according to a certain standardization, the retrieval of information content can be easier. However, official documents play only a minor role among the written information. For other documents, researcher structure content and storage differently from each other, which can hinder the exploitation of available documents.

3.5 EXISTING USED TOOL SUPPORT FOR RESEARCH ACTIVITIES

In the following sections, we will describe the used tool support for the research activities. We will discuss furthermore, how the used tools support the practices of the researchers and the limits for a better information handling and exploitation.

The tools are used to identify and acquire information from various resources, to structure the information, to share information with other researchers and to support the reuse of information for research result production. Therefore, the tools support parts of the different practices.

3.5.1 DESCRIPTION OF EXISTING TOOL STRUCTURE AND SUPPORT

We can distinguish between a collective working space and an individual working space (see Figure 3.5). In the collective working space, several researchers have access to tool support to organize and share information. In the collective working space we distinguish between the following used modules:

- Common document classification directory. The common document classification directory represents the structure of the shared folders on the server. This means that these folders are accessible for each researcher. This classification directory can be divided into the directory folders containing the official documents for the different research projects and the general directory folders for each competence center. The structure for the project relevant documents is oriented according to the ISO certification framework (see also Figure 3.3 from section 3.4.2). In the directory for the competence centers we can find folders containing documents from technology watch activities, general operational unit needs description documents, useful administrative information, etc.

As the different official documents for the different research projects and the different research themes are preserved in an equivalent manner, their retrieval is easier for other researchers not involved in the projects and research domains. The shared structure gives a shared context, known by the researcher, to the documents.

The shared structure allows also comparing between the different research projects and themes according the available information. This comparison can lead to conclusions about the overall research activities in the different projects and themes.

The structure of the folders in research result folders, minutes folders, client data folders can allow (if well structured) to follow the information concerning the elaboration of the current research results and the needs of the operational units.

- Forum. The forum is accessible for each researcher. He can post new messages with or without attached documents. The other researchers have access to the messages and can post responses to the posted messages.

  The forum supports the distribution but especially the sharing of new information estimated as important for the community of a competence center. The industrial researchers have the possibility to discuss their opinions accessible for every other researcher.

- Common agenda. The common agenda is also accessible for every researcher. In the common agenda, the industrial researchers mark their meetings with operational units, visits at conferences, internal meetings, etc.

  The common agenda indicates the different contacts of the industrial researcher with other peoples and the different activities (meetings, visit of conferences, etc.) of the industrial researcher in his research domain. This can initiate an information exchange with other researchers who are interested in the activities.

- Electronic document management. Electronic document management assures the administration of the self-produced official documents (reports, minutes of meetings, letters, and other official documents). It references the self-produced documents with a reference. If the document is relative to a research project, the reference number contains the description number of the research project. The researchers have the possibility to introduce key words and abstracts (only for the reports). This allows other researchers to search for official documents.

Individual working spaces can only be manipulated by the researcher to whom they belong to. In the individual working space we distinguish between the following modules:

- Private document classification directory. In the private document classification directory the industrial researcher stores the documents concerning his private research interests. The structure is free and depends of the habits of the industrial researcher.

- Email. The email is personal for every researcher. With email, he communicates with other people concerning his research activities. In the email folder, he structures the different received and sent mails according to a personal structure. Some emails have attached documents and are stored with the emails.

- Private agenda. In the private agenda, the industrial researcher marks his private meetings. Some of these meetings concern the private research interests.
- Internet. Although that Internet is a tool accessible for every researcher, the manipulation stays individual. Different researchers use different search engines. Furthermore, each researcher has a selection of bookmarks. These bookmarks are not shared among the researchers.

Using Email and Internet, the researchers have access to internal and external information. Email can be used to distribute information. In order to produce new documents (for example for the elaboration of new research result reports, for minutes, for presentations, etc.) the industrial researcher uses standard office software.

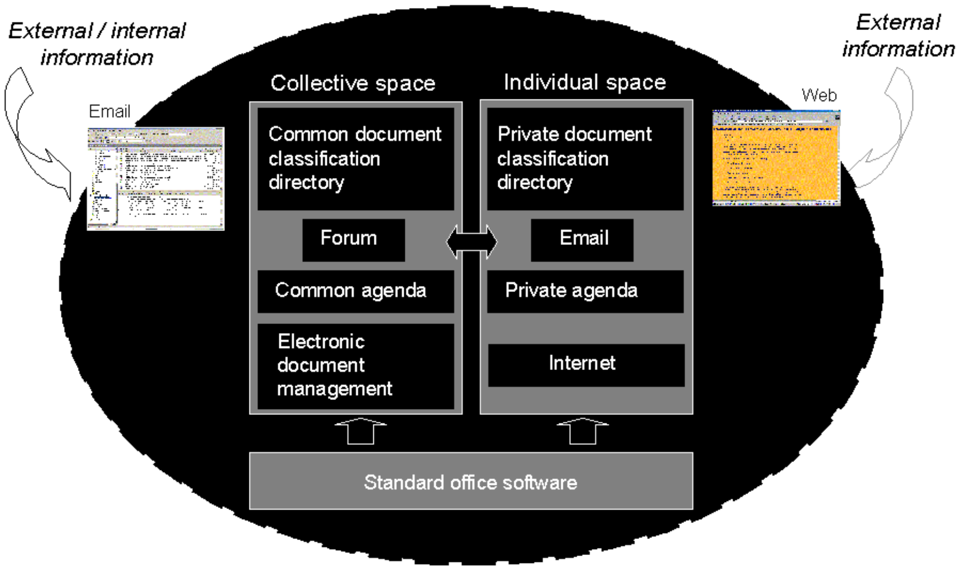

Figure 3.5 – Actual used tool structure in research center of the case study

This tool structure is not optimal in order to support the handling and exploitation of information and information content for the context of industrial researcher activities. In the following section, we will describe the problems with the existing tool structure which will lead us to the needs.

3.5.2 Description of the problems with the existing tool structure

We have seen that written information plays an important role for industrial research activities. The industrial researcher produces written information in order to document new research findings and relevant events. He also uses existing written information in order to exploit it for new research result production. Therefore, an optimal handling of written information in the context of industrial research activities might support the performance of these activities (Frank and Gardoni, 2002c).

In order to structure the existing problems, we oriented the description on a user segmentation. People have widely divergent views on how documents are accessed and used by different users. The needs of users from different job functions varied in terms of role or job function and experience. At one extreme, users need only high-level information: an executive summary or a descriptive framework for a number of available documents. At the other extreme, users need very detailed information.

People with a long experience in a specific research domain are able to understand the context and content of a document relatively fast. But people who are new in a certain research field are often unfamiliar with the content of certain documents and therefore have difficulties to find existing information.

Therefore, we propose to distinguish between the following user segments:

- Problems concerning the industrial researcher as individual,
- Problems concerning groups of industrial researchers or interaction between industrial researchers and
- Problems concerning the industrial research manager.

For each of these three groups, we describe the main problems (causal factors) and the impacts these problems might have on the research activity.

3.5.2.1 Causal factors and impacts for industrial researcher as individual

The industrial research as individual encounters the following problems:

- Loosing the overview of collected documents: what is collected, why are they collected, where are they stored, what are they talking about. The actual document classification directory is static and does not allow to store documents according to these questions.
- The researcher is confronted with too much available information which he cannot structure for a better retrieval.
- Loosing the track of which document or document section was important to take into account for later research work and what for. He has too much implicit information about the different documents and document section which he cannot remember when he needs to reuse the information.
- The context or the description of the use of documents or document sections stay implicit and risks to be lost after some time.
- The actual storage structure and server structure has limited capacities in order to store and to find documents according to their storage context. This aspect addresses the retrieval problem for stored documents and information in general.

These aspects can have a direct impact on the performance of the industrial researcher in order to achieve his research objectives:

- He risks to not taking into account important information identified at an earlier moment.
- He risks to not taking into account or loosing the argumentation for intermediate information, research results and ideas. This argumentation can be necessary to constitute final or later research results. He therefore can loose important information to create new innovative solutions.
- It takes him too much time to re-access and to re-analyze the already identified information or documents in order to known in which context he planed to use them.

3.5.2.2 Causal factors and impacts for groups of industrial researchers or interaction between industrial researchers

Groups of industrial researchers meet the following problem:

- There are two main ways of storing identified documents in the existing system: documents can be stored according an official research project repository structure or they can be stored in a private structure. The private structure might not be linked to an official structure. A transversal structure in research themes or research domains is not very explicit. Transversal structures would be necessary to share a common contact database for example, to share documents between researchers with similar research interests, etc.
- Practices to structure information are individual. The responsibles for the different research projects organize their relevant information differently and use different file names. Other people do not know this organization and have difficulties to understand the different file names.
- In terms of impacts, people tend to share information only at its end state, when it is ready for consumption, and not during discovery. This situation can create duplication of efforts for people working on similar research problem environments. People might rediscover known problems that had not been communicated to others. According to Intel (Intel, 2002), people estimated 15% to 20% of their time for rework due to the lack of clear and current information.
- The implicit communication (reactions) on information in form of documents or document sections is lost after a while and not accessible for other people.
- Reactions in form of dialogues on internal documents or document sections are not transmitted or lost for the author if he is not available during a certain time. The use of electronic mail does not replace a space where it is possible to exchange about document or document sections.

These aspects have the following impacts on the performance:

- There is little shared structure for an information basis for common research interests among different people. This could mean that researchers have limited access to already identified important information because they do not know, how the information is organized. Therefore, people have difficulties to share information.
- A significant problem was the lack of communication regarding the repositories: where the documents were stored and what other document repositories existed. Even when the users knew which document repositories existed, access to them was often problematic because the structure was unknown.
- The unknown structure of the information lead to the fact that researchers had difficulties to follow the evolution of the different research projects and therefore the maturity of the results.
- The variety of document organization leaded to the fact that researcher did not use information identified by other researchers.
- There is a very limited preservation for exchanged additional information. This sort of information can be considered as explicit knowledge. The additional information might contain relevant new elements for new research products.

3.5.2.3 Causal factors and impacts for industrial research managers

The industrial research manager encounters the following problems:

- He has a limited overview of available information (in form of documents) collected by industrial researchers for various research objectives or themes. He needs a global overview of available information for the different research activities to support decision making.
- He has the difficulty to see which external information helped to constitute the research results. This problem concerns two aspects: he has the difficulty to see the origin (in terms of references) of used external information and has the difficulty to see, how this information is used to get the new research results.

In terms of performance influences, the problems can have the following impacts:

- The research manager has a limited view of existing possibilities and choices in terms of technologies and customer requirements. This can lead to decision without knowing the relevant information and therefore lead to critical decision in terms of new research objectives.
- He has only a little possibility to know if the information used to achieve research results was sufficient and exhaustive.

This problem description and the discussion of the impacts on the research activities for the individual researcher, the research teams and the research manager constitute the basis for the formalization of the needs. The needs were analyzed on two levels: on a first level, a functional analysis helped to clarify the potential functions for a knowledge management system architecture. On a second level, we structured the needs for a better management and exploitation of information content according the knowledge manipulation activities as structured in section 1.4.2.

3.6 FUNCTIONAL ANALYSIS – A CLARIFICATION OF THE NEEDS

With a group of industrial researcher and research managers, we lead a functional analysis in several meetings. The objective was to clarify the needs for potential functions of a system supporting industrial research activities.

The first part of the analysis was to determine the environment interfaces of a potential system. The second part determines the desired functions of the system. The functions link the different environment interfaces throughout the system.

3.6.1 DEFINITION OF THE ENVIRONMENT INTERFACES

The system should help the industrial researchers improve the management of information content for their daily research activities. Therefore, the environment interfaces should represent the environment of an industrial researcher: he is in interaction with external information suppliers, internal information suppliers, information resources concerning the operational units (research customer requirements), and teams of researchers. Each environment interface can be characterized with different aspects.

- Operational unit environment: this environment concerns the operational requirements and research requirements of the operational units. Furthermore, the environment concerns the context of operational unit environment business processes and their business strategy.

- External information supplier environment: this environment concerns competitor markets, other industrial research laboratories, academic (university) laboratories, technology suppliers and research partners. These items are potential information resources for internal research activities. The potential interesting information coming from these information resources concern: new innovative concepts, new methodologies, new technologies, new tools, experiments with tools and new technologies, etc.
- Internal research activities: This environment concerns relevant aspects for internal research activities. These aspects can be described by the research results as products of industrial research processes, research activities in general and the acquired competencies and knowledge in certain research domains.
- Internal information supplier environment: it can be considered as an information resource for information concerning new methodologies, tools, etc. Nevertheless, we distinguish between the internal information supplier as a team and the internal information supplier as an individual. There is a difference between teams and individuals as information suppliers (Leadbeater, 2001). Teams have common knowledge, knowledge based on a certain consensus. In order to be part of a team, individuals need to adapt their knowledge to the team knowledge. This can be done through intensive communication between team members and new individuals. On the other side, individuals coming to an existing team can enrich the team knowledge.

After defining the environment interfaces of the potential system, we defined the potential functions which could link the different environment interfaces.

3.6.2 Definition of the functions

The functions are described below (Figure 3.6):

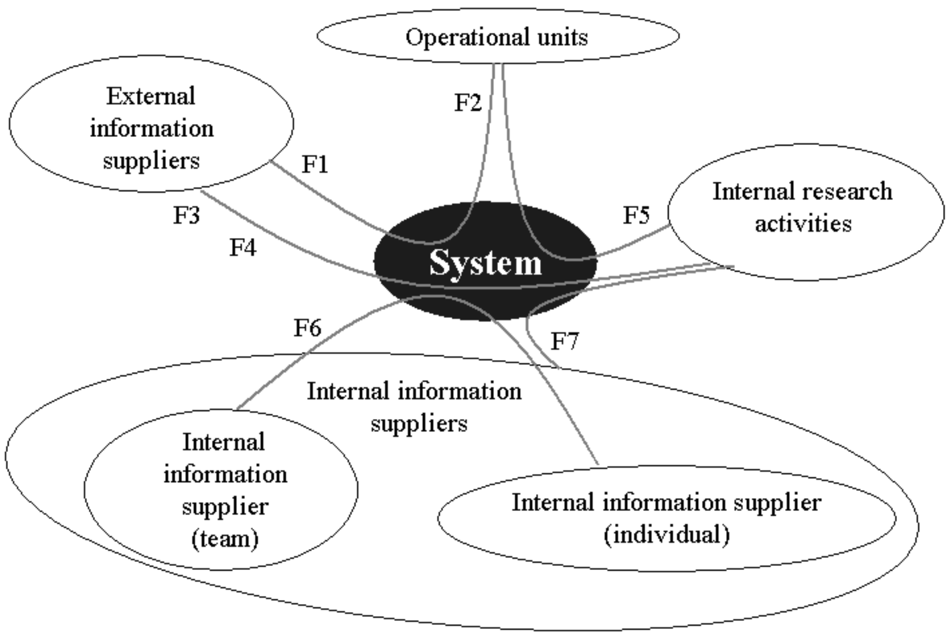

Figure 3.6 – The environment interfaces of a potential system for industrial research processes and its potential functions

- *F1*: The system should help to identify external industrial problems comparable with the problems of the research customers. The objective is to identify external industrial problems, industrial requirements among industrial partners, competitors, etc. similar to the problems and requirements of internal research customers. Certain external problems could be equivalent to the implicit customer needs not yet identified. This could help to identify future research domains in order to be able to propose solutions when the internal operational units confirm their requirements.

  The fact to compare external and internal problem environments helps to understand different contexts of a same problematic aspects. External industrial problems could help to specify the problems of the operational units. After comparing the problem environments, it is interesting to get access to external solution propositions. These propositions concern the functions F2 and F4.

- *F2*: The system should help to identify external solution proposals (concepts, methods, technologies, etc.) for the research customer requirements. The objective here is to support the identification of technologies and external methods which could support the solution development for customer problems.

  The external solutions could be taken into account for research results experiments which aim to resolve operational units problems.

- *F3*: The system displays the gap between the research activities conducted by external research organizations and the internal research activities. This function allows the visualization of an evaluation of external research activities compared to internal research activities concerning a research subject. It could show in which way external research problems are treated. After such a comparison, it would be possible to decide whether to integrate external research activities and results and to orientate the internal research activities. The knowledge management system can thus contribute to an evaluation for knowledge and supports to select between obsolete, basic and new knowledge (Tiger and Weil, 2001).

- *F4*: The system helps to identify external elements (concepts, methods, technologies, tools, competencies, etc.) in order to carry out internal research activities. The objective of this function is that the system provides the industrial researcher with external elements necessary to conduct his research activities and especially his different studies. The external elements can be necessary to realize new research products but they are also necessary for the research manager as orientation to elaborate new research plans. Therefore, the external elements can also influence the decision process for new research activities. New concepts or methodologies could be judged as important enough to start a new research activity in order to explore the new elements.

  For the research projects, the external elements help to elaborate new solutions. They can play an important role as a part of a solution in form of a research product.

- *F5*: The system should show in which way the research activities cover the customer requirements. The objective here is to visualize the difference between the customer research requirements and the requirements treated and covered with internal research activities. This difference indicates the need for future research activities and the need to deepen already existing research activities and initiates actions to create new knowledge.

- *F6*: The system should support a sense of sharing among internal researchers working in the same research area. In order to create this sense of sharing between researchers, it will be necessary to develop competencies references, to rely similar professions, similar project environments, and perhaps transverse organizations (Tiger and Weil, 2001).
- *F7*: The system should help to identify internal elements (concepts, methods, technologies, tools, and competencies) that help to carry out internal research activities. This function is similar to the function F4. Nevertheless, it takes into account internal elements instead of external elements. The function should support the identification of internal existing elements. This could also be a support in order to demonstrate the maturity of internal knowledge according to existing problem environments.

These different functions need to be included in a global solution framework proposition for industrial research activities.

As we have seen, the functions are based on the handling and exploitation of information content for industrial research activities. The actual used tool structure does not allow an optimal handling and exploitation of documents for the existing practices of the industrial researcher. The following section describes the concrete needs concerning the handling and exploitation of information content which support the description of the above functions.

3.7 NEEDS FOR A BETTER HANDLING AND EXPLOITATION OF INFORMATION CONTENT IN WRITTEN INFORMATION

The industrial researcher works with the document content in order to produce new research results. According to the nature of the document content, different elements play an important role for research activities:

- For external documents, important elements concerning the document content are bibliographic reference indicating experts of a certain domain, technology references indicating new technologies and their suppliers, various concept, method, technology and tool descriptions as well as their use in comparable industrial environments indicating potential contacts for experience feedback, etc.
- For operational unit documents, important elements for the document content concern the description of existing processes and used tools, an indication of a contact person working in the existing processes and with the existing tools, actual project descriptions and information about project participants and the project leaders, etc.
- For internal documents, important elements for the document content concern the description of new research solutions, experimentation results and the people who were involved in the elaboration of the new solutions.

According to the knowledge manipulation activities, the needs can be structured as discussed in the following section 3.7.1 to 3.7.5.

3.7.1 IDENTIFICATION AND ACQUISITION

In the functional analysis, especially the functions F1, F2, F4 and F7 focus on the need to identify information for industrial research activities. Concerning the identification of written information, the industrial researcher needs rapid access on the content of the written information. This means especially that the researcher gets access to the information content of documents in various formats and that he identifies the relevant information for his research activities without loosing time.

3.7.2 STRUCTURING

A structured storage of documents is possible with the existing tool structure. However, the researcher needs a deeper structure for document contents. The large amount of written information needs to be structured from a content point of view in order to favor the retrieval and sharing of existing documents.

In the actual tool structure, the industrial researcher can store a document in one or several folders. In order to give a broader retrieval context to one document he needs to duplicate it. He therefore needs the possibility to add supplementary context to a document according to his research context.

This plays also a role for parts of documents: the industrial researcher can use different document parts for different research objectives. Therefore, he needs to be able to structure parts of documents and to add also supplementary context to these parts.

3.7.3 SHARING AND DISTRIBUTION

The industrial researchers have the possibilities to share documents. However, what is interesting for the industrial researcher is the sharing of the document content and the connected argumentation concerning a research objective. The sharing of document content should support the elaboration of new research results as well as a common progress in certain research domains. Furthermore, in order to support a common analysis about new information for certain research objectives and research domains, the industrial researchers need a framework where they can share their argumentations based on the information and on a certain research objective context.

In order to share information content with other researchers, a certain common context based on a common understanding of research objectives and research interests is necessary for a better understanding of the information content.

3.7.4 COMBINE AND USE

The combination and use concern the introduction of existing information with its relevant argumentation in new research result documents. The researcher needs access to the information content of documents in order to reuse for it the elaboration of new research results. By reusing the information for new research results, the information resources (references, citations, etc.) of the used information need to be introduced as references.

In order to reuse existing information content, the industrial researcher needs to know the context of the different information contents of various documents. He needs a synthetic overview of reusable information content in the context of his research objectives and research interests.

3.7.5 PRESERVE AND ELIMINATE

The preservation of information content is linked to the structure and reuse. A structured preservation of information content supports a more effective reuse. In the context of our work we therefore focus only in this context on preservation.

The elimination of information content and therefore documents concerns the need of eliminating an information overflow. It is important to preserve relevant information for the research activities and to eliminate irrelevant elements. Therefore, the researcher needs a set of criteria in order to be able to judge the relevance of information content.

3.8 CONCLUSION

The analysis of the activities during research projects showed that they could be structured in different tasks. These tasks can represent in fact different maturity phases in the research process concerning a certain research question or theme. The researcher starts with state of the arts and process analyzes, passes then through concept and method elaboration with prototype validation and goes then to a deployment phase with transfer of the results. During these different research process phases, the knowledge maturity concerning the research question or theme increases.

The aspect of the knowledge maturity was also indirectly highlighted with some functions defined with the functional analysis. The functions F3 and F5 define more an evaluation framework for industrial research products towards the external and operational unit environment. The evaluation indicates a certain level of the maturity towards other research activities. It could indicate if it is necessary to conduct further or future research activities or to purchase existing external research results to close the gap between the research results and the operational needs or the external research activities.

During the different research process phases, the researcher has different practices to manipulate, manage and exploit information. This helps him to acquire more information for the research question or theme and therefore more knowledge. The practices have an individual and collective dimension and can be structured according to the knowledge manipulation activities. The analysis of the practices leaded to the needs.

The needs concern the exploitation of the individual practices and processes for a collective reuse. This includes the exchanged information in written format or via dialogues and the different forms of information memorization (mail, minutes of meetings, classification, etc.). The researchers need a better exploitation on a collective level (for example for a competence center) of written information content. This can concern for example parts of documents or other written information which are important for research projects (Figure 3.7).

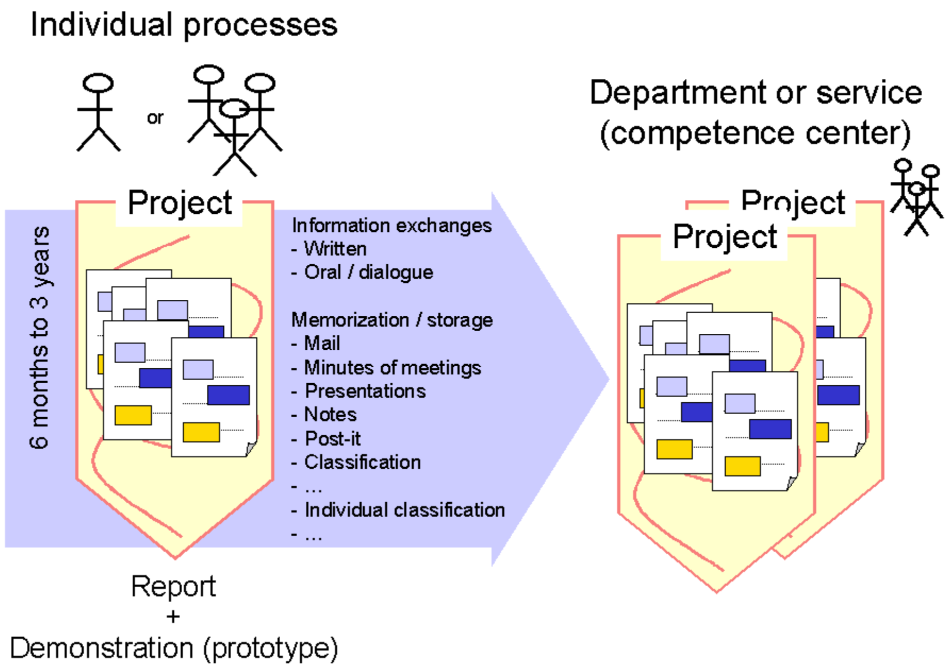

Figure 3.7 – Exploitation of individual processes for a collective level applied on written information content

The analysis of the actual used tool support showed, that there are several problems of supporting the different practices. Therefore, the objective of the majority of the different functions of the functional analysis was to supply the industrial researcher with new information from different resources, support the access and reuse, and the sharing between the researchers.

These different analyses provide an overall framework for industrial research activities. On the one side we have the different research process phases. The phases are supported with the different practices structured according to the knowledge manipulation activities. A shared referential integrity based on an quality procedures and document standards, an organization in competence centers and shared research domains and themes allows to support the shared practices and to structure information content based on shared ontologies for a better management and exploitation and therefore knowledge creation. This needs to be integrated as support for the different practices.

4 A KNOWLEDGE MANAGEMENT FRAMEWORK FOR AN INDUSTRIAL RESEARCH CENTER

4.1 INTRODUCTION

Based on the general context of an industrial research center, the organization of the competence centers in research domains (chapter two), the project structure and the analysis of the practices (chapter three) we propose in this chapter a general framework architecture for knowledge management in industrial research centers. According to CIMOSA (Vernadat, 1996) we propose an architecture with three sub-models: generic model, partial model, particular model. The generic model will be a process-oriented model. Therefore, our proposition will be process oriented.

The general framework architecture allows to structure a potential tool support for the research activities (Frank and Gardoni, 2003a). We therefore use the framework architecture, to structure the requirements of the functional analysis and the needs identified in section 3.7.

With the focus on a better handling of information content especially in written information we analyze existing tools. After the description of the still existing problems with existing tools we will propose additional tool functions for a prototype development based on the general framework architecture.

4.2 THE CONSTRUCTION OF A FRAMEWORK PROPOSITION FOR INDUSTRIAL RESEARCH ACTIVITIES

In order to structure the different elements of the previous chapters for a framework proposition we propose to use parts of the CIMOSA framework (Vernadat, 1996) (for more details about the CIMOSA framework we described it in the appendix A.3). We propose to use the principle of "instantiation" with its three generic levels – generic model, partial model, particular model – in order to describe our framework proposition.

- Generic model: for the generic model, we propose to assemble the different elements describing the overall industrial research center context. This includes from our point of view, that the industrial research center has a defined customer structure and therefore an objective oriented activity structure based on operational needs, a defined product model, a general resource structure, and a general project framework structure. According to the principle of the generic model, we will propose a general objective oriented research process framework model based on the above elements.

- Partial model: for the partial model, we propose to assemble the different practices of an industrial researcher as individual and as acting in a team. The general objective oriented research process framework implies different practices in order to produce new research products. According to the principle of the partial model, we will propose a general activity management framework model.
- Particular model: for the particular model, we propose to assemble the different items which influence the elaboration of research results from a content point of view. The content oriented structure is specific to research problems and research project objectives and can be structure according to research domains, research interests, etc. The content oriented organization of the research activities influences the information content necessary for the research result production. According to the principle of the particular model, we will propose a resource element content and research activity content structure framework model.

These three models will constitute a general model framework proposition for industrial research activities (Figure 4.1). This general model framework will allow to structure and analyze knowledge management activities, organizational aspects and technical support for the research activities of an industrial research center.

Figure 4.1 – Application of the CIMOSA model to elaborate general framework model for industrial research activities

CIMOSA		General framework model for industrial research activities
Instantiation	Generic model	General objective oriented research process framework
	Partial model	General activity management framework
	Particular model	Resource element content and research activity content structure framework

In the next sections, we will describe the different parts of the model frameworks in detail.

4.2.1 General objective oriented research process framework

The organization of the research result production in research projects and the evolution of research activities in research domains implies a process oriented structure. The analysis of the research projects in section 3.3.2.3 sowed that it is possible to distinguish different phases in a research process.

An industrial research process is initiated by a need to improve processes and/or products of the operational system or by the discovery of the importance of new innovative concepts. According to the maturity degree of the researcher's knowledge, the research process can be decomposed into three phases: investigate, focus, deploy (Figure 4.2):

- The activities concerning the investigation phase characterize the identification of new research domains, the observation of new technological possibilities and activities and aims to constitute state-of-the-arts mainly about new concepts, new technologies and new methods. Therefore, the industrial researcher transfers and transforms external information into internal knowledge: an information flow from the external environment to the internal environment supports the production of new knowledge which is transcribed in new research result descriptions. The monitoring activity is very important for this phase of the research process. Before transferring external information into internal knowledge, the researcher evaluates the utility of the external information for his future research activities or for the activities of other researchers. Besides the monitoring activity concerning external information the industrial researcher investigates about operational unit processes, used technologies, needs, etc. He consolidates the different information in order to identify new research orientations and opportunities.

- The objective of the next phase is to focus on new technologies and methods and to acquire new knowledge and competencies in order to propose new concept models for identified or possible needs. Experimenting and illustrating prototypes by using new technologies and methods help to acquire new knowledge and competencies. The experiments and illustration of prototypes are based on real or fictive use case data. The real case data is often provided by the operational units. The experiments and illustration help to constitute new concepts which in fact represent the main results of the research activities. This combination is characterized by learning processes for researchers, by knowledge exchanges among researchers and initiatives of innovations.
- Deploy driven research is directly related to the operational unit requirements. The industrial researcher transfers the new developed concepts with prototype or method application to the operational units. He supports the operational units by the development system specification in order to make the new concepts operational. By proposing solutions for the identified problems, the research units transfer their knowledge into the operational units. A way of transferring the results is developing presentations and teaching the new finding to the people of the operational units. Learning processes for researchers also accompany the transfer of knowledge: the feedback of the operational units about implemented research solutions.

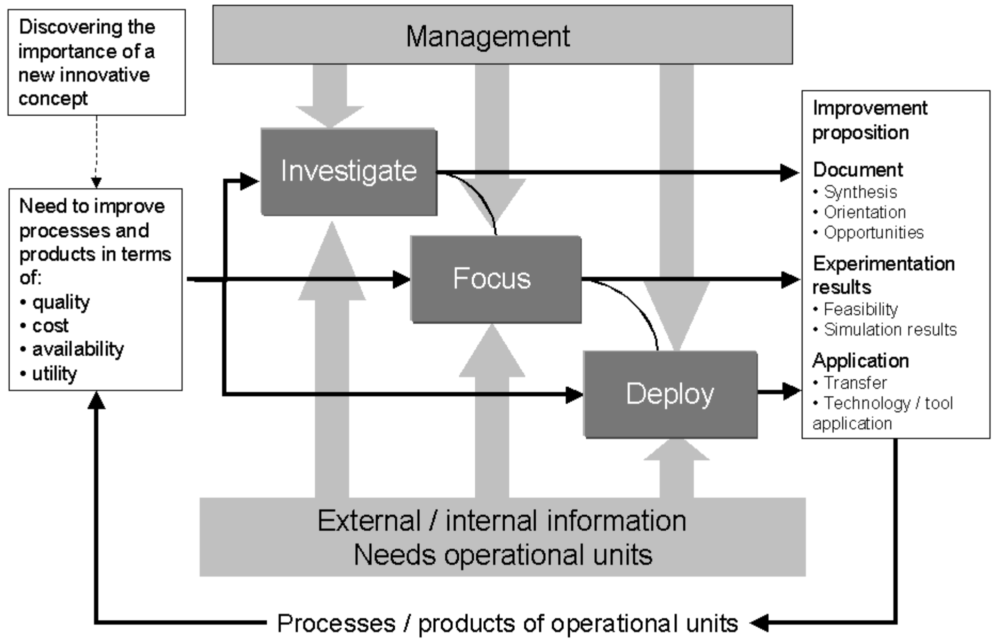

Figure 4.2 – Objective oriented research process framework

Each phase describes activities which have different forms of results. In order to produce these results, the industrial researcher needs resources. These resources are external information / knowledge and the needs of the operational units.

The different phases are linked between each other. Results from the investigation phase can be used in the phase focus. The results from the phase focus can be used in the phase deploy. By following the development of research activities through the different phases, the industrial researcher improves his knowledge maturity for the relevant research domains. The value of his expertise for the operational units improves by following the phases. The distinction between the different phases can therefore be used in order to evaluate the knowledge maturity for certain research problems or operational needs and could lead to a "go / no go" decision between the phases to start the activities of a new phase (Frank and Gardoni, 2003b).

4.2.2 THE GENERAL ACTIVITY MANAGEMENT FRAMEWORK

We have seen in section 3.4 that the researchers have common practices to drive research activities. The practices can be structured according to the knowledge management relevant manipulation activities synthesized from the knowledge management models of APQC and Romhardt as described in section 1.4.2. We therefore propose to integrate a cycle model of knowledge management relevant manipulation activities in the global framework proposition. This integration allows to structure the different knowledge and information management activities as well as the potential knowledge management tool support.

The functional analysis gave some first indications about the information relevant activities needed to be technically supported by a potential system. The different functions stressed the activities identify, acquire, share and evaluate.

We propose to extend the knowledge management relevant manipulation activities of the APQC and Romhardt models to the following nine activities: identify, acquire, structure, combine, share, distribute, use, preserve, and eliminate (Figure 4.3).

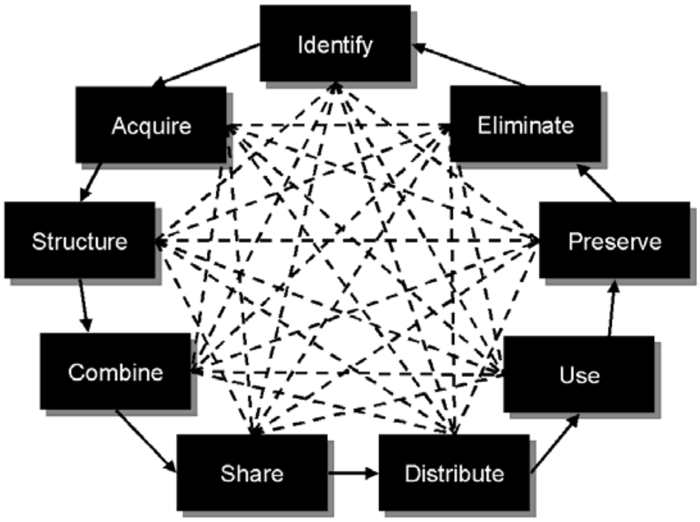

Figure 4.3 – General activity management framework

All the activities are linked to each other as also shown in the model of Romhardt. This means that several manipulation activities can take place at the same time.

There is a certain direction flow between the different activities. This flow depends on the management of knowledge through the knowledge lifecycle (Romhardt, 1998).

According to Romhardt, the different knowledge relevant manipulation activities from his model support a better handling of internal and external knowledge. Our proposition does not limit the activities on knowledge. We propose to take into account essentially information elements or information content elements which can contribute to the progress on research activities and research domains. As we consider knowledge as being fictive elements being in people's brain, the only way to handle it with the different activities is to manage people.

The activity management framework provides a framework for a possible support for the practices of the industrial researcher. However, the elaboration of new research results depends on the use of new information content (often in written information), coming from various resources, combined with existing knowledge (information content used by industrial researchers for an objective in research activities). The new research results are linked to their depending research domain or interest of the industrial researcher. In order to be able to provide a support for research activities via the activity management framework, we need to know what kind of information content the industrial researcher uses for new research results. Furthermore, we need to know, which information content represents an interest for which research domain. We therefore propose a resource element content and research activity content structure framework.

4.2.3 Resource element content and research activity content structure framework - an ontology for industrial research

We described the information resources with real objects. We expressed this description framework in a sort of “knowledge typology” for the industrial researcher. This knowledge typology describes the knowledge of the researcher he needs to produce.

We elaborated two levels to describe the knowledge typology. First, we created a global knowledge typology, describing the global necessary knowledge the industrial researcher has of its environment in order to produce new research results during his daily activities. On a second level, we focused on a detailed content description concerning the needed information.

For the content description we used the concept of ontology (see section 1.7.3.4). This means that the content description represents in fact an ontology for industrial research activity relevant information content. In order to specify a knowledge typology in form of an ontology, we analyzed the document content produced and used during a research projects and hold interviews with people in order to characterize their knowledge.

4.2.3.1 The global knowledge typology

During this analysis, we observed the same environment constellation of the resource environment as the environment interfaces for the functional analysis: corporate research center external environment, operational unit environment, and internal (corporate research center) environment. This confirmed the constellation of the knowledge and information resources for an industrial researcher.

The study in the EADS context gave twelve main knowledge types (Figure 4.4). In order to place the knowledge types describing the information and knowledge resources in the overall research activity environment, we divided the knowledge typology into four groups of three knowledge types. Three groups of the knowledge types describe the resources environment of the research activities. The fourth group gives a brief description of the assembling process, the knowledge about the research product and the context about the research product.

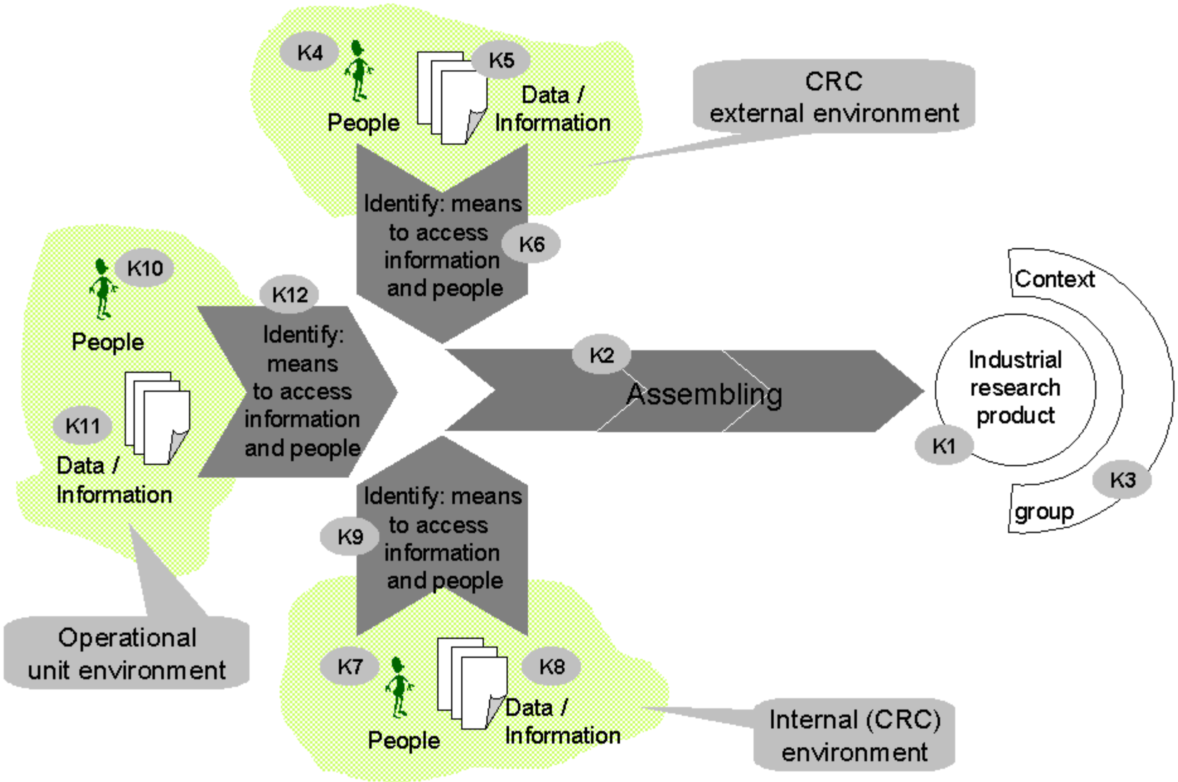

Figure 4.4 – General knowledge typology for an industrial researcher

We will first describe the group of knowledge types which does not concern the knowledge and information resources:

- *K1* describes the researcher's knowledge concerning his own research products. He knows the structure and the content of his products.
- *K2* describes the researcher's knowledge concerning the process and daily activities to reach research results and products. This concerns the assembling activity of the different knowledge and information resources to the final product. The knowledge type contains cognitive processes as well as manual assembling activities (programming, execution of programs, report writing, etc.).
- *K3* describes the researcher's knowledge concerning the global group context of the use of his research results. The industrial researcher knows, how his research result production could affect the operational unit environment of the group. He knows, how the results are evaluated by other people and how they estimated their usability according to other external solutions.

The following knowledge types describe in detail the information resources and the objects, how the information is transferred to the industrial researcher. The different knowledge types describing the resources concern the people as information and knowledge resources, technical and physical objects as knowledge and information resources and the means how to access to these resources.

A first group of knowledge types describes the external environment of the research center (Table 4.1): K4, K5 and K6 describe the entire knowledge of an industrial researcher concerning his knowledge about the external information provider system. For the external environment the analysis and the interviews showed that we can distinguish between three sub-groups as external information and knowledge provider: the academic / industrial laboratories, the suppliers, and the external users (partner / competitors).

K4 describes the knowledge of an industrial researcher about the people he can contact from the external environment. K5 describes the knowledge he has about concrete technical objects describing information which represents and interest for his research activities. K6 describes his knowledge about the means how to access the knowledge and information.

For K5, it is possible to distinguish between written documents and demonstrators or tools. Both forms contain information important for the research activities. The demonstrator is a mean to verify concepts and methods. Therefore, it can constitute an important information resource. Concerning the knowledge type K6, means to access information and people, it is possible, to make the distinction between the means giving access to documents (Internet, written press, Email, etc.) and the means giving access to meetings with people (trade shows, conferences, visits, etc.).

Table 4.1 – Description for knowledge types K4, K5 and K6

		K4	K5	K6
External environment for research center	Academic / industrial laboratories	External researchers, doctoral students and internship students. These people can have a certain expertise for a certain research domain.	• Scientific articles • Commercial articles • Doctoral documents • Activity reports • Presentations • Demonstrators • Minutes of external meetings • Web pages • Patents	• Internet • Written press • Trade shows • Conferences • Visits (meetings) • Verbal communication • Email • Peer to peer transfer of documents
	Supplier	People who are able to manipulate tools and their accompanying methods. These people have experiences about the use of tools and methods in other industrial contexts.		
	Other external users	People from the external user environment can have an expertise about problem environments which are similar to the operational unit problem environments. They can have experiences about the use of methods and tools.		

The different knowledge types describing the internal environment of the industrial research center are the following (Table 4.2):

Table 4.2 – Description of the knowledge types K7, K8 and K9

	K7	K8	K9
Internal environment for research center	Concerns the competencies and expertise of other people working in the same competence macro-domain. These persons are other researchers and research managers.	• Research plan • Study program • Minutes • Study report • Presentation • Doctoral thesis • Internship report • Scientific article • Intermediate documents	• Intranet • Email • Phone • Meetings • Peer to peer transfer of documents • Document management • Yellow pages

K7, K8 and K9 are the counterpart of K4, K5 and K6 and describe the knowledge of an industrial researcher concerning his knowledge about the internal industrial research system.

The different knowledge types describing the operational unit environment are the followings (Table 4.3):

Table 4.3 – Description of the knowledge types K10, K11 and K12

	K10	K11	K12
Operational unit environment	Means the knowledge concerning people working in the operational unit environment. These people can be in interaction with the researcher for a research project.	• Presentations • Procedures / processes descriptions • Internal norms • Tools • Research sheets • External minutes of meetings	• Intranet • Email • Phone • Meetings • Peer to peer transfer of documents

This global knowledge typology describes, how the industrial researcher can access to the different knowledge and in which format or physical object the information or knowledge is available. However, in order to produce new research results, the researcher uses the content of the different available knowledge and information.

We therefore, based on the above described analysis, developed a content knowledge typology which describes and structures the relevant content the researchers need to produce new results. The content description represents in fact an ontology for relevant information content for industrial research activities.

4.2.3.2 The resource element content knowledge typology for industrial research activities

With the first level of knowledge typology, we were now able to determine the second level of the knowledge typology, the content oriented knowledge typology. In working groups we elaborated the different content oriented knowledge types. This content knowledge and information specifies the knowledge types K4, K5 for the external environment, K7, K8 for the internal environment, and K10, K11 for the operational unit environment.

For the external environment, we distinguish between academic and industrial laboratories, suppliers like technology suppliers and external users combining partners and competitors. By external users the industrial researcher is interested how other industrial environments face actual research problems. We describe the different content knowledge types in tables Table 4.4 to Table 4.8.

Table 4.4 – The content knowledge typology for the external environment - academic / industrial laboratories

Knowledge environment	Knowledge type	Description
Academic / industrial laboratories	Research directions	Concerns long-terms planning of research activities and the strategic positioning according to technologies but also according to the industrial environment
	Innovative concepts and models	New innovative concepts and models, what they are for, what they could benefit for
	Methods	New methods, what they do, what they are for, what they could benefit for
	Prototypes	New prototypes, what they do, what they are for, what they could benefit for
	Means	The technology and human capacity to elaborate new research solutions
	Experiments	Experiments and experiences with innovative concepts, methods, prototypes

Table 4.5 – The content knowledge typology for the external environment - suppliers

Knowledge environment	Knowledge type	Description
Supplier	Research directions	Future technological orientations and positioning according to industrial environment
	Innovative concepts and models	New innovative concepts and models as background for new proposed technologies and tools
	Methods	New methods, what they do, what they are for, what they could benefit for or methods accompanying the use of technologies or tools
	Tools	Description of tools, what they do, what they are for, how they are implemented
	Means	Development means and human capacity for new methods and tools
	Experiments and feedback	Feedback concerning the implementation and the use of methods and tools

Table 4.6 – The content knowledge typology for the external environment - academic / industrial laboratories

Knowledge environment	Knowledge type	Description
External users (competitors / partners)	Strategy	Future orientation for the use of technologies; intention for cooperations
	Use cases	Process and organizational environments comparable to the group environments or where methods and tools (potentially interesting for the group) are used (user feedback)
	Needs	Needs concerning a problem environment
	Methods	The use of methods, their constraints and benefits concerning the use case environment
	Tools	The use of tools, their constraints and benefits concerning the use case environment
	Solutions	Description of solutions in terms of tools and methods for the needs; the solution description describes how the existing methods and tools have been replaced with new solutions

Table 4.7 – The content knowledge typology for the internal environment

Knowledge environment	Knowledge type	Description
Research center	Strategy	Positioning for mid- and long-term research objectives (roadmaps)
	Needs / processes	General needs for new research solutions and description of problem / process environment
	Research objectives	Objective concerning the elaboration of solutions in a specific research area
	Approach	The way how research results were / could be reached (practical aspects) and which concepts were / could be taken into account
	Innovative concepts	New developed or to develop innovative concepts and their meaning
	Methods	New developed or to develop methods, what they do
	Prototypes	New developed or to develop prototypes, what are they for
	Means	Means which leaded to research result development or which could be used for further objectives
	Experiments	Experimentation results of developed methods and tools (by the research center) and conclusion

Table 4.8 – The content knowledge typology for the operational unit environment

Knowledge environment	Knowledge type	Description
Operational units	Strategy	Product and process strategy of operational units including research strategy
	Organization / methods / tools / constraints	Existing organizational environment, used methods and tools and constraints concerning the organization, methods and tools
	Research requirement	Expressed or potential needs concerning potential research activities
	Experiments	Potential and existing use cases for research activity experiments
	Processes	Process description of existing use case for research activities and results
	Used methods for experimentation	Information concerning implementation and experimentation of method developed by the research center for concrete use case
	Used tools for experimentation	Information concerning implementation and experimentation of method developed by the research center for concrete use case
	Feedback	Information concerning implementation and experimentation of methods and tools

With this content knowledge typology, we have now an overview, of what knowledge and information content the industrial researcher uses from the resources to produce new research results. This represents in fact a typology of interests necessary for new research results. In this context, we can make the link to the concept of aboutness concerning document content as discussed in section 1.7.3.2. This typology describes from what an information is talking about and represents the content the researcher should know to produce new results.

In order to be able to attribute the different information content for the different research results, we elaborated a second content structure which is oriented according to the research objectives. We named this second structure the research activity content structure.

4.2.3.3 Research activity content structure

A second dimension of the information content structure concerns the characterization of the information content according to the research domain, the research problem and the research objective the information content addresses. This is a direct link to the concept of relevance as discussed in section 1.7.3.2. We named this dimension the research activity content structure.

This structure depends on the structure of the research activities in the different research domains. We propose to structure this content dimension according to the following schema (see Figure 4.5):

- A competence center can be structured in one or several research domains. The research domains address coherent research questions and work on similar research objectives.

- The research domains can be structured in research themes. These themes are sub-groups concerning similar research questions and research objectives. As a example: a research domain can concern the research activities concerning knowledge management; in this domain we can have several research themes as for example the evaluation of knowledge management activities, the knowledge management technologies, ontologies for knowledge management, etc. We propose to provide sub-structures for the research themes:
  - Shared research themes are themes concern themes which are shared among several researchers. Information content according to these research themes might be interesting for several researchers.
  - Non-shared research themes concern private research interests of the different industrial researchers. These themes are not really shared between the different researchers. However, the industrial researcher collects information content according to this research themes for later reuse. The researcher has the possibility to give access to the non-shared research themes for other researchers. The research themes become then a shared research theme.
  - Emergent research themes can concern shared and non-shared research themes. They concern new research interests or problems for which the industrial researcher starts, as individual or with other researchers, to collect information. Emergent research themes imply a very little knowledge maturity among the researchers. After a while, emergent themes become normal shared or non-shared themes. However, it is up to the researchers to decide, when this conversion takes place.
- The shared themes can be related with research projects. The different research projects work on a specific research objective which concerns a research theme. One research theme can have different research projects and one research project can be affected to different research themes. The research projects concern the project structure as discussed in section 3.3. They correspond to a concrete realization of different research questions in a research theme. In order to continue the above examples, a research project could be a concrete realization of a measurement framework for knowledge management activities of an operational unit. This project would be attached to the theme concerning the evaluation of knowledge management activities.

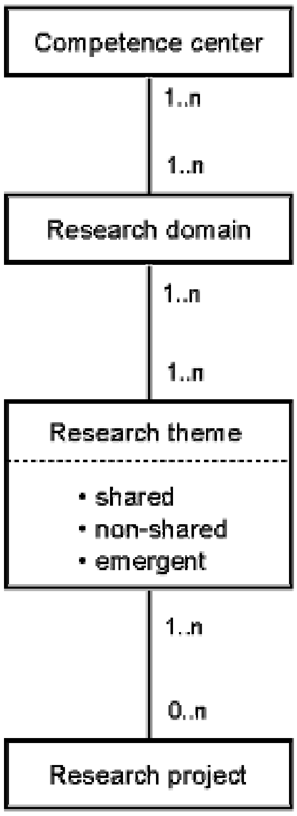

Figure 4.5 – Research activity content structure

With this content structure, the industrial researcher is able to structure information content according to research objectives and research themes. He would be able to indicate, why and for what an information content plays a role for the context of his research activities.

With the general objective oriented research process framework, the general activity framework and the resource element structure (content knowledge typology) and research activity content structure framework we are now able to propose a general framework for industrial research activities.

4.3 GENERAL FRAMEWORK ARCHITECTURE

According to the CIMOSA structure and our adaptation to the industrial research center context, we propose a global architectural framework based on the three model frameworks from the above sections. This gives us a three layer architectural framework (Frank and Gardoni, 2003b; 2003c; 2003d):

- As a basic layer we will use the general objective oriented research process framework which helps to categorize the different research activities in three phases representing a coherent activity structure: investigate, focus, deploy.

  The elaboration of the different research results in the different phases influences the use of different information resources and different information content. Therefore, for each phase the industrial researchers define objectives for information content to produce and to acquire. This goes along with an evaluation of the maturity of the research results (go / no go decision), an evaluation of the existing information and knowledge and the new acquired information content.

Therefore, in each phase we have a definition of objectives for phase-related activities and an evaluation of existing and new elements. This definition of objectives and the evaluation activity are similar to the control process activities of the knowledge management according to Romhardt (see Figure A.8 of the appendix). The control process activities play a role for each phase (see Figure 4.6).

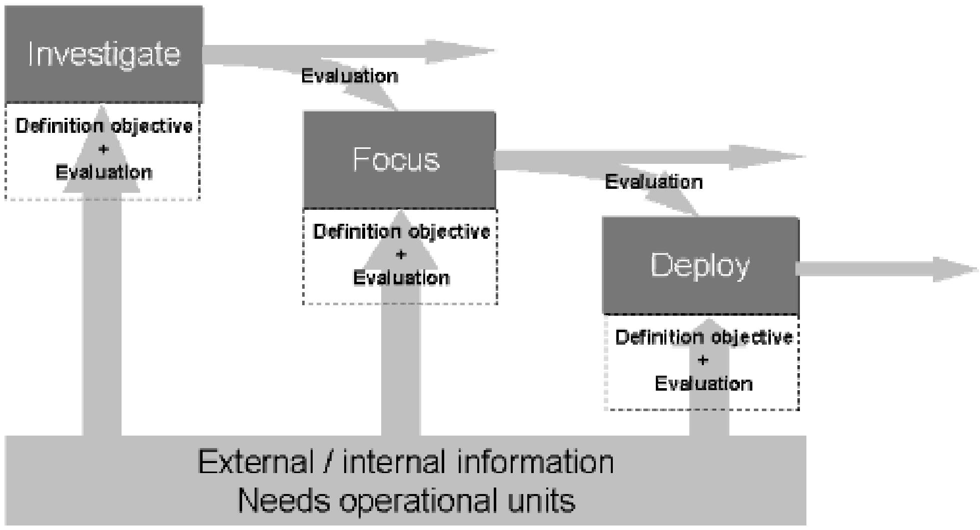

Figure 4.6 – Control activities for the industrial research process

As in the model of Romhardt the control activities are related to the core process activities, we can define for each phase an activity management framework including the nine relevant activities supporting the practices of the industrial researcher.

- The activities in the phases can be supported by the activities as described in the general activity framework. The information and knowledge relevant activities are similar for each phase. Nevertheless, as the content is different in the different phases and for different research projects, some information and knowledge relevant activities might be more stressed according to the phase. This will play an important role for our global architectural framework proposition.
- In order to support the different activities from the general activity framework in the different research phases we propose a toolbox for each activity. This toolbox should enable the execution of the different activities from the general activity framework. Each toolbox contains an information input field, a field describing the activity of the general activity framework and an information output field. The information input and output field describe the different resources and products according to the resource element content and research activity content structure framework. Therefore, the input an output fields use a shared ontology which is in our case specific to the industrial research activities. As this framework represents the necessary content for research activities, it assures the availability of critical information and knowledge content.

This three layer architecture allows to coordinate the different knowledge and information relevant activities to support the practices of the industrial researchers and to integrate a process view, an activity view and an information and knowledge content (ontology) view (Figure 4.7).

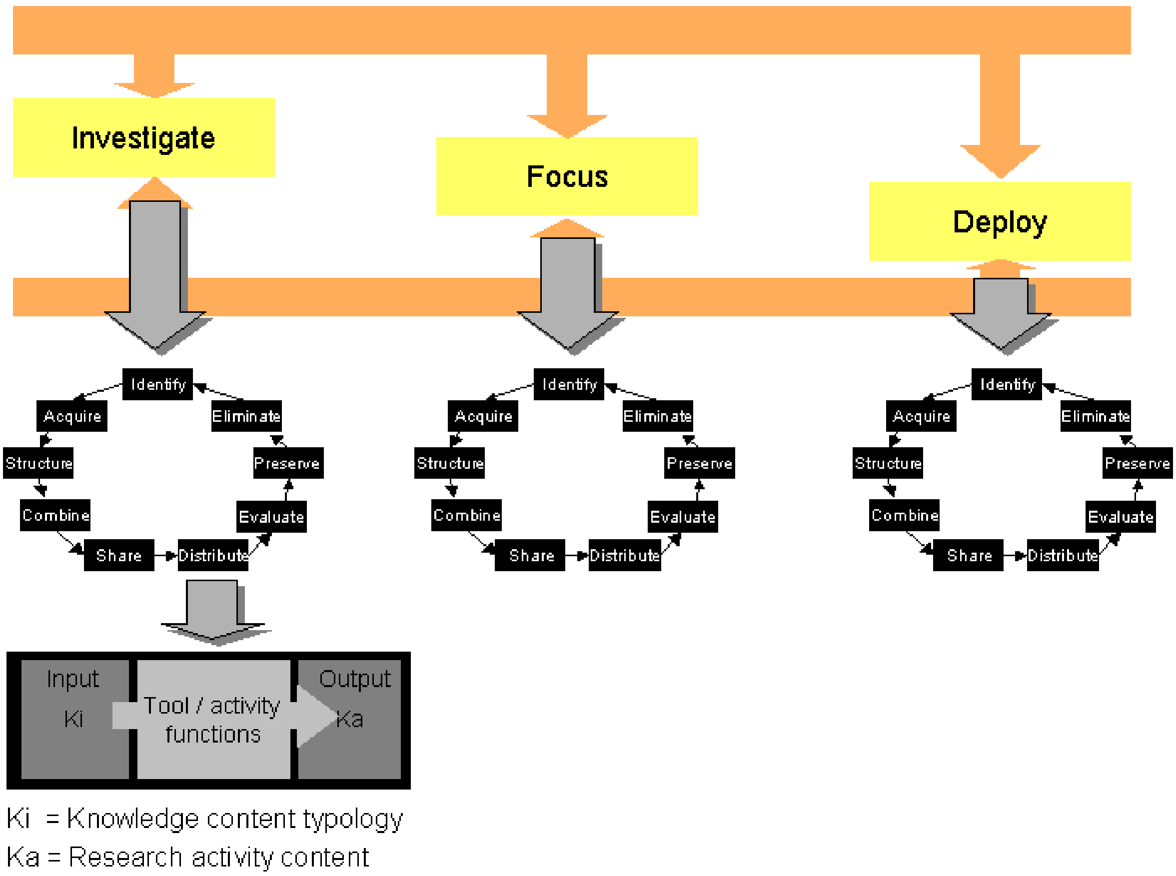

Figure 4.7 – Knowledge management architectural framework for industrial research activities – three layer architecture

This general framework architecture allows to specify the different information and knowledge relevant activities for each phase of the research process model and to define a support environment for the different practices of the researcher. Based on this architecture we propose a table in which the fields concern the different information and knowledge relevant activities for each phase.

In each field we specify the different activities for the different phases in order to be able to propose relevant support methods or tools. This specification includes a description of the different input and output knowledge or information (Table 4.9).

Table 4.9 – Description table for knowledge management architectural framework

	Investigate	Focus	Deploy
Identify	Identify new external and internal knowledge / information for new research questions. Identify new needs of the operational unit environment.	Identify possible use cases in the operational unit environment for research result experiments.	Identify application and transfer environment for new research results.
Acquire	Transfer external and internal knowledge / information into research environment.	Acquire information and test data for the new research results.	Acquire transfer and implementation conditions.
Structure	Structure new acquired knowledge / information into existing internal knowledge / information environment.	Structure operational unit information according to new research result development.	Structure implementation information.
Combine	Combine new external and internal knowledge / information for conclusion.	Apply internal and external knowledge to produce new conceptual models and their simulation applications with operational unit data.	Combine and adapt research result according to transfer and implementation conditions.
Share	Share new external knowledge / information with other researchers.	Share new developed knowledge / information with other researchers and operational environment.	Implement research result and teach use to operational unit environment.
Distribute	Distribute conclusions about new external and internal knowledge to other researcher and operational unit environment.	Distribute simulation results and new research product to other researcher and operational unit environment.	Distribute research result and feedback of implementation to operational units and other researchers.
Use	Use collected knowledge / information for research result elaboration and further research activities.	Use results for proposition of new research results and therefore new concepts.	Use relevant information to transfer research results to operational units.
Preserve	Preserve knowledge conclusion and important external knowledge / information.	Preserve conclusion about research results and new "lineage knowledge".	Preserve feedback of research result implementation for further research activities.
Eliminate	Eliminate external information if no value for further research activities.	Eliminate "lineage knowledge" if further research activity is not possible.	Eliminate information with no value added for past research project.

According to the resource element content and research activity content structure framework, the different knowledge and information elements in the fields of the above table are structured for the input and output according to their content. They therefore represent parts of the shared ontology describing the relevant content for industrial research activities.

In section 3.4, we structured the different practices according to the knowledge manipulation activities. The different fields of the above table can also provide more specified structure for the different practices of the researcher.

However, the content of the different fields can vary according to the research activities. Furthermore, there might be additional information to include in the different fields depending on different points of views of the researchers. According to the research activity, the different activities in the different fields might be more or less important. However, the different fields indicate, what kind of information content is relevant for the different activities in the different phases.

With this architectural framework, we will explore in the following sections the possible support of knowledge and information technologies and tools for the different phases. This exploration will lead us to the limits of the technologies today and to the proposition of supplementary technology and tool functions for a better handling and exploitation of information content mainly for written information.

4.4 KNOWLEDGE MANAGEMENT RELEVANT TECHNOLOGIES AND TOOLS TO SUPPORT THE GENERAL FRAMEWORK ARCHITECTURE

In section 1.7.2, we described some important knowledge management relevant technologies. These technologies could be used in order to support the activities of the industrial researcher in the context of the proposed framework. In the following table, we propose a selection of technologies and their tool applications to support the different activities for the different phases of the industrial research process.

As the research activity is largely based on the handling of existing information in various formats like documents, presentations, mails, etc. and the research result is often formulated in documents (as discussed in section 2.7), the different application will also largely be based on the management of information in a written format.

However, other applications could support the exchange of oral information between researchers, and researchers and their environment. In this work, we will not focus on these sorts of applications.

It is important to mention that the proposition of the different tool applications is not an exhaustive list but shows more tendencies for the different activities in the different phases. Several tool applications might also be used for more than one activity. However, we tried to show the possibility to support the architectural framework with existing tools and tool functions.

The following table shows possible applications which basically handle written information (Table 4.10):

Table 4.10 – Possible knowledge management technologies and tools for the general framework architecture

	Investigate	Focus	Deploy
Identify	• Business intelligence • Search engines	• Expert database (yellow pages)	• Organization database
Acquire	• Automatic summarizing	• Transcription tool (voice to written)	• Transcription tool
Structure	• Automatic indexing	• Automatic indexing	• Automatic indexing
Combine	• Edition support	• Edition support • Prototype environment	• Edition support • Training material edition support
Share	• Portal solutions • Presentation • Forum	• Portal solutions • Presentation and simulation • Forum	• Portal solutions • Course support • Forum
Distribute	• Email	• Email	• Email
Use	• Portal solution	• Portal solution	• Portal solution
Preserve	• Document management • Evaluation criteria	• Document management • Evaluation criteria	• Document management • Evaluation criteria
Eliminate	• Evaluation criteria	• Evaluation criteria	• Evaluation criteria

Some of the different proposed tool applications already exist in the actual used tool environment (for example email, forum and document management). Therefore, the proposed new applications need to be adapted to the existing environment.

In order to propose operational tool applications for a possible deployment, we identified two tools which integrate several functions and which can therefore support to a certain extent different fields of the framework propositions: Eroom of Documentum (Documentum, 2002) and Quantum of Entopia (Entopia, 2003). These tools support the manipulation of written information according to their content. Therefore, they can take into account certain aspects of the resource element content and research activity content structure framework. Both tools support especially the activities: identify, structure, combine, share, distribute, and use. However, the different functions support only parts of the activities and it is difficult to take into account the context of the research process phases. As the different activities and the related practices are very complex, further support is needed.

The main tool functions for both tools are presented in the following table (Table 4.11):

Table 4.11 – Main Eroom and Quantum tool functions

	Eroom / Quantum tool functions
Identify	• Searching for documents by search for items with particular names, text or date in the document title and their content.
Structure	• Structuring of the information (documents, mails, presentations, etc.) in different "rooms" (for the Eroom application) or different folders (for the Quantum application) which can concern the structure in different projects, themes, private themes, etc. These structures can be used by individuals but can also be shared among different users.
Combine / Use	• The viewing and editing of documents for individual user but also for several users via a document use control mechanisms. • A version tracking in order to indicate the latest version of a document.
Share / Distribute	• The indication to the user of a shared work spaces for read and unread items. This can be coupled with a notification service via email where the user of shared work space gets an email as soon as other users of the same workspace modify an existing document or introduce a new one.

Other common tool functions are:

- The possibility to integrate a database to update user profiles but also to preserve final documents.
- An integrated shared calendar.

Besides these common functions, both tools are different in the following points:

- Eroom is a task centric collaboration system. It is a collaborative workspace designed primarily for project and task tracking. Quantum is a document centric collaboration system.
- Eroom has basic document management file upload/download features. Quantum is designed to manage larger volumes of documents.

Differences between the two tools concern the following functions (Table 4.12):

Table 4.12 – Differences between Eroom and Quantum tool functions

	Eroom	Entopia Quantum
Identify	• Eroom has a basic text search that searches file names and a full text search	• Quantum automatically builds searchable metadata to help retrieve information items
	• Eroom has an integrated employee expert database (yellow pages)	• Quantum automatically identifies employee experts through document creation and activity
Share	• Users can give comments on documents on which other user have access.	• Quantum provides collaboration feature sets to view, markup, and highlight important content. • Users can also hold threaded discussions and notify groups of important content.
Combine / Use	• Documents can be linked to each other.	• Quantum supports the creation of new documents based on existing document parts (copy and paste) by keeping the reference of the information resource

Both tools provide a certain support for the knowledge management relevant activities and therefore for the practices of an industrial researcher as identified in section 3.4.

The tools provide a support for a better document handling. It is possible to make comments on documents or discuss documents with other people. Quantum provides functions which allow to work on existing document content inside the document: it is possible to highlight different parts of documents in order to indicate their importance for different issues.

According to the functional analysis, the tool applications support partly the functions F6 for a better document sharing (support a sense of sharing among researchers) and partly F7 for a better identification and reuse of existing internal information. Functions F1, F2 and F4 can be partly supported when the external information in form of documents is already identified and introduced into the system. Therefore, a combination of the two tools with a business intelligence application could be helpful.

However, the tools allow only a management of documents. It is not really possible to manage and exploit the content of documents which means for example parts of documents, schemas in documents, etc. as described with the needs in section 3.7. This implies that the functions F3 and F5 are not supported by the Eroom and Quantum tool applications. In order to support these functions, there is a need to be able to analyze and structure document contents and to compare or represent them for the different research content structures.

For the functions F1, F2 and F4 there could be an improvement if it would be possible to exploit the content of a document. A better handling of the content could allow to work only with important content parts of a document according to specific research objectives. This implies also the functions F6 and F7. Teams of researchers could share and therefore better exploit document content.

As seen in the structuring of the different tool applications according to the knowledge management manipulation activities, it was not possible to integrate a structure according to the different research process phases and according to the content knowledge typology or research activity content. This leads to the conclusion that it is difficult to handle document content according to the resource element content and research activity content structure framework as defined in section 4.2.3. The tools do not allow to structure document content according to the concepts of aboutness and relevance as discussed in section 1.7.3.2 and therefore do not support the application and use of a shared ontology.

The different tools do not support in a sufficient way the exploitation of individual practices (as described in section 3.4) for a collective use.

Especially for the activities identify, structure, combine, share use and preserve we think it is important to propose additional functions for a better handling and exploitation of written information content based on the needs and the identified practices.

Using the architectural framework for a functional specification, we propose the following additional functions (Table 4.13):

Table 4.13 – Specification of additional tool functions according to architectural framework

	Investigate	Focus	Deploy
Identify		• Re-identification and re-access facilities for already identified written information content (documents and parts of documents with comments) according multi-view context. Information content lies on operational unit needs and existing technologies and tools with user feedback. • Realizing the functions F2, F4, F7.	• Re-identification and re-access facilities for already identified written information content (documents and parts of documents with comments) according multi-view context. Information content lies on operational unit needs and existing processes.
Acquire			
Structure	• Provide multi-view context structures to written information content (documents and parts of documents) with content knowledge typology and research activity content.	• Provide multi-view context structures to written information content (documents and parts of documents) with content knowledge typology and research activity content.	• Provide multi-view context structures to written information content (documents and parts of documents) with content knowledge typology and research activity content.
Combine	• Facilities to combine and assemble written information content of external information resources. • Combine existing content with own ideas.	• Combine existing information content with own ideas. • Realizing of the functions F1, F5.	• Combine existing information content with own ideas in the context of research result transfer.
Share	• Realization of the function F6 especially concerning external information content, with annotated comments.	• Realization of the function F6 especially concerning external information content combined with new propositions, with annotated comments.	• Realization of the function F6 especially concerning user feedback and implementation feedback, with annotated comments.
Distribute			
Use	• Assemble identified information content and own ideas to research results. • Realization of function F3 with identified written content.	• Assemble identified information content and own ideas to research results.	• Assemble identified information content and own ideas to research results.
Preserve	• Preserve with multi-view context (similar to structure activity).	• Preserve with multi-view context (similar to structure activity).	• Preserve with multi-view context (similar to structure activity).
Eliminate			

In order to demonstrate these new tool functions based on document content in the context of industrial research processes, we specified and developed a prototype demonstrating the feasibility of the general framework for industrial research activities.

The prototype proposition will take into account the general objective oriented research process framework as overall concept giving the context to the prototype, the general activity management framework and will use the resource element content and research activity content structure framework and therefore a shared ontology. These different concepts will be applied on document content in order to support the production of new research results.

4.5 CONCLUSION

Based on the elements of the previous chapters and on CIMOSA we proposed a general three-layer framework architecture for industrial research activities:

- The basic layer consists of a general objective oriented research process framework.
- For each phase of the research process framework, we propose a general knowledge manipulation activity framework as the second layer.
- A resource element content (content knowledge typology) and research activity content structure framework constitutes the third layer. The different elements can be seen as elements of a shared ontology. We elaborated this ontology in consensus with the researchers. The elements of this third layer structure the different inputs and outputs of the general knowledge manipulation activity framework from the second layer. This structure corresponds in fact to the concepts of aboutness and of relevance for information content. Therefore, with the elements of the third layer, it will be possible to describe from what an information is talking about (concept of aboutness) for what an information represents an interest (concept of relevance) for the context of industrial research activities.

This three-layer framework constitutes in fact a set of coherent typologies for the industrial research context. This set of typologies can be added to already existing typologies as typologies of documents, etc. (Figure 4.8).

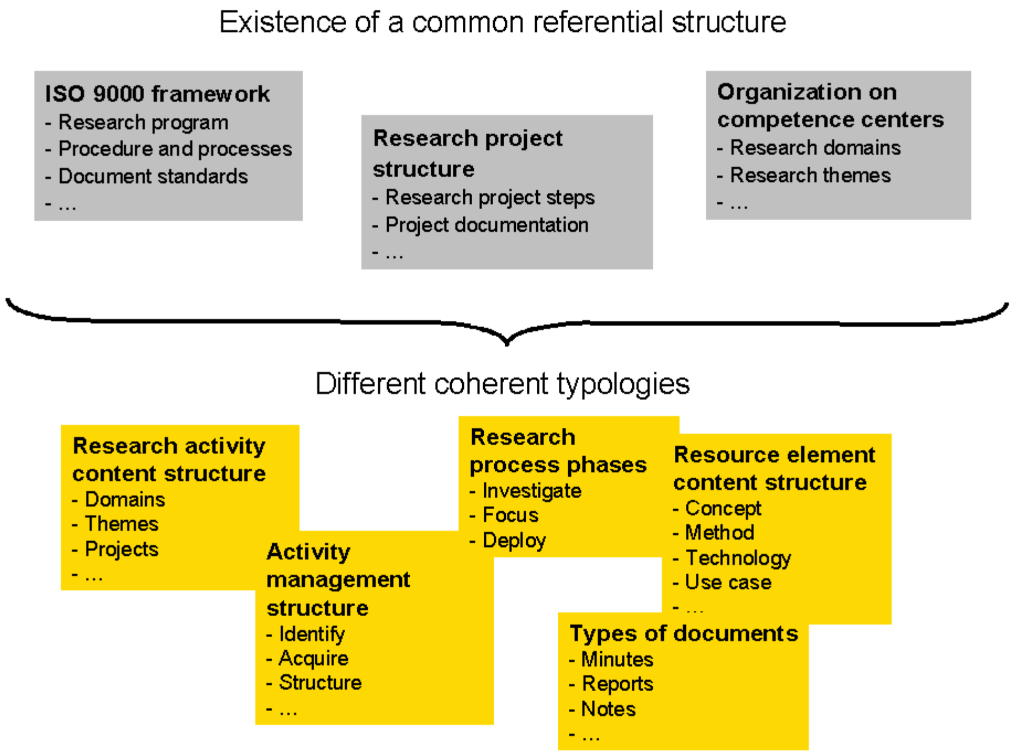

Figure 4.8 – Set of coherent typologies for industrial research context

We used the general framework architecture to structure a possible tool support for the knowledge and information management relevant activities. However, actual operational tools provide only a limited support for the different functions of the functional analysis and for the needs. Especially the needs for a better exploitation of the individual practices for a collective level based on a better exploitation of written information content need further support.

Based on the general framework architecture we propose additional new functions for a prototype development. With the available set of typologies, we will propose support functions to favor the emergence of collective practices based on the shared ontologies to exploit written information content.

5 A.N.I.T.A.: A TOOL FOR A BETTER DOCUMENT CONTENT EXPLOITATION APPLIED TO THE KNOWLEDGE PRODUCTION PROCESS

5.1 INTRODUCTION

In this chapter, we will describe the specifications and the development of a prototype supporting a better handling and exploitation of written information. We called this prototype A.N.I.T.A. which stands for ANnotation tool for Industrial TeAms. The theoretical basis constitutes the general framework architecture proposition of section 4.3. As this framework architecture is based on the organization of the research activities (organization in projects and themes, standardized processes with ISO certification, etc.) and on the practices of the industrial researcher as individual and acting in a team, also the prototype proposition can take into account these aspects.

We will first discuss the solution principles of the different modules of the A.N.I.T.A. tool. It consists of three main modules: an attribution of points of views (concepts of aboutness and relevance) and annotation module, and retrieval and visualization module, and an assembling module. Then, we will go into deeper detail for the different modules and discuss their structure, their theoretical background and their links to the other components.

We will deepen the specification with UML use cases and class diagrams. Further on we will go into deeper detail of the technical specification and realization and will demonstrate a user scenario. With an experimentation feedback and discussion we will conclude this chapter.

5.2 PRINCIPLES OF THE SOLUTION – MANAGEMENT OF WRITTEN INFORMATION CONTENT WITH SHARED ONTOLOGIES

The principles of the solution are based on the general framework architecture of section 4.3 and therefore the set of typologies describing in fact an existing referential structure as discussed in the conclusion of chapter four. This set of typologies provides us in fact with a shared ontology among researchers.

We propose to use this shared ontology in order to index (manually) documents and parts of documents. The indexing represents a manual annotation of fix elements coming form the ontology. This generates a sharable document repository for documents but especially for parts of documents. It allows to manipulate and exploit written information content for groups of researchers with similar research interests.

Therefore, we name our tool proposition A.N.I.T.A. which stands for ANnotation tool for Industrial TeAms. Besides the indexing with elements of the shared ontology, we allow also the annotation of free text to documents or parts of documents.

The shared ontology concerning the research activity domains can be replaced with other ontologies. Therefore, the A.N.I.T.A. tool functions are not specific only to industrial research activities. The use of the elaborated ontology from section 4.2.3 introduces the application of the A.N.I.T.A. tool to the context of industrial research activities. With the more general name, we want to give the possibility to use the functions for other domains (see also section 6.4 for further perspectives of the use of the A.N.I.T.A. tool).

With this basic proposition, the A.N.I.T.A. tool can be structured in three main modules (see Figure 5.1):

- A structure and annotate module.
- A retrieval and visualization module.
- An assemble module.

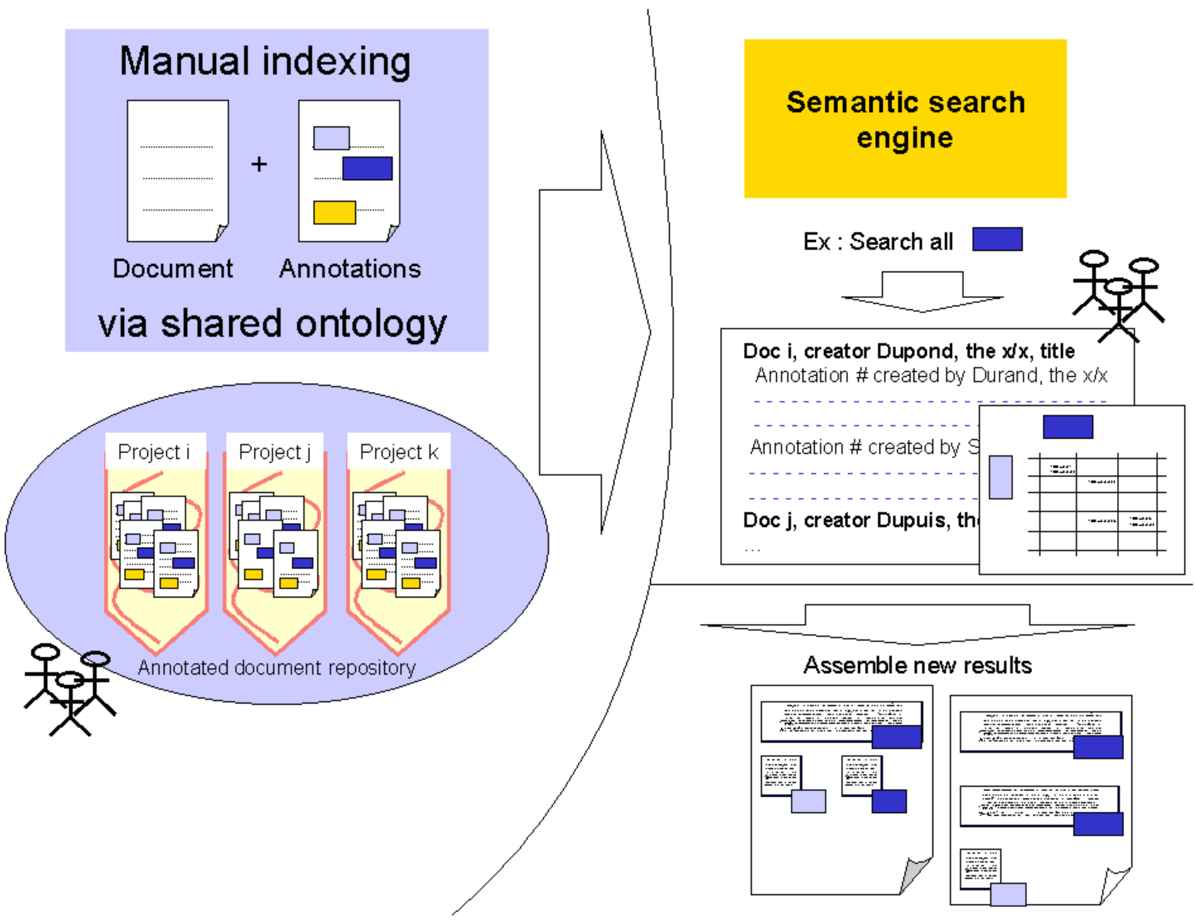

Figure 5.1 – Description of the solution principles for the A.N.I.T.A. tool

In the structure and annotate module the industrial researcher can structure documents or parts of documents according to different meta-data. The different meta-data represent in fact the different elements of the resource element content and research activity content structure framework as defined in section 4.2.3 and therefore the different elements of the shared ontology. Structuring here means attributing these meta-data. One document or part of document can have several meta-data. According to the meta-data, documents and parts of documents are then structured in a shared or private working space.

Besides the attribution of meta-data, the industrial researcher has the possibility to add an annotation to documents or parts of documents. In this annotation, the industrial researcher can add additional information to the documents or parts of documents. The shared work spaces give other people the possibility to react on given structures and annotations with new structures and annotations.

In the retrieval and visualization module, the industrial researcher has the possibility to access existing documents or parts of documents with their annotations. In order to get access, he chooses according to the meta-data the information he wants to get. This is in fact the realization of a multiple choice access: the industrial researcher can select among the different meta-data and constitute set of meta-data according to the information he is looking for. As the ontology for industrial research activities are linked to the concepts of aboutness and relevance, the researchers can access parts of documents according to their interests or objectives.

The industrial researcher has also the possibility to visualize the different documents and parts of documents according to cross set of meta-data. Here we focalize on a two dimensional representation of information according to the chosen sets of meta-data structured on a vertical and horizontal table. This gives him the possibility to analyze to a certain extent written information content according to different interests and objectives.

In the assemble module the industrial researcher elaborates new documents and has the possibility to integrate existing parts of documents and annotations. The new documents can represent new researcher results.

After this more general description of the different modules, we will go into deeper detail for the prototype description and its different modules.

5.2.1 DOCUMENTS AND ZONES OF DOCUMENTS

We have seen that parts of one document might talk about different things and might be relevant for different research activities. According to the needs (described in section 3.7), researchers require access to parts of documents, manipulate parts of documents (annotations in form of post-its, etc.) and have the possibility to share them with other researchers. We therefore propose the tool functions for documents and parts of documents.

The industrial researcher is confronted with a various number of document types. Each document contains logical elements which can be of interest for the researcher. Different sections or even paragraphs of the same document can talk about different issues. Indeed, long documents contain very often various sections, which talk about different issues (Feldman, 1998).

Examples for logical elements in the research context can be figures representing new concepts in a synthetic overview. In addition, references might be interesting because they are an indication for further information resources concerning the specific issue of the document or sections of the document.

It is possible, that the combination of different logical elements of a document represents a coherent ensemble according to a research objective. We therefore introduce the notion of "zone" to characterize a coherent ensemble of logical elements in and on a document.

This leads to the definition of a zone of a document: "a zone of a document is an ensemble of logical elements of a document or parts of logical elements of a document representing a coherent entirety according to their content and their possible interest for an industrial research issue (Figure 5.2). One document can have several zones".

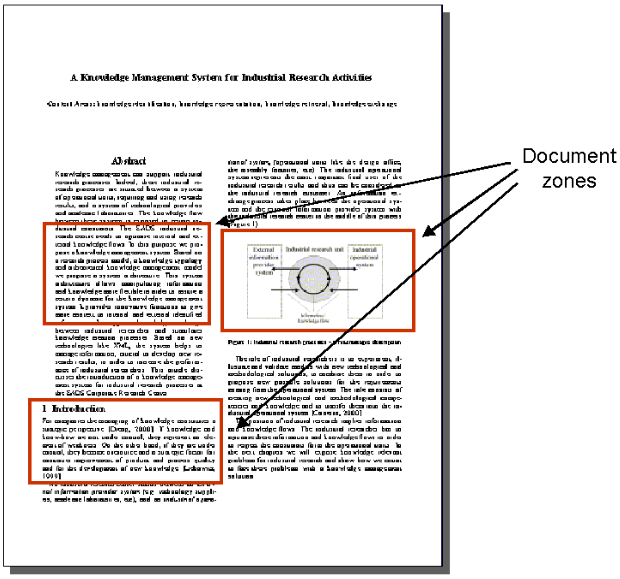

Figure 5.2 – Selection of document zones

According to the model Taghva (Taghva et al., 1998) as presented in section 1.7.3.1, we propose the following specifications for zones:

- Text: the zone covers only text.
- Images: the zone covers images or figures. Images can represent concepts, models or other synthetic aspects important for research activities.
- Sketches: the zone covers only sketches. Sketches can be part of new solution developments for industrial products and therefore play a role for research activities.
- Formulas: the zone covers only formulas. For certain research activities, formulas are needed to elaborate research results.
- Reference: the zone covers a reference. As mentioned above, references can constitute further information resources for certain issues or research domains.
- Mix: the zone covers several types of elements at the same time.

With the introduction of zones for documents, we can distinguish between the documents as physical objects, specifying the content in form of logical elements of the document. The researcher can select several zones in a document for his research interests.

5.2.2 META-DATA – CHARACTERIZATION OF WRITTEN INFORMATION CONTENT WITH POINTS OF VIEWS

For the reuse and sharing of document content for the research result production, the researcher needs to know, from what the document content is talking about and for what it represents an interest.

In order to support these two aspects, we apply the resource content knowledge typology (section 4.2.3.2) and the content relevant structure of the research activities and research domains (section 4.2.3.3). In order to support this framework, we propose to use the concepts of "aboutness" and of "relevance" as discussed in section 1.7.3.2.

5.2.2.1 Resource element content – concept of aboutness

For the industrial research activity context, we introduce the concept of aboutness for documents and document zones. We propose to distinguish between two relevant aspects describing the aboutness:

- From whom (which organization) is the document and / or zone talking about.
- From what is the document and / or zone talking about.

These two aspects allow the reader to describe the content (what is it talking about) of a document or the zone of a document. In order to propose a balance between objective and subjective aboutness, we use the elements of the knowledge typology to describe the two aspects which represent in fact part of the shared ontology. Therefore, a certain objectivity is assured and information content is shareable among researchers.

In order to specify the information content we propose to use fix elements according to the knowledge typology. Additional to that, the user can add free text elements in form of key words to precise the fix elements.

For the aspects "from whom (which organization) is the document and / or zone talking about" we propose categories reflecting the different items from the external environment, operational unit environment and the internal environment of the research center. The different categories we propose are (see section 4.2.3.2 for their definition):

- External laboratory, meaning external academic and industrial laboratories,
- External supplier,
- External industrial environment,
- Operational units,
- Internal research center.

Furthermore, the user has the possibility to describe the different categories with real names and free descriptions.

For the aspect "from what is the document and / or zone talking about" we propose to use the different knowledge types of the content knowledge typology model (Table 5.1):

Table 5.1 – Knowledge types for concept of aboutness

External laboratory	External supplier	External industrial environment	Operational units	Internal research center
Research directions	Research directions	Strategy	Strategy	Strategy
Innovative concepts and models	Innovative concepts and models	Use cases	Needs / processes	Organization / methods / tools / constraints
Methods	Methods	Needs	Research objectives	Research requirements
Prototypes	Tools	Methods	Approach	Experiments
Means	Means	Tools	Innovative concepts and models	Processes
Experiments	Experiments and feedback	Solutions	Methods	Used methods for experimentation
			Prototypes	Used tools for experimentation
			Means	Feedback
			Experiments	

For each category the user can add supplementary information in form of key words in order to specify the category.

For the A.N.I.T.A. tool specification, the user should be able to choose among the different knowledge types describing the environment and their respecting information content types.

5.2.2.2 Research activity content structure – concept of relevance

The information content represents an interest for a research objective or research domain. The information content is therefore relevant for the research activity context.

We adapt the concept of relevance and utility as discussed in section 1.7.3.2 to our industrial research activity context. The industrial researcher collects and reuses information for a certain research objective. The research objectives are structured according to the research activity content structure framework. We will apply the concept of relevance also for documents and document zones.

According to Mizzaro (Mizzaro, 1997), we need to create the relation between documents and document zones and problems and / or information needs. The problem or / and information needs come from the above problem description of the environment for industrial research activities. The concept of relevance for industrial research activities is therefore related to the question “for what does the document represent an interest”.

According to the research activity content structure (section 4.2.3.3), we propose the following structure to use the concept of relevance:

- Relevance for research studies:

  The industrial researcher has to conduct official research studies. Each of these research studies is described with an official research objective. As identified in the functional analysis with the function F4, the industrial researcher needs access to information representing a certain utility for his research studies. We therefore define the research studies as a first dimension for the concept of relevance.

- Relevance for shared research themes:

  Different research objectives can be grouped under shared research themes. The organization of the different researchers as experts in a competence center implies that the different researchers can work on similar research objectives. Therefore, research activities can be grouped under themes.

  The structure in themes allows collecting relevant information for a broader information basis from which new research activities can take resources to produce new results. This can support the function F2 of the functional analysis: the collected information of a theme gives a broader overview whether or not there is a gap between internal and external research activities.

  We therefore define shared research themes as a second dimension for the concept of relevance.

- Relevance for non-shared research themes:

  The industrial researcher has personal research interests. These interests can be directly linked to his official research studies or are free general interests. Personal research interests can influence official research activities. New ideas, based on personal research interests can emerge as new official research activities.

  The industrial researcher collects therefore various information for which he admits a personal interest. We therefore define non-shared research themes as a third dimension for the concept of relevance.

- Relevance for emergent research themes:

  The industrial research does not only resolve actual research problems but has also to prepare future possible research requirements of the operational units. This is directly linked to the function F3 of the functional analysis. The industrial researcher has to analyze the gap between current research activities and present or / and future research requirements of the operational units. This means that the industrial researcher needs to collect relevant information for emergent research themes.

  Emergent research themes can also cover information produced during official research activities which show new interesting concepts. We talked about the production of “lineage knowledge” in this context as discussed in section 2.8.2. Lineage knowledge can lead to new research activities besides the already existing activities. The collection of information for emergent research themes can therefore support the development of new research activities.

  We define emergent research themes as a fourth dimension for the concept of relevance.

- Sharing document content with groups or individuals:

  The function F6 of the functional analysis discusses the need of a support for the sharing of information among researchers working on similar research problems. Therefore, information can exist and can concern a group of researchers.

  This function is partly covered with the introduction of shared research themes. However, they concern more themes which are common for researchers working in the same competence center. As we have seen, it is also possible that researchers from different competence centers work on a common research objective. This characterizes a multidisciplinary team-working among industrial researchers. These common research objectives define therefore shared research themes belonging to several competence centers. The research themes are constituted around a group of researchers.

Another aspect for the introduction of groups as a relevant dimension for information content is that each participant of the group introducing new information acts a an "information filter" for other people. Filtering information for other people represents attributing a certain relevance to an information for other people in the context of a common research objective.

We can transform this argumentation logic from the group context to the peer to peer context. An industrial researcher can identify information which might be interesting for another industrial researcher. Therefore, he should be able to indicate this information for the research objectives of the other industrial researcher. As in a group, the industrial researcher acts as a filter.

We define themes concerning groups as a fifth dimension for the concept of relevance. The peer to peer transfer of information represents a sixth dimension for the concept of relevance.

- The author of an information and the relevance for industrial research activities:

  The production of a document is a transformation of the expertise or knowledge of the author into tangible information. Therefore, reading a document can give an indication of an external existing expertise to the industrial researcher.

  The interest for a document might lead to possible cooperations with the author or the author organization for further research activities. Therefore, we consider, knowing the author or the author organization of a document can be relevant for the industrial research activities. We apply the concept of relevance to the author of a document.

  In order to describe the author organization we propose to use the categories describing the environment of the knowledge typology. The different categories we propose are: external supplier, external laboratory, external industrial environment, operational units, and internal research center. Furthermore, the user has the possibility to describe the different categories with real names and free descriptions.

In order to characterize documents or document zones, the user has the possibility to choose several elements at the same time which means several meta-data to describe the content. He attributes in fact points of views to information content.

5.2.2.3 Representing the concept of aboutness and relevance with points of views

The concepts of aboutness and relevance allow describing the potential reusability of documents and document zones. The different items describing the concept of aboutness detail the information content. The different items describing the concept of relevance detail the utility of the information content for the research activities.

In the context of industrial research activities, the same documents or document zones can be of different relevance for different industrial researchers. As the relevance criteria can vary according the industrial researcher and his activities, we prefer to talk about "points of views" to characterize the different items describing the concept of aboutness and relevance in an industrial research context. The following table gives an overview about the different points of views for the two concepts and their description (Table 5.2).

Table 5.2 – Description of concepts of aboutness and relevance for the tool A.N.I.T.A.

Concept	Points of views			Application document / zone
	Description (and used concepts)	Fix elements	Variable elements	
Aboutness	From whom / which organization is it talking about (environment knowledge typology)	• External suppliers • External laboratories • External industrial environment • Operational units • Internal research center	Name of organization and / or department.	Document and zone
	From what is it talking about (simplified knowledge types)	List of knowledge typology	Keywords for further detailed description	Document and zone
Relevance	For what does it represent an interests (organization of research activities)	List of research studies	*No variable description*	Document and zone
		List of shared research themes		Document and zone
		List of non-shared research themes		Document and zone
		List of emergent research themes		Document and zone
		List of interest groups		Document and zone
		List of people		Document and zone
	From whom is it coming (author) (environment knowledge typology)	• External suppliers • External laboratories • External industrial environment • Operational units • Internal research center	• Name of organization and / or department • Name of people	Document

With the above description framework we try to adopt a philosophy of "minimal ontological commitment" (Gruber, 1995) and incremental formalization (Shipman and McCall, 1994). This reflects an emphasis on making explicit just enough structure to be usefully expressive and enable the provision of valuable computational services, but leaving the document texts to express the details and nuance of an author's arguments (as opposed to trying to formalize it). This minimizes the effort required to submit an exhaustive document description.

With the concept of relevance, the researcher does not have the possibility to introduce an argumentation, why an information is interesting. Therefore, as a third dimension besides the concept of aboutness and relevance, we propose to use free text annotations for supplementary argumentations.

5.2.3 ANNOTATIONS

Annotations (as already discussed in section 1.7.3.3) concern document and document zones. The annotation environment we propose is specific to the industrial research environment. Annotations concern not only the Web environment but also all research relevant documents. Annotations represent additional information to the attributed points of views. Therefore, the annotations are always situated in specific environment of the research activities. They do not play only the role for commenting information content but they contribute to the research production process.

5.2.3.1 Argumentation for written information content

An industrial researcher can elaborate argumentations on the content of a document or a document zone. These argumentations can be of implicit format or of explicit format. Written argumentations exist in form of notes, post-it's, attached documents, etc. and can be shared among different researchers.

The argumentation content of an annotation is leaded by the objectives of the researcher. According to the analysis of the practices (section 3.4), the argumentation can represent a hypothesis, it can represent an argumentation for or against the document content concerning its relation to the research objectives or it can represent a synthesis of the document content. We therefore propose three dimensions of annotations:

- Annotations synthesizing the information content of a given document or document zone focusing on the relation to a given research objective.
- Annotations representing an argumentation concerning the content of a given document or zone for a specific research objective. In this case, the annotations can play the role of constraints or evaluation criteria representing a reference model for the creator of the annotation (Zacklad et al., 2003).
- Annotations representing a hypothesis of the utility of the content of a given document or document zone for specific research objectives. In this case, the industrial researcher formulates possibilities to use information content for research objectives. The formalization of possibilities can in fact represent the formalization of possible "lineage knowledge" which could lead to new research activities.

As the annotations can have these three dimensions, the user has the possibility to characterize the annotations according to these three dimensions (Figure 5.3).

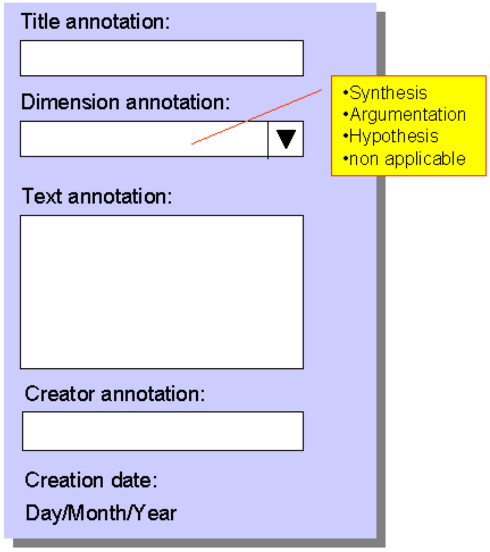

Figure 5.3 – Annotation formula

As the objective of an annotation is to argue on specific document content for a specific research objective, they cannot be dissociated from the document or document zone.

5.2.3.2 Exchange argumentations with other researchers

With the attribution of certain points of views (study, official research themes, interest groups, etc.) the industrial researcher has the possibility to share information content with other researchers concerning a specific research objective. However, with the point of views, industrial researcher does not have the possibility to exchange argumentations.

Therefore, the annotation function gives the possibility to exchange argumentations among researcher concerning specific information contents. With the dimensions "argumentations" and "hypothesis" the industrial research can provoke a discussion in order to capitalize the different arguments of the different researchers. The capitalized arguments can then be introduced in new research results.

The attribution of various points of views and annotations on documents and document zones implies different access and different information representation means.

5.2.4 Retrieval and visualization

In order to access the different information contents we propose in the A.N.I.T.A. tool a multi-view access and visualization forms. These functions are based on the attributed points of views on documents and documents zones.

5.2.4.1 Multi-view access on information

Access on information is usually possible via search engines or via fixed document repository structures. Search engines can provide pertinent search results when documents are correctly indexed. Otherwise, the user is confronted with non-accurate results affecting the performing of these search engines.

Fixed document repositories have limited capacities to attribute several points of views to one document as shown in section 3.4.2 and 3.7.2. Physically, the document needs to be stored in several repositories. However, when the user accesses one repository he usually does not have the information of the other points of views attached to the document.

We therefore propose a dynamic access to the documents. Furthermore, we extend this function to document zones. The user creates, based on a choice of different items from the list of the different points of views, a dynamic tree structure. After creating this tree, the user navigates in the tree structure. In each leaf of the tree he will find documents or document zones which contain the chosen points of views. If the different documents or document zones contain additional points of views which were not selected at the beginning, the user has the possibility to choose these new points of views from the leaf where the documents and document zones are located for further navigation. As we assign the concepts of aboutness and concept of relevance to documents and document zones, the industrial researcher has the possibility to navigate between these different concepts. Navigating in points of views describing the concept of aboutness allows a navigation in document content descriptions. Navigating in points of views describing the concept of relevance allows a navigation in document interest descriptions.

We do not support a separate navigation in annotations. Annotations are always linked to documents or documents zones. Therefore, the dynamic navigation in documents and document zones gives automatically access to the relevant annotations.

5.2.4.2 Visualisation forms for selected content

The attribution of the different content description concepts enables inference-based representations. This inference-based representation can be used instead of search engines when the user does not look for precise information. The user has the possibility to display the available information according to different points of views. This gives him an overview of the information basis available for the researcher activities.

As the information is structured according the different points of views we propose cross-structured representations. The possibility to cross the points of views concerning the aboutness concept with the points of views concerning the relevance concept allows the user to conclude on available information representing a certain interest for research objectives (Figure 5.4).

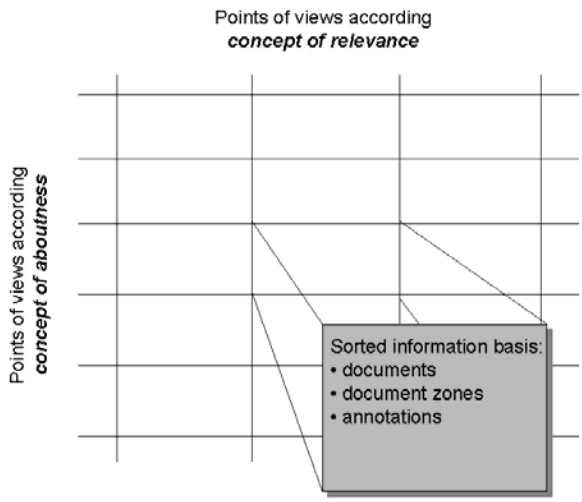

Figure 5.4 – Visualisation of written information content with table frame

The cross-representation allows to navigate but also to follow the evolution of available information for certain research activities (Montmain, 2001). The representation can therefore lead to a decision support for existing and future research activities (Grabisch and Roubens, 2000). According to Montmain, such a representation can lead to a referential and a support for argumented decisions.

The dynamic representation allows to see the available information basis for given research activities but also for new emergent research themes for different viewpoints. It can lead to decisions and conclusion for the actual and future research activities.

An important advantage of our approach is the existence of a formally represented knowledge model (the knowledge typology and the research environment) that makes it possible to envisage additional reasoning services on the top of the "basic" search support.

After re-accessing relevant information for the research result production, the researcher assembles this information to the new products by adding his additional new ideas and knowledge. We propose to support this assembling process.

5.2.5 ASSEMBLING

The knowledge production process is not an ad-hoc knowledge production process. Industrial research results do not emerge at the end of the year when the researcher has to produce his research reports. Research results emerge during the whole period of research activities. If the industrial researcher does not have the possibility to keep these results, they risk of getting lost.

The information in documents constitutes an important resource for the knowledge production process. Parts of internal and external documents can be assembled, together with additional knowledge, to a coherent new research product. This assembling process is not supported for the industrial research context.

Furthermore, the different annotations produced on documents or document zones can represent "intermediate research results" which can play a role for the final research result argumentation.

Therefore, we propose to indicate zones of documents or annotations, if they are relevant for the final research result production and for which research activity. Indicating the use of document zones or annotations for the final research result production goes further than the concept of relevance. The indication represents a real evaluation: the information plays an active role for the research product.

The indication allows the industrial researcher to constitute his research results during the whole study lifecycle. The indication allows also establishing a real link between the research results and the resources which contributed to the achievement of the research results. As the citation of the resources which contributed to the research results is often neglected this could help to resolve these problems.

This function is limited to document zones and annotations. Documents cannot directly be taken into account for intermediate research reports.

Because of the time constraints of this thesis project, we will realize this proposition on a prototype environment later.

5.3 FUNCTIONAL SPECIFICATION – THE ARCHITECTURE

The functional specification is based on UML. We will first describe the different use cases. Furthermore, we will specify the class diagrams and their different associations.

5.3.1 SPECIFICATION OF THE USER TYPES

Among the different actors, we identified three categories of users: creator, reader and administrator (admin).

- The user group "creator" attributes points of views or annotations to documents or document zones and has the possibility to select document zones or annotations for the assembling to research results.
- The user group "reader" visualizes the documents or document zones according different points of views and can read the different annotations and selected documents and zones.
- The user group "admin" has the possibility to create new points of views (new meta-data) or to modify exiting ones.

For each user group, we identified different use cases.

5.3.2 THE USE CASES

The use cases describe the different possible actions for the different user categories. Therefore, we will describe the use cases for the creator, reader and admin.

5.3.2.1 The use cases for the user category "creator"

We identified six use cases for the user group "creator" (see Figure 5.5):

- Use case one: attribution of points of view to a document.
- Use case two: attribution of points of view to a document zone.
- Use case three: attribution of annotations. The attribution of annotations is possible for documents, document zones but also for other annotations. This means that users can attribute annotations on annotations.
- Use case four: select information for research result document. This describes the possibility to select document zones or annotations to take into account for research result documents. The use case implies the creation of research result documents (use case five).
- Use case five: create research result document.
- Use case six: create new point of views. The user has a limited possibility to create new point of views. These points of views concern in fact the different key words which allow to specify the fix point of views.

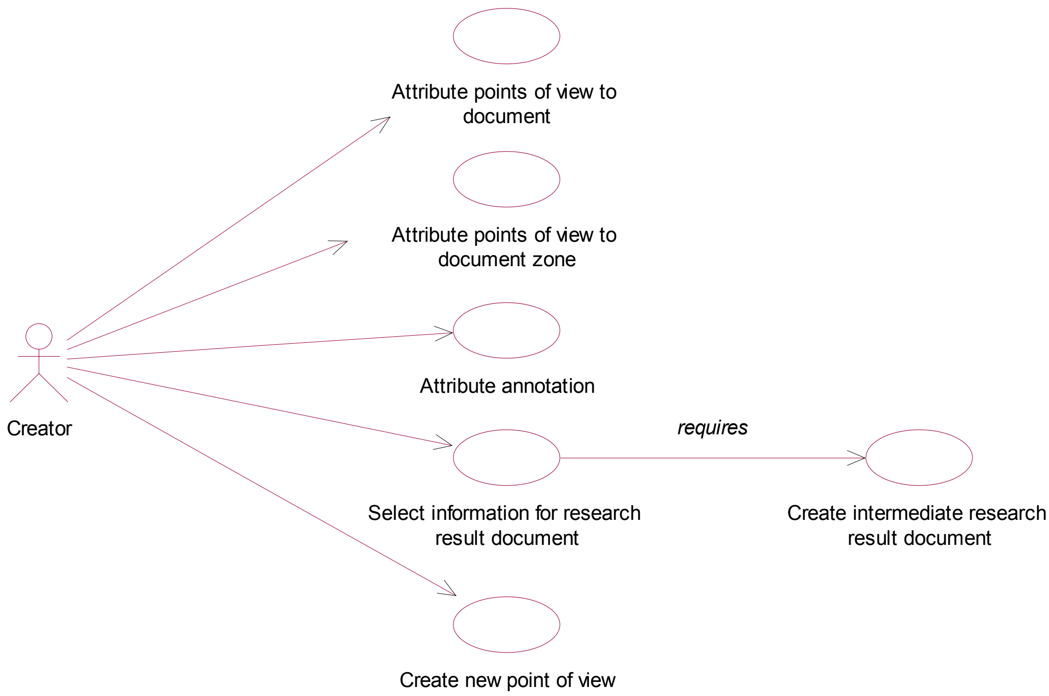

Figure 5.5 – Use cases for user category “creator”

5.3.2.2 The use cases for the user category “reader”

For the “reader” user category we identified two use cases (see Figure 5.6):

- Use case one: list information according selected points of view. This use case describes how the user selects the different points of views to represent the different documents or document zones.
- Use case two: display selected information. The user has the possibility to display information which are characterized via viewpoints. This information can concern documents, document zones and annotations. For a document zone this means for example, once he chooses to represent a document zone, the zone is immediately displayed. The user does not need to scroll the document to find the document zone.

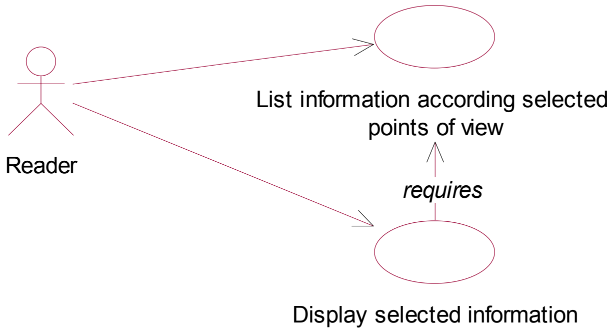

Figure 5.6 – Use cases for the user category “reader”

5.3.2.3 The use cases for the user category “admin”

We identified two use cases for the user category “admin” (see Figure 5.7):

- Use case one: define points of views. The administrator defines the possible list of points of view and describes their definition or explanation.
- Use case two: modify points of views. The administrator can modify and delete existing points of views. Nevertheless, he has to verify the consequences of any modification for already structure documents and zones.

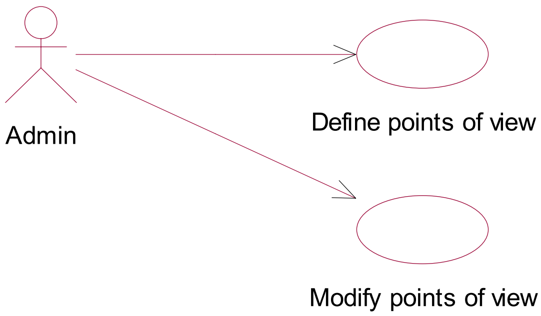

Figure 5.7 – Use cases for user category “admin”

5.3.3 THE CLASS DIAGRAM

Based on the use cases and the theoretical specification we will define the different classes. For each class we will define the corresponding attributes, if necessary specify their values, and the connection with other classes.

We define the following classes:

- Actor: represents the user categories described in the previous section,
- Document: represents the documents which can contain different point of views and annotations,
- Document zone: represents a zone of a document,

- Annotation: represents an annotation for a document or a document zone,
- Aboutness and relevance: represent the different possible points of views a creator can attribute on documents or document zones.

The overall class diagram is represented in the following figure (Figure 5.8). We will discuss each class in the following sections.

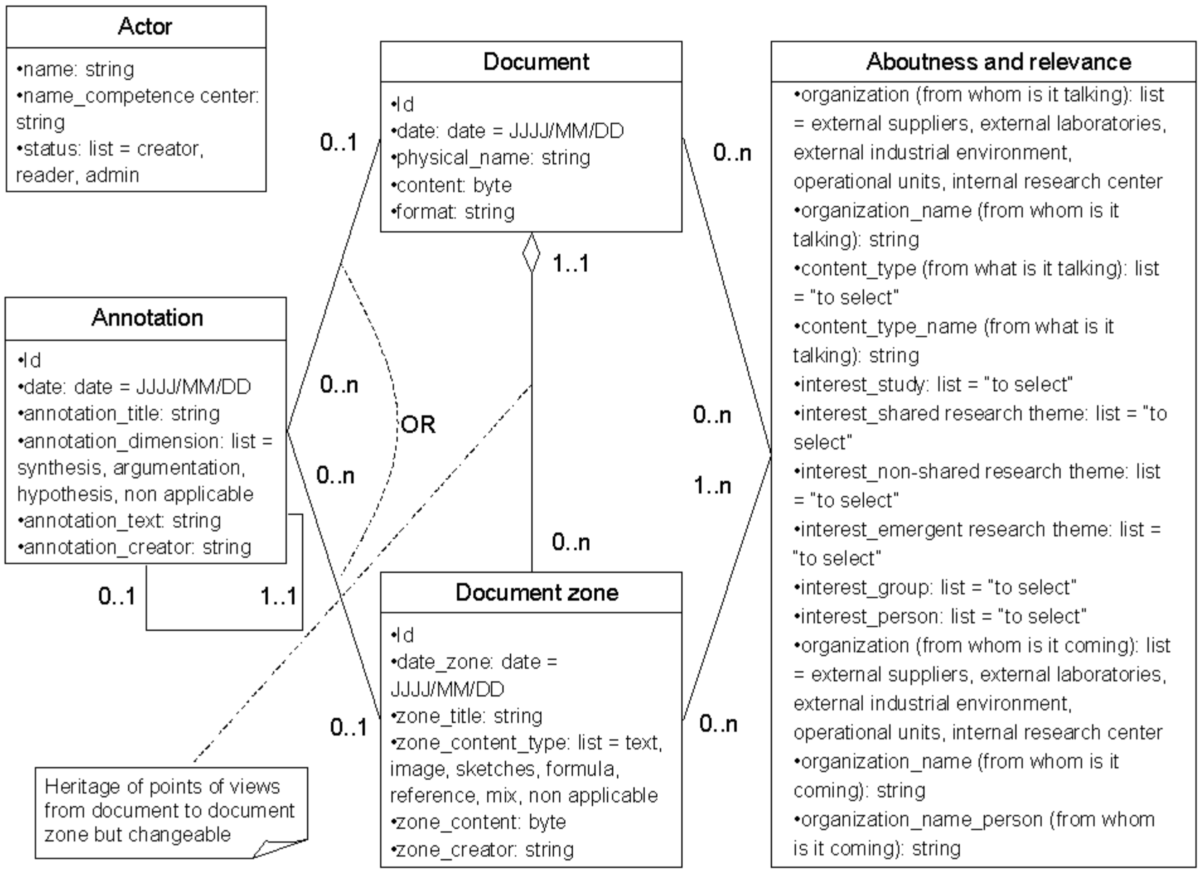

Figure 5.8 – Specification of A.N.I.T.A. tool with class diagram

5.3.3.1 Class Actor

The class Actor describes the different attributes of a user of the system. As described, the class concerns different user categories. The class actor has the following attributes:

- name: specifies the name of the actor.
- name_competence center: specifies to which competence center the actor belongs to. In our case, according to the internal organization, every actor belongs to a service.
- status: list = creator, reader, admin: specifies the different possible status of the actor towards the system. This represents an attribute value according to a list format with the elements: creator, reader, admin.

5.3.3.2 Class Document

The class Document describes the documents which are manipulated by the system. The class Document has the following attributes:

- Id: this attribute identifies a unique instance of the class Document.
- date: indicates the date when the document enters the system for the first time.
- physical_name: indicates the name of the document file. In order to keep the consistence of the different document files when used by different users, other users cannot change the physical file name.
- content: describes the content of the document.
- format: indicates the original format of the document. As all documents are converted into a PDF format, this information can play a role in order to know the original format.

The connections of the class Document with other classes are the following:

- Document <> Document zone: an instance of the class Document can refer to none or several instances of the class Document zone.
- Document <> Annotation: an instance of the class Document can refer to none or several instances of the class Annotation.
- Document <> Relevance and aboutness: an instance of the class Document can refer to none or several instances (sets) of the class Relevance and aboutness.

5.3.3.3 Class Document zone

The class Document zones describes the document zones which are manipulated by the system. The class Document zones has the following attributes:

- Id: this attribute identifies a unique instance of the class Document zone.
- date_zone: indicates the date when a creator creates a document zone in a document.
- zone_title: indicates the title of the document zone. The title is defined by the creator. In order to avoid confusions between the different titles, the system proposes an automatic title for each document zone of a document. The proposed title consists of the physical name of the document (attribute of the document) and the next following number according to the number of documents zones of the document (for example: physical name_document zone 1; physical name_document zone 2, etc.).
- zone_content_type: list = text, image, sketches, formula, reference, mix, non applicable: specifies the possible different content types of a document zone. This information is optional for the user.
- zone_content: indicates the content of the selected document zone.
- zone_creator: indicates the name of the creator of the document zone. The system proposes via a profiling function automatically the name of the creator.

The connections of the class Document zone with other classes are the following:

- Document zone <> Document: an instance of the class Document zone can refer to only one instance of the class Document. As the document zone is part of the document it can follow the heritage of the points of views of the document for the document zone. However, the creator has the possibility to change these points of views.

- Document zone <> Annotation: an instance of the class Document zone can refer to none or several instances of the class Annotation.
- Document zone <> Aboutness and relevance: an instance of the class Document zone can refer to one or several instances of the class Aboutness and relevance. When the creator creates a document zone, he has to attribute at least one point of view.

5.3.3.4 Class Annotation

The class Annotation describes the annotations which can be attributed to a document or document zone by a creator. The class Annotation has the following attributes:

- Id: this attribute identifies a unique instance of the class Annotation.
- date: indicates the date when a creator creates an annotation on a document or document zone.
- annotation_title: indicates the title of the annotation. The title is defined by the creator. In order to avoid confusions between the different titles, the system proposes an automatic title for each annotation. The proposed title consists of the physical name of the document (attribute of the document) or the title of a document zone (attribute of the document zone) and the next following number according to the number of the annotations of the document or document zone. For example for a document: physical name_annotation 1; physical name_annotation 2, etc.. For example for a document zone: physical name_document zone 1_annotation 1; physical name_document zone 1_annotation 2, etc..
- annotation_dimension: list = synthesis, argumentation, hypothesis, non applicable: specifies the different dimensions of an annotation. This dimension id defined by the creator during the creation of the annotation.
- annotation_text: indicates the content of an annotation described by the creator.
- annotation_creator: indicates the name of the creator of the annotation.

The connections of the class Annotation with other classes are the following:

- Annotation <> Document: an instance of the class Annotation can refer to none or one instance of the class Document.
- Annotation <> Document zone: an instance of the class Annotation can refer to none or one instance of the class Document zone.

An annotation can only refer either to one document or to one document zone. It is not possible that one annotation can refer to a document and a document zone at the same time.

- Annotation <> Annotation: an instance of the class annotation can refer to one instance of the class annotation. This means that a creator can create an annotation on an annotation.

5.3.3.5 Class Aboutness and relevance

The class "Aboutness and relevance" describes the different points of views which can be attributed to documents and document zones. For the different points of views we decided, in order to keep the use and the maintenance tasks of the administrator easier, not to introduce the different possible hierarchical relations (for example between study and shared research themes as indicated in section 4.2.3.3). This allowed us to model the different points of views all on the same level and therefore avoid using a class for each point of view. However, if there is the need to introduce hierarchical relations between the different points of views, the proposed class description has to be reviewed.

The class aboutness and relevance has the following attributes:

- organization (from whom is it talking): list = external suppliers, external laboratories, external industrial environment, operational units, internal research center: specifies the organization environment from whom the document or document zone is talking about. This description is linked to the concept of aboutness.
- organization_name (from whom is it talking): specifies the exact name for the above attribute organization (from whom is it talking).
- content_type (from what is it talking) list = "to select": provides list elements of the following table (Table 5.3):

Table 5.3 – List elements to describe variable "content_type" of class "Aboutness and relevance"

External laboratory	External supplier	External industrial environment	Operational units	Internal research center
Research directions	Research directions	Strategy	Strategy	Strategy
Innovative concepts and models	Innovative concepts and models	Use cases	Needs / processes	Organization / methods / tools / constraints
Methods	Methods	Needs	Research objectives	Research requirements
Prototypes	Tools	Methods	Approach	Experiments
Means	Means	Tools	Innovative concepts and models	Processes
Experiments	Experiments and feedback	Solutions	Methods	Used methods for experimentation
			Prototypes	Used tools for experimentation
			Means	Feedback
			Experiments	

The elements represent the concept of aboutness.

- content_type_name: gives the creator to specify the content type (the above attribute) with a variable name.
- interest_study: list = "to select": gives the possibility to the creator to indicate for which study the document or document zone represents an interest (concept of relevance). The creator will have the choice among a list of fix elements. However, this choice will vary according to the actual studies. Therefore, we do not define new list elements in this specification. The administrator will define these list elements by activating the different points of views.
- interets_shared research theme: list = "to select": gives the possibility to the creator to indicate for which shared research theme the document or document zone represents an interest (concept of relevance). The creator will have the choice among a list of fix elements. However, this choice will vary according to the actual shared research themes.

- interest_non-shared research theme: list = "to select". The principle of the non-shared research theme is the same as for the shared research theme attribute.
- interest_emergent research theme: list = "to select". The principle of the emergent research theme is the same as for the shared research theme attribute.
- interest_group: list = "to select": gives the creator the possibility to attribute a document or a document zone to a defined group of researchers with similar research objectives (concept of relevance). These groups are defined by the administrator.
- interest_person: list = "to select": gives the creator to attribute a document or a document zone to a person. The creator thinks therefore, that the information might be relevant for this person (concept of relevance).
- organization (from whom is it coming): list = external suppliers, external laboratories, external industrial environment, operational units, internal research center: specifies the organization environment from whom the document or document zone is coming.
- organization_name (from whom is it coming): indicates the real name of the organization from whom the information is coming. This specifies the above attribute organization.
- organization_name_person (from whom is it coming): indicates the name of the person from whom the information is coming.

In order to access and visualize documents and document zones, the reader uses the same attributes of the class Point of view in order to select his set of points of views to access and visualize documents or document zones.

The connection of the class Aboutness and relevance with other classes are the following:

- Aboutness and relevance <> Document: an instance of the class Aboutness and relevance can refer to none or several instances of the class Document.
- Aboutness and relevance <> Document zone: an instance of the class Aboutness and relevance can refer to none or several instances of the class Document zone.

An instance of the class Aboutness and relevance needs to refer at least to one instance of the class Document or the class Document zone.

5.4 TECHNICAL SPECIFICATION AND REALIZATION

For the technical realization of the A.N.I.T.A. tool, we used different technologies and technological concepts. According to the different functions and the different used technologies, we can divide the A.N.I.T.A. tool into two main modules:

- The attribution of points of views and annotation module,
- The access and visualization module.

In the next sections we will present and discuss the global architecture of the prototype and the different modules with their technical specifications.

5.4.1 ARCHITECTURE OF THE A.N.I.T.A. TOOL

The following figure presents the architecture of the A.N.I.T.A. tool. The different steps in the figure represent the different manipulation of the user and the different automatic mechanisms (Figure 5.9).

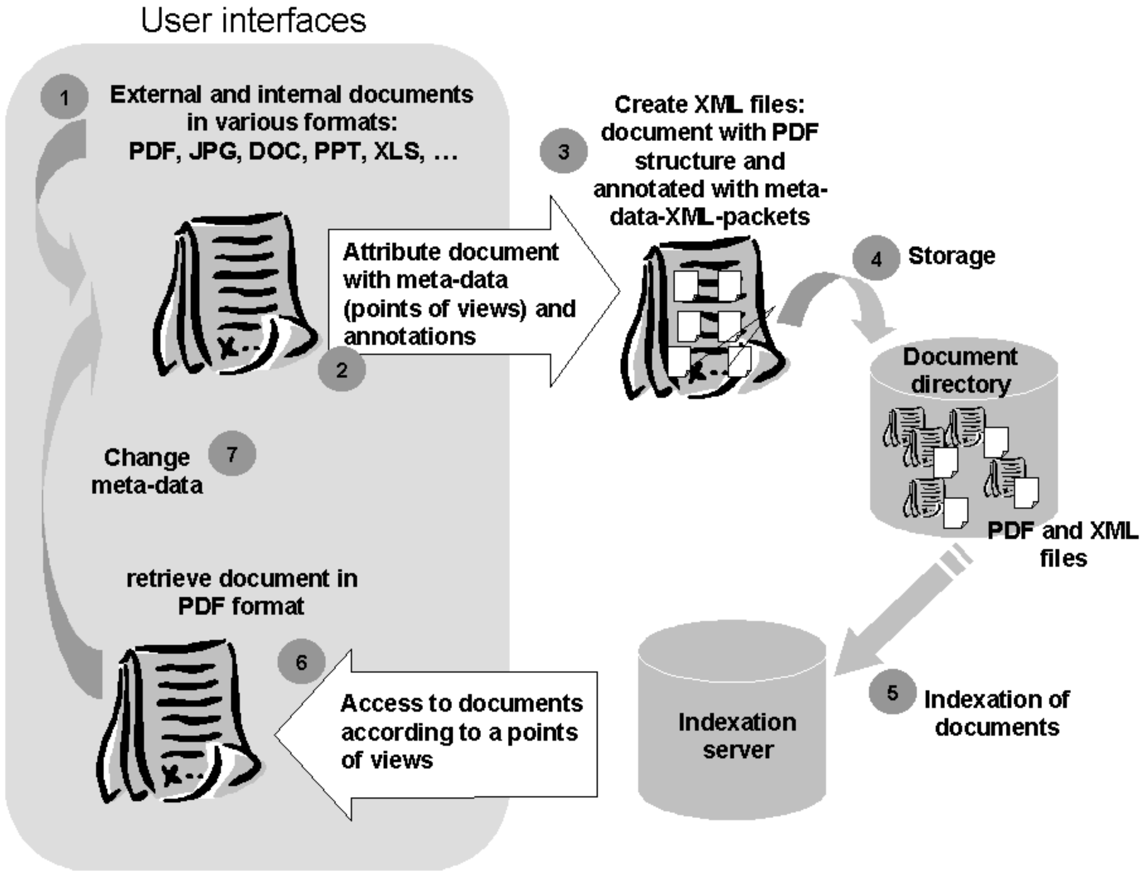

Figure 5.9 – Global architecture of A.N.I.T.A. tool

1. The user chooses the documents, which he wants to introduce into the system and transforms it into a PDF format.
2. By a graphical interface, he chooses the meta-data (points of views), which he wants to attach for the PDF document or the document zone. He also has the possibility to attribute an annotation.
3. The meta-data are attached as separate XML files which contain the structure of the points of views and annotations. The XML files are linked to the PDF document.
4. The PDF document and XML file are stored together in a file directory (for example in a Windows explorer directory).
5. The indexation server crawls periodically this file directory. If he finds a new document with an XML file, it indexes the XML file.
6. The user retrieves the information according to multiple points of views by a graphical interface.

7. In the case, the user wants to change or to add points of views and annotations, he repeats steps 2 to 6 and the index is updated by the next periodic crawl.

The interface between the two modules is the XML structure that has to be readable by both modules. For this reason, the nature and names of the XML tags and their order within the XML structure have to be defined. A meta-data description begins with the description of the physical description of the document like physical name, storage path, date, etc. followed by the meta-data packets. Meta-data packets are the different meta-data describing one selection of points of views by the user. After the meta-data packets for the document, but still within the physical document description, descriptions for document zones containing also meta-data packets are introduced. This order of the structure is important, so that the structure is readable by the indexing server.

In the sections 5.4.2 and 5.4.3 we will detail the two modules.

5.4.2 THE ATTRIBUTION OF POINTS OF VIEWS AND ANNOTATION MODULE

The attribution of points of views and annotation module is developed as an Adobe Acrobat 5.0 plug-in. The Adobe Acrobat 5.0 plug-in is developed in Visual C++ 6.0 with standard libraries as well as the Acrobat SDK, XMP SDK and AFC. It is designed as a new annotation tool and will appear in the Acrobat application as an icon.

5.4.2.1 File format retained

Therefore, today, the existing solutions either are based on a Web environment or need a database for the storage of the annotations. These solutions present some handicaps: the industrial researcher uses all sorts of documents in various formats. Not all formats can be converted in a Web environment. The database solution needs a heavy administration between documents and their annotations. Other points concern the limitations of attributing points of views (meta-data) to document zones and annotations at the same time. Cutting out parts of documents (creating document zones) to make annotations might be difficult to administrate if for example the user wants to create a large number of document zones in a long document.

For these reasons, we propose to integrate points of views and annotations in a PDF format environment based on XML and RDF technology. The points of views and annotations are linked to the XML tags of the PDF document. Working with XML makes it possible to create points of views and annotations for documents and for documents zones. As the items are expressed in XML they are directly linked to the structure of the document. There is no need for a database and the documents do not need to be cut into different physical pieces of documents.

Although an XML solution would be preferable from a technical point of view, being easy to implement and maintain, such a solution would have to expose the user to tasks demanding in-depth knowledge concerning a computer's file system, rendering the tool difficult to use. Problems such as documents contained over more than one file, lack of a sufficiently user-friendly and standardised document-viewing application supporting XML, as well as a lack of sufficiently powerful file conversion routines for the different document file formats, render the Adobe Acrobat's PDF as the preferred solution. PDF was also retained for the solution prototype.

The principal arguments were based on the importance of keeping a document's visual appearance unchanged after file conversion, and keeping the annotation process simple and user-friendly.

5.4.2.2 Editing documents

Editing non-final documents including meta-data attributed by the A.N.I.T.A. tool might cause consistency problems. Changing parts of the document could render attributed annotations or points of view invalid.

As no solution had been identified prior to development, a temporal solution assuming that all documents treated are final was chosen. The consequence is that it is not possible to modify the content of the documents once they are annotated and structured in document zones.

5.4.2.3 Technical architecture

With the file format specification of PDF v. 1.4 supported by Adobe Acrobat 5.0, it is possible to create an independent logical structure in a PDF document defining the document structure. It is also possible to attribute meta-data (points of views and annotations) to the different structural elements in the logical structure. This feature permits a page-independent organisation and structuring of a document's content, allowing the formulation of a document's structural meta-data.

A typical document can be structured into structural elements such as document, part, article, section, division, block quotation etc., where each structural element refers to one or several content elements in the original document, such as a passage of text, or graphical representation like an image or a table. Furthermore, for each structural element, characterising attributes can be attached. Any byte stream might serve as a valid structural attribute.

The fundamental technical idea behind the prototype was to use the PDF document embedded logical structure to define and describe a document's document zone and their points of views as well as points of views concerning the document as an entity. The relations between the different structural elements and their appropriate zones in the document were intended to be done by tagging the relevant parts of the document and adding references to them to the structure element.

In the A.N.I.T.A. tool, valid and well-defined XML streams, applying only a restricted set of linguistic components defined in RDF, were used to describe the structural elements' meta-data (Figure 5.10). Furthermore, each XML stream had to be codified and wrapped into self-containing packets, according to rules defined in Adobe's XMP (XML similar structure defined by Adobe for PDF documents), in order to permit other applications, that are not capable of understanding PDF syntax, to easily separate the XML streams from the PDF file. These packets were then attributed to a given structural element.

As the header and tail of a XMP packet are also written in XML, in order to extract these XMP packets from a given PDF file, a well-constructed XML parser is sufficient.

The intention behind using XMP packets instead of ordinary XML streams was to permit the meta-data based indexation of PDF files by primitive search engines not capable of accessing the PDF files' logical structure. This was done to facilitate the realisation of the visualisation module.

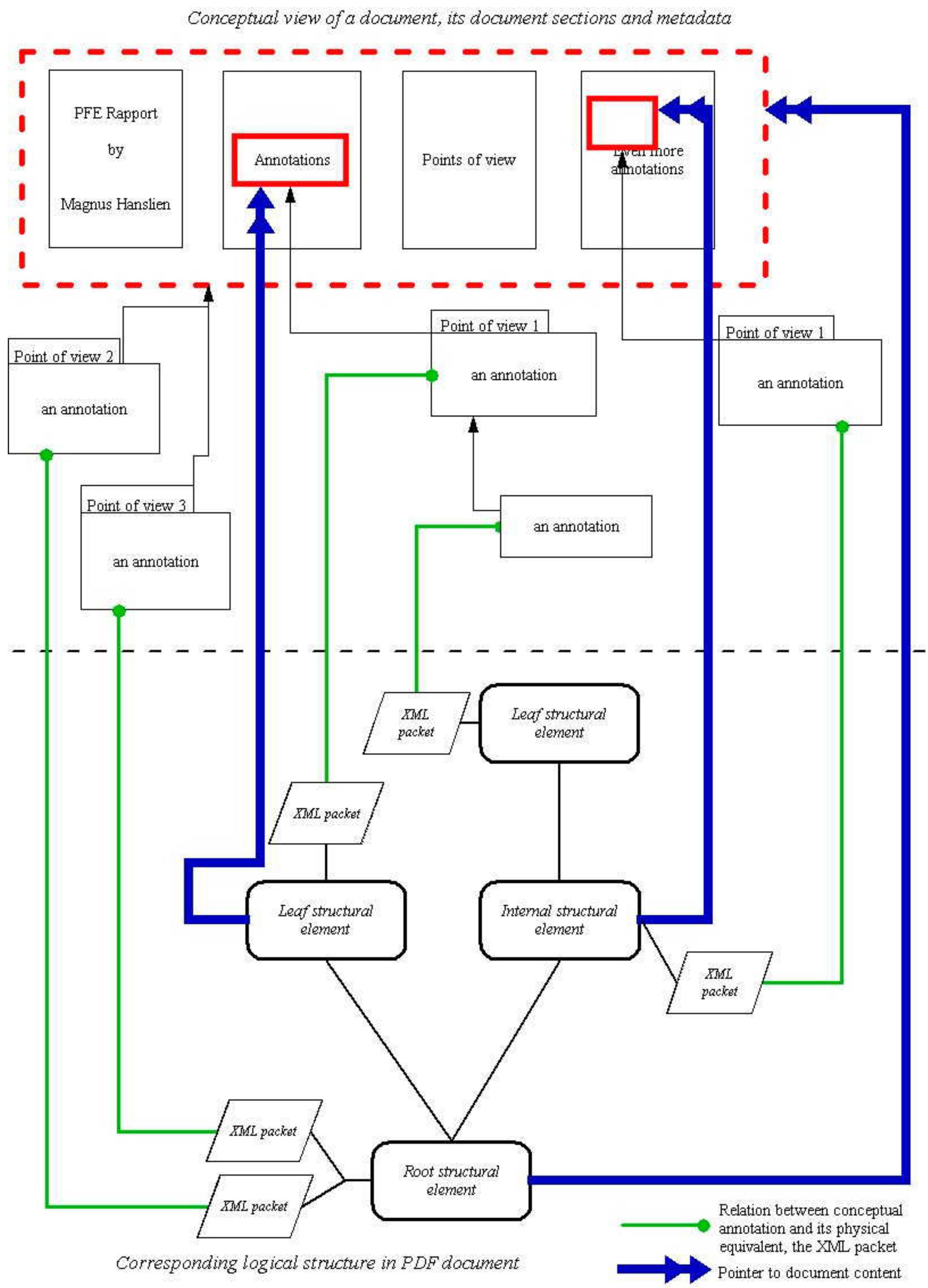

Figure 5.10 – The annotation concept and its conceptual physical equivalent

The A.N.I.T.A. tool is disabled until Adobe Acrobat 5.0 is running and a valid PDF document is opened, after which the tool is enabled. It remains enabled until the document is closed.

5.4.2.4 Decomposition of the architecture for the attribution of points of views and annotation module

The architecture of the A.N.I.T.A. tool module allowing the attribution of meta-data and annotations can be divided into four layers, where only the three first are under the control of the programmer:

1. Graphical user interface (GUI)
2. Logical interface
3. Document interface
4. File interface (controlled by Adobe Acrobat)

The first layer, GUI, handles the operations concerning visualization of points of views and dialogues.

The logical interface layer handles information, such as converting a XML tree to a set of attributes, as well as the drawing of rectangles. Rectangles were used to mark the document zones.

The document interface includes methods manipulating the PDF document, such as the addition of a logical structure and attribution of points of views to a structural element.

The file interface is handled automatically by the main Adobe Acrobat application itself. However, certain file-oriented commands such as "save" and "close" can be invoked from the document interface layer, although options concerning how these actions should be performed are strictly limited.

5.4.2.5 Realized annotation module architecture – technical limits

Although principally equal, the realized prototype differs slightly from the envisaged prototype in terms of user functionality and referencing techniques intended to connect the logical structure with the document content. Mostly due to a combination of technical difficulties encountered during the programming and a general lack of sufficiently detailed documentation of the Adobe Acrobat SDK, several low-priority functions that was originally intended included in the prototype, such as functionality for deleting points of views were decided to be postponed to later versions.

Furthermore, as marking passages of text with Adobe native tags turned out to be technically infeasible, spawning off numerous problems, a simplified referencing between the logical structure and its document, consisting of four graphical coordinates and page number was implemented as a temporal solution.

However, the realised A.N.I.T.A. tool works well, satisfying the initial expectations set.

5.4.3 THE ACCESS AND VISUALIZATION MODULE

For the realization of our system, we chose Adobe Acrobat for the visualization of the documents and XML to manage the meta-data to develop a tool that is independent from other technologies. For the development of the access and visualization module, we chose to use a graphical web interface written in PHP[2] to offer the interface with a minimal system

[2] A server-side scripting language. The PHP commands, which are embedded in the web page's HTML, are executed on the web server to generate dynamic HTML pages.

requirements. Furthermore PHP offers certain dynamic possibilities and allowed to adapt the interface according to the restrictions of the points of views and annotation attribution module.

5.4.3.1 The technical architecture

The users annotate documents with points of views. Once, the annotated document is transferred in the document directory, the index server updates the index which contains the values of the points of views, the XML structure and the link to the origin document.

The access and visualization interface is predefined in the way that the categories are already defined. The possible values for each category are retrieved from the index, each time the interface is used. It is thus a dynamic initial creation of an interface.

As the meta-data are managed in XML structure, the categories are predefined by nature of tags that are filled by text presenting the values of a point if view. As already discussed, XML allows to structure a text and to organize document zones into a hierarchy. This advantage can be used to keep a hierarchy inside certain categories if required

5.4.3.2 Decomposition of the architecture for the access and visualisation module

The architecture of this module can be divided into four layers.

- Graphical user interface (GUI)
- Logical interface
- Indexation server interface
- Document and module interface

The first layer, GUI, handles the operations concerning building multiple points of views for a search and handles the visualization of the results.

The logical interface layer handles information, such as converting the multiple points of views chosen in the interface in a searching demand for a database. We use a mySQL database for this manipulation. As we use PHP and a mySQL database, the user demand is converted in a SQL demand.

The indexation server interface handles on the one side the SQL demand to retrieve results from the data-base. On the other side it handles the crawling of the specified storage directory to index the XML-structure of documents for the system. This implies the converting of a XML tree to a set of attributes to write in data-base tables.

The document interface represents the storage path and combines the two modules.

5.4.3.3 Access and visualization module – technical limits

The interaction of the modules (point of view attribution and visualization) causes one risk concerning the management and the retrieval. The user wants to have an "actual" interface, which always lists all possible values for a search. To avoid incoherence between the search interfaces and the values for the description of documents, we suggest basing the research interface on the values existing in the document directory. This means that we define an interface for the attribution that includes all the values defined for the system. These values can also be changed according to new requirements.

Technical aspects limit the functions of the realized prototype module. PHP offers a dynamical creation of web pages for the interface and an access to the database. However all actions depend on the user. That means, that a periodic indexation is not supported in this version. Every update of the index server implies an updated by starting the module.

5.5 USE CASE SCENARIOS

We will illustrate the functions of the A.N.I.T.A. tool with several screenshots. These screenshots could illustrate a use scenario for the two realized modules. For the scenario, we will focus on the attribution of points of views and annotations on document zones.

- Attribution of points of views (Figure 5.11):

  The user opens a PDF document and activates the module to attribute points of views. He now has the possibility to select a document zone (rectangle on PDF document). After selecting the document zone, a new window pops up with the possibility to attribute the different points of views according to the specification of section 5.3.3.5.

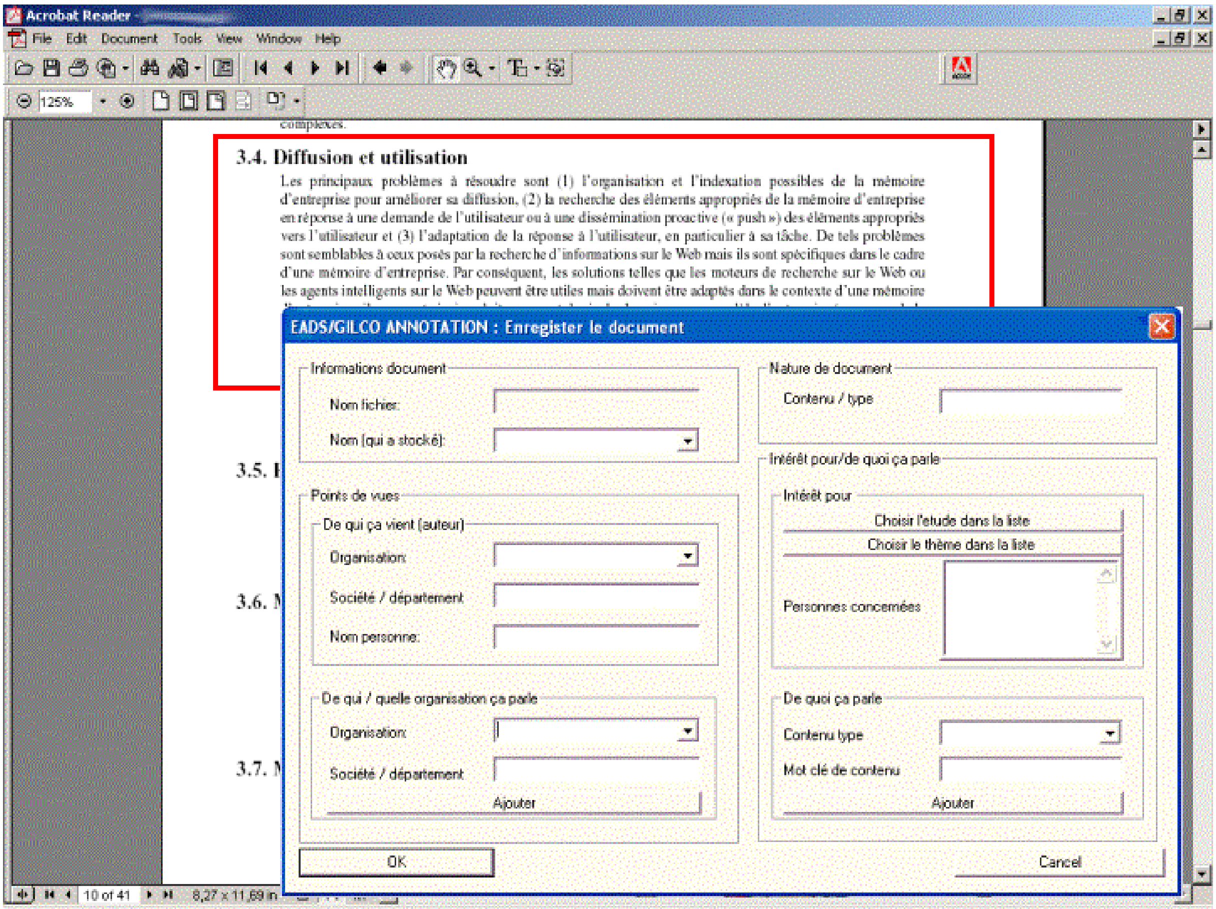

Figure 5.11 – User interface for the attribution of points of views

- Attribution of annotations (Figure 5.12):

  The next figure shows the possibility to attribute an annotation to a document zone. The principle is the same as attributing points of views.

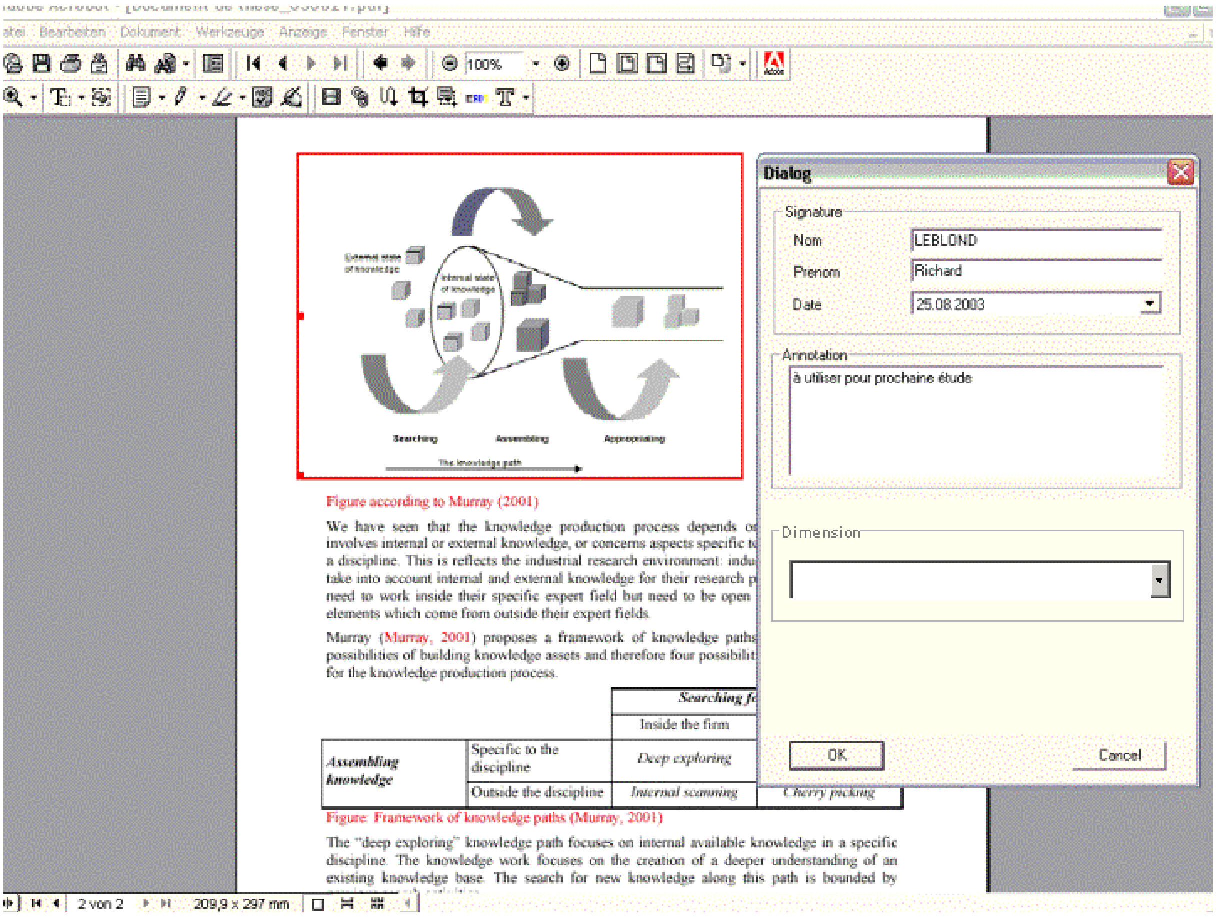

Figure 5.12 – User interface for the attribution of annotations

- Access limited by a point of view (Figure 5.13):

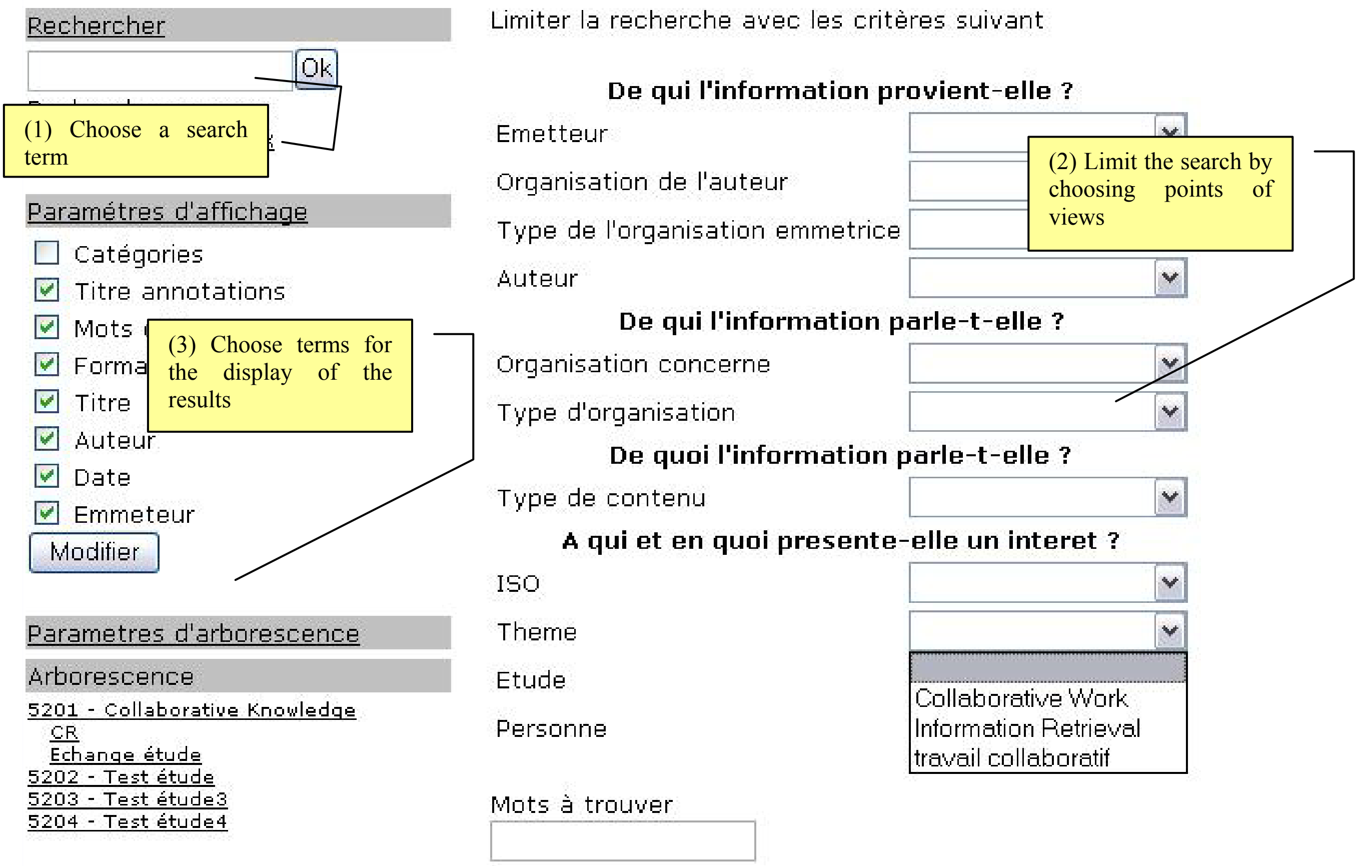

Figure 5.13 – Access by a search engine according to multiple points of view

The user types one or some keyword(s) for the search (1). Furthermore, to limit the search results he can choose some points of views according to the concept of aboutness and relevance (2), in order to precise the results.

For the display of the results, the user can choose which properties of meta-data he wishes to visualize (3).

It is also possible to ignore keywords for a search. In this case, the user receives a list with all the documents according to a certain point of view (combination of the attributes). This functionality is similar to the click on a file in the navigation-tree described with the following screenshot.

- Show the results of a search limited by a point of view (Figure 5.14):

The following screenshot shows the result for a demand according to the keywords “KM and TOOLS” with the meta-dated “auteur=Christian TRINQUIER, Organisation d’emetteur= ITK, et intéret_pour=Hendrik BUSCH”:

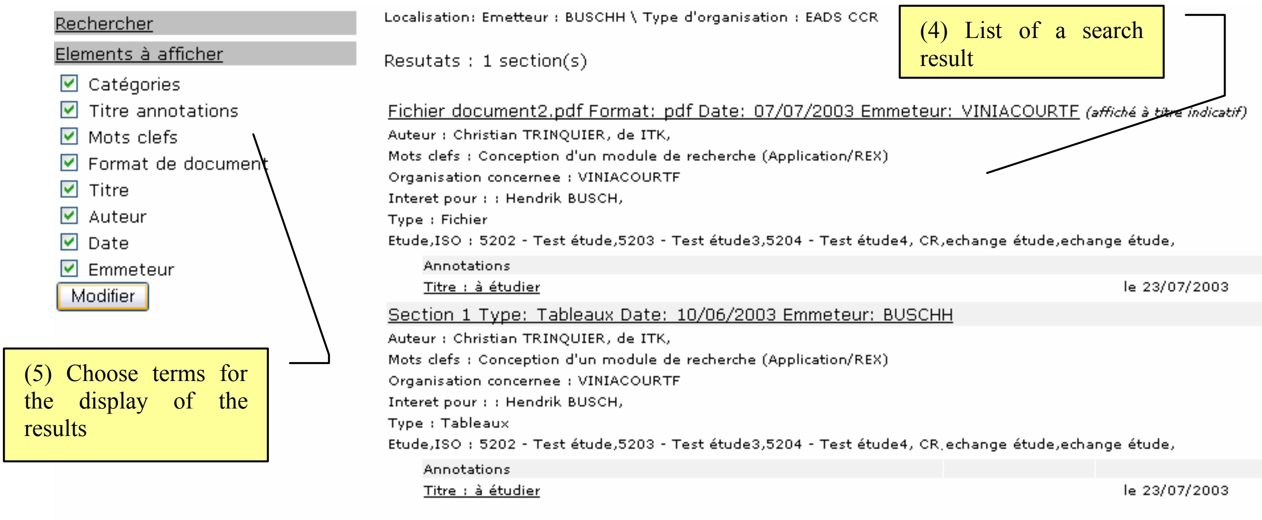

Figure 5.14 – Possible result according to an access by multiple points of view

The list of result visualizes the result of documents that contain certain meta-data characteristics determined in the search-interface (4). Furthermore, it is possible to modify the properties of the result-visualization (5).

- Modification of the order of categories for a navigation tree (Figure 5.15):

  Another functionality of the search function is the modification of the order of levels in the navigation tree. We saw that the categories are independent from each other, so the user can change the order with the following interface:

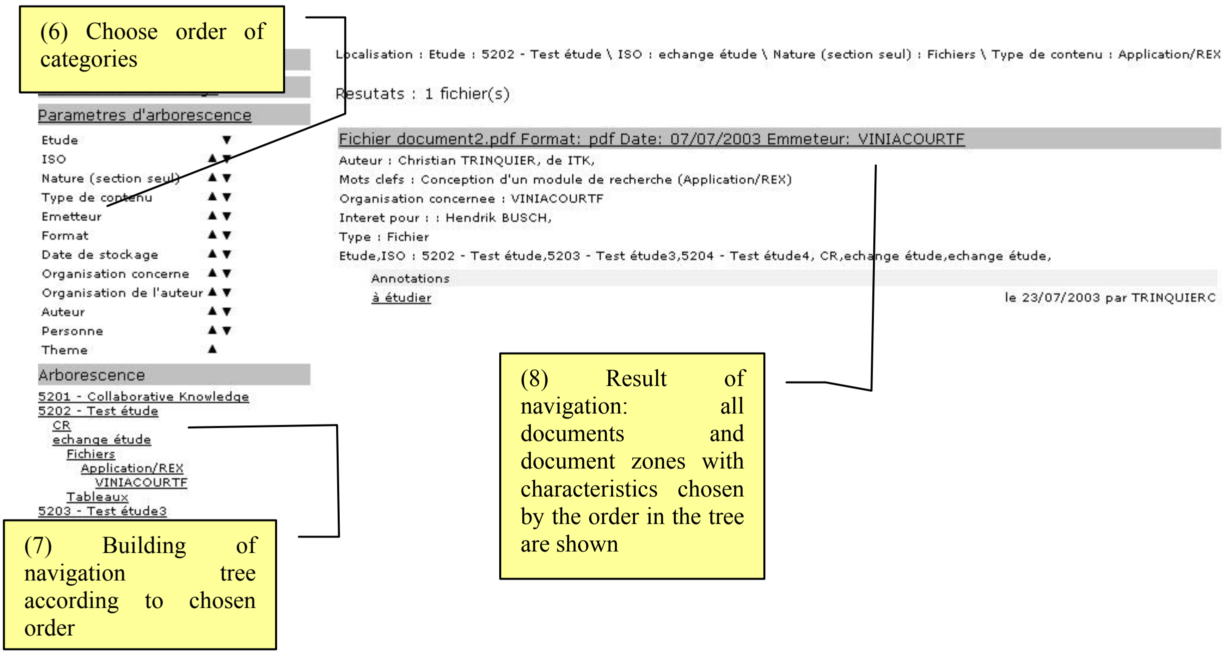

Figure 5.15 – Access by a navigation tree with changeable order of categories

The user can determine the order of the navigation tree (6). By default, a structure is given that can be changed. To move a category to a higher (upper) level of this tree, the user has to click on the up (down) arrow. The tree-structure is rebuild automatically. After the rebuilding, he can navigate in the tree (7). Each time he clicks on an attribute of a level, a result is visualized on the right, equivalent to a search in the database for documents and document zones that contain all attributes chosen on the path to this level (8).

On the preceding screenshot (Figure 5.15), we build a tree according to the following order:

Etude, ISO, nature de section, etc.

The result visualized on the right side of the screen, presents the choice for "etude=5202, ISO=Echange etude, nature de section= Application/rex, emetteur=Viniacourtf" by clicking on the attribute "Viniacourtf".

The user has access to the document zone via the link above the search results for each zone. Furthermore, he can display the different annotations via the link.

- Search by a crossing of categories (Figure 5.16):

  This can be interesting for the user to find search results and precise them to obtain a preferred number of found document contents for further analysis. This functionality is shown in the following screenshot:

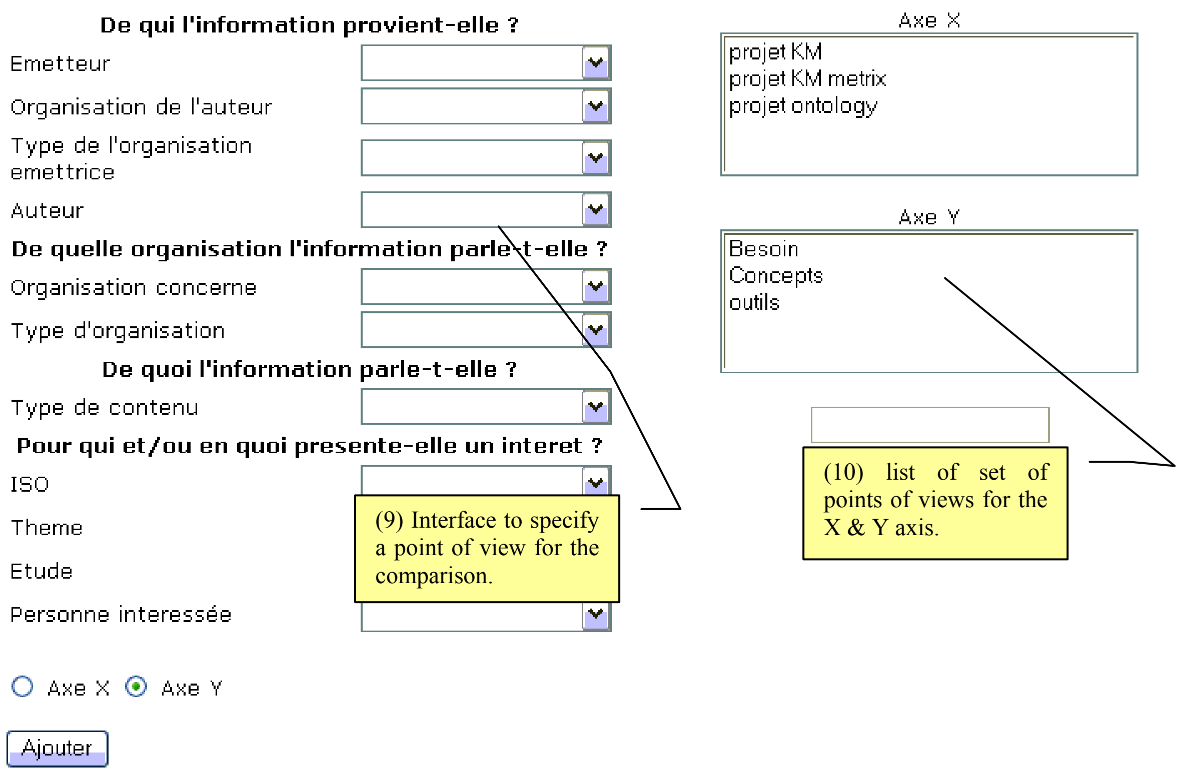

Figure 5.16 – Access by a navigation tree with changeable order of categories

The user can determine a point of view (9). He can use this selected point of view for a comparison to put it on the X or Y axis. Once he has chosen the set of points of views, he makes the search and the systems builds a comparison-table with the number of found documents and zones (here sections) (10) (Figure 5.17).

Tableau

	projet KM	projet KM metrix	projet ontology
Besoin	1 fichier(s)		
Concepts	2 section(s)	1 fichier(s) 3 section(s)	2 fichier(s)
outils	2 section(s)	2 section(s)	2 fichier(s)

Graphique

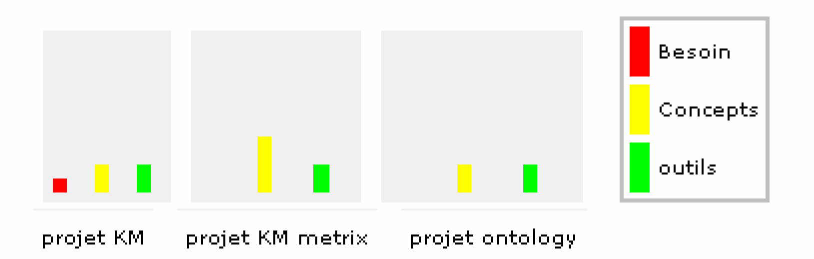

Figure 5.17 – Representation of information content in cross table format

The user has access to documents and zones via the links in the table.

5.6 EXPERIMENTATION FEEDBACK FOR THE A.N.I.T.A. TOOL

Already during the specification and conception phase of the A.N.I.T.A. tool, we collected relevant comments concerning the different functions. Due to time constraints, we had only little time to experiment the A.N.I.T.A. tool with groups of researchers for a full project lifecycle. In work sessions, we accompanied some researchers during the test phase in order to discuss their comments. However, the experimentation phase will continue in order to improve the already existing functions and to propose new features.

In the following sections, we will discuss the different experiences during the test phase according to the initial concepts and propositions.

5.6.1 SUPPORTING THE GENERAL FRAMEWORK ARCHITECTURE FOR INDUSTRIAL RESEARCH ACTIVITIES

At the end of section 4.4, we proposed and structured the prototype functions according to the general framework architecture. In the next sections, we will discuss the comments according to this structure.

5.6.1.1 Identify

Initially the prototype should support the identify activity for the focus and deploy phase of the research process model. However, the use was more intensive for information relevant for the focus phase. One of the reasons was that much of the information used in the focus phase was external information coming from the investigate phase. For the deploy phase the researchers uses more implicit knowledge.

Giving the possibility to structure and annotate document zones helps especially for the focus phase. In the focus phase, the researcher uses concept figures and method descriptions to work in them. Document zones allow the selection of concept figures in documents, presentations, etc. The annotation function allows making a comment during the structuring of these figures which can be reused especially in the focus phase.

The function F2 of the functional analysis can be supported with the cross structured representation concerning the availability of information. A representation with the activity content structure on the horizontal axis (themes, projects, etc.) and knowledge types like methods, tools, concepts, etc. helps to identify relevant information for similar projects or themes and therefore for similar research objectives. However, comments indicated that this representation might be difficult for large projects, as much information might be available.

It was difficult to support the F7 of the functional analysis for the focus phase. The objective of the function is to identify internal elements for new research activities. Internal elements exist in internal developed minutes, reports, presentations, etc. During writing the documents, the researcher does not structure the document in zones and he has not always the time to do that after finishing the document.

5.6.1.2 Structure

The structuring concerns mainly the attribution of points of views to documents and document zones. The use of this function is independent to the different research process phases. However, the function was mainly used to structure external or operational unit documents. The industrial researcher producing internal documents does not really structure these documents. They tend to give the same points of views for the document as in the actual system (folder classification).

Structuring manually the documents and document zones according to the proposed propositions takes more time than before. This might be because people are not used to the new system and because they have a larger possibility to give several attributes at the time to information. As people do not have this additional time, there is a risk that they only structure new information only with a strict minimum of attributes.

However, some people are very open to take additional time for attributing points of views to document zones. This allows a better reuse for important parts of long documents or images describing new concepts, methods, etc. The combination with free text annotations helps to prepare the research result production.

5.6.1.3 Combine and use

As we already mention before (section 5.2.5), we did not have the time to develop fully the assembly function. However, two other major tool functions allow, from the point of view of the user, a certain aspect to combine the already structured information: the function of making a free text annotation and the function allowing the cross-structured representation.

Annotations give the possibilities to combine own ideas with documents and document zones. Before the prototype, they used post-its to make comments on parts of printed documents or wrote the comments on the printed document zone by marking the concerned part. This can be replaced by using the prototype. The user has also the possibility to share the ideas or argumentations in form of annotations with other researchers. However, the activity of making annotations in an electronic format takes time as the users are still used to print out the different documents, mark the comments on the documents, and go see the other researchers (if possible) in order to discuss the documents. One factor supporting the use of electronic annotations concerns the geographical distance between people.

The cross-structured representation of information content can support the combination of information content only to a certain extent. In order to combine information content it could support here the functions F1 and F5. For the function F1 the researcher could compare identified information concerning external industrial problems on one axis with the identified information concerning operational unit problems on the other axis. However, a real comparison is not possible with this function. The function gives only the indication of available information concerning the crossed fields. The researcher has to analyze this information in order to combine it. However, for well structured document zones, the researcher gets a rapid overview of the existing information concerning this specific comparison. The prototype supports the function F5 in the same manner.

5.6.1.4 Share

The user used two functions of the A.N.I.T.A. tool in order to share information: the shared ontology and the annotations.

The ontology (concept of aboutness and relevance) allowed the different user to give information content for similar research activities a similar shared structure. This allowed that other users had access to this information without asking explicitly for the information.

Annotations supported additional argumentations among the researchers. As researchers could react on existing annotations, little discussions emerged. Annotations for sharing information appeared often when the researcher identified information structured by another researcher for specific research objectives. The researchers made comments about the attributions of the points of views or indicated additional information. However, with technologies like email, telephone, etc. it is not sure that the researchers will continue annotations for exchanging ideas after the test phase. It is important that the researcher sees a benefit of the exploitation of the annotations.

The better sharing of information had the consequences that researchers felt that they were able to learn more about certain subjects and that they were able to take more information into account for their research result production. Hatchuel talks about “cross learning” in this context (Hatchuel, 1994). These cross learning interactions allow to create new knowledge and facilitate the organization learning processes (Midler, 1991), (Midler, 1993).

5.6.1.5 Preserve

The preservation of information content is linked to the structuring with points of views. In order to examine the use and practices concerning this activity, a longer observation is necessary (at least one project lifecycle). We did not analyze this activity because the test phase was to short in order to make pertinent conclusions.

5.6.2 DOCUMENTS AND DOCUMENT ZONES

The possibility to structure the documents in document zones enables the researcher to improve the exploitation of written information content. This is especially the case, when the user re-accesses already structured document zones. Before, in order to reuse certain parts of written information, the researcher needed to re-read the whole document or take the printed version with handwritten annotations.

Besides this, already existing functions for documents, for example share documents, distribute documents, store documents, are now possible with parts of documents. As our solution is based on an XML structure for the document zones, the different manipulations could be possible probably also for other tools working with XML.

One significant advantage of our solution is that the document zone stays in the context of the document (no "cut and paste") which helps to keep the overall context of the zone for other readers. This plays an important role when other users access the zones and want to share their ideas via annotations with the creator of the zones.

However, the possibility to manipulate document zones needs a certain adaptation for the user. In order to be able to attribute points of views or annotations to document zones, the use has to read documents on the screen of a computer. This implies a change of reading habits especially for long documents. Before, users were used to print long documents on paper format in order to read it. Using the electronic format for reading does not give the same possibilities for handling a document as handling it in printed format.

There is no minimal limit for creating a document zone. User could even mark one single letter and create a document zone. Therefore, it could be possible that users create many small document zones. This could lead to an information overflow of document zones.

5.6.3 THE SHIFT FROM ORAL TO WRITTEN COMMUNICATION

"The implicit and indirect exchanges are often more important than the explicit communications." (Connexion, 1994). With the possibility to attribute and share points of views and annotations with other users, the communication among user becomes a written communication. The actual culture in enterprises implies a sort of an importance hierarchy according to how information is transferred and communicated. Therefore, people tend to associate less importance to information when it is orally communicated.

One problem the users encounter concerns of what the user should write and what he should keep for oral communications.

Users could confront other users could with their own remarks. If people write information down and especially ideas or argumentations about other information content, they take the risk to get open critics about their work and their ideas.

This might imply that people are more reluctant to publish information. However, the user of our prototype has the possibility to avoid the publication of his annotations: he can create non-shared research themes and structure information content and annotations according to these themes.

5.6.4 MULTI-VIEW ACCESS AND REPRESENTATION

One advantage of the A.N.I.T.A. tool is that the researcher gets a dynamic access to documents but also to document zones. As the researcher works with an important number of documents which can be sometimes significantly long, the access to zones is necessary. The content of a document can have several zones which might represent different interests for given or future research activities.

The cross-structured representation of the available information according to the different points of views can provide a decision support for the researcher and the research manager. They can see the status of available information for a given or future research objective. This representation can provoke reactions in order to deepen certain activities.

5.6.5 Pre-coordinate structuring versus post-coordinate full text search

Document indexing and search can be implemented through pre-coordination or post-coordination. In pre-coordination, the documents are associated with content description items and interest field descriptors. Post-coordination is so named because the key-words are combined at search time. There are no content description items or interest field descriptors specified a priori.

Organizations usually resort to post-coordination or full-text search and impose no vocabulary control. However, in standard web-based full text search, we encounter problems such as homonym, where words mean different things in different contexts, lowering precision.

Therefore, our solution proposition favors the pre-coordinate structuring as the researcher adds points of views and annotations manually to the information re-accessing or sharing the information.

Pre-coordination implements a centralized ontology (Ginsburg and Kambil, 1999), but we have seen, the effort to set up an ontology (in our case the knowledge typology) and classify documents or zones of documents is manually intensive. As the document base grows, it becomes difficult and expensive to adapt new knowledge types or research environments descriptions and reconcile classifications to suit the interests of many different users..

5.6.6 Ontological framework – the question of an exhaustive description

Every research is an expert on a certain research field. However, it is possible to group researchers under research domains where the research activities show a certain coherence. This makes it possible to elaborate an ontology for research domains and research activities.

During the elaboration of the ontology and the testing of the A.N.I.T.A. tool we realized that some users found the ontology not "deep" (detailed) enough and other users found the ontology too detailed. This had a relevant consequence for the use. Some users used the different points of views differently to structure similar information content.

However, this was not a general problem. As the ontology was based on a certain consensus among a group of researchers, most of the information content was structured with similar attributes.

The introduction of the concepts of aboutness and relevance helped to give the ontology a certain orientation. The researchers had the possibility to structure their written information content according to a resource point of view and according to an activity point of view.

5.6.7 Capitalization of "lineage knowledge" and the knowledge maturity – annotations as support for both concepts

It is possible to make a link between the concept of annotations and our form of realization, and the concepts of lineage knowledge and knowledge maturity.

5.6.7.1 Annotations to capture lineage knowledge

Annotations constitute in fact a direct link to the concept of lineage knowledge as discussed in section 2.8.2. As we link annotations strictly to documents or document zones, the researcher has the possibility to explicit new knowledge which is in relation with existing information. Especially for the description of new ideas which are linked to an existing information content, we can talk about lineage knowledge.

These new ideas could lead to new research interests and therefore to new research activities. The lineage knowledge captured in annotations can therefore lead to lineage research activities. However, the practical exploitation of annotations in order to identify new lineage research activities might need further support.

Already at the beginning of our study we identified lineage knowledge in minutes of meetings. In minutes the researchers made sometimes new propositions or transcribed new ideas pronounced during meetings. However, it was difficult to analyze the minutes for this lineage knowledge. Our prototype allows further structural elements in order to make this analysis possible. However, further tests, especially over a longer period, need to be done in order to support this argumentation.

5.6.7.2 Annotations as a mean to support knowledge maturity progress

Researchers can react on expressed ideas or argumentations via annotations. This can lead to a certain form of discussion. This discussion is linked to certain information content. The information content and the accompanying discussion can lead through the three research process phases investigate, focus and deploy.

This can in fact lead to a certain knowledge maturity progress of the researcher towards his external environment. Annotations can constitute a mean, to support this progress. As researchers might argue about special information content and this throughout the different research process phases, researchers might learn from each other in a special way as their argumentation is linked to existing information content.

5.7 CONCLUSION

In this chapter we presented and discussed the realization of a prototype, named A.N.I.T.A. tool. It is based on the architectural framework proposed in chapter four. The prototype supports different knowledge and information relevant activities and this in the different research process phases. It focuses on a better management and exploitation of written information content.

The architecture uses the shared ontology elaborated in section 4.2.3. This allows to improve a better information sharing among researchers.

As the A.N.I.T.A. tool supports the architectural framework as well as certain functions of the functional analysis, it supports also to a certain extent the emergence of common practices. Common practices allow a better communication and information exchange among the researchers. The consequences are better learning processes and an improvement for the knowledge production process.

In terms of use, the A.N.I.T.A. tool is relatively easy (improvements need to be done) to manipulate. Technically, it is based on XML which will allow to link the prototype with other tools using this technology. As we can distinguish between three independent modules, where two were realized, which are only linked with the construction and exploitation of XML files, we could use the modules and adapt them for other tools dealing with similar problems.

As we work with only one single document format (PDF format) the attribution of points of views and annotations on documents and even document zones is relatively easy. The access and visualization module provides a certain dynamic to represent written information content. Therefore, the researcher has still the possibility to use the prototype to his individual convenient based on shared aspects among the researcher community.

In order to complete the prototype specification, the assembling module needs to be developed.

6 SYNTHESIS AND PERSPECTIVES

6.1 INTRODUCTION

In this chapter we will synthesize our results and give perspectives for further research works. We will give a synthetic overview about the general framework architecture and the A.N.I.T.A. tool proposition. The synthesis includes an analysis about cultural aspects and their link with the use of the A.N.I.T.A. tool. In a second part of this chapter, we will discuss some perspectives for further research.

6.2 A GENERAL KNOWLEDGE AND INFORMATION MANAGEMENT RELEVANT FRAMEWORK ARCHITECTURE FOR AN INDUSTRIAL RESEARCH CENTER

A major result of this work is the proposition and use of a general knowledge and information management relevant framework architecture for an industrial research center. This framework is based on a detailed literature analysis concerning knowledge management and industrial research as well as a field analysis of the existing activities, organizational aspects and practices.

The general framework takes into account important aspects, characterizing the context of an industrial research center. This constitutes a first pillar for our framework:

- The customer structure: the customer is usually well identified for an industrial research center. The major customers come from the operational units of the industrial group to which the research center belongs. The well-defined customer structure defines the research product.
- The research product: in difference to academic research, industrial research has to produce results often directly usable by the operational units. Central to the research product stays the new innovative concept model. However, the concept often needs to be illustrated with a prototype in order to verify its validity and in order to gain implementation knowledge.
- The resource structure: in order to produce new research results and products, the researcher uses three major knowledge and information resources:
  - The external environment comprising technology suppliers, academic and other industrial laboratories and other industrial partners. The external environment constitutes an important resource for information concerning new concepts, methods, tools, needs, etc.

  - The operational unit environment as an important resource for new research needs.
  - The internal environment comprising the internal research center environment as resource for new solutions and validation feedback.
- Production process structure: the production process structure describes the different activities and practices of the researcher leading to the assembling of new research products and the creation of new knowledge.
- The organizational structure of the research activities: the organizational structure concerns for example the organization of the researchers in competence centers and the research activities in research projects. Other structural elements can concern the structure of document formats, reporting procedures, etc. In our special use case, one of the research centers had an ISO certification.

These different aspects are linked to each other. They constitute at the same time to a certain extent a resource for common practices among researchers.

The context of industrial research involves intensive information and knowledge flows. The researcher uses existing information and knowledge in order to produce in new knowledge. To support these flows and the different practices and activities for an improvement of the research result production process, concepts, methods and technologies coming from the field of knowledge management could play an important role.

In this work, we merged some concepts of knowledge management with the context of industrial research activities. Therefore, the second pillar of our framework constitutes of a cycle model of knowledge management relevant activities based on theoretical knowledge management models. This cycle model supports the relevant activities to manage and exploit information and knowledge.

In order to be able to characterize the content of this information and knowledge, we introduced a shared ontology. This ontology helps to structure information content and represents the third pillar of our model.

As researchers have to manage, exploit and produce a lot of written information, we deepened the concept of the shared ontology in order to be able to describe and improve the use of written information content: we used the concept of aboutness and relevance. We therefore developed an ontology for industrial research activities.

With the different concepts described in the three pillars of the framework, we used part of the CIMOSA structure in order to propose a three-layer framework (see Figure 6.1).

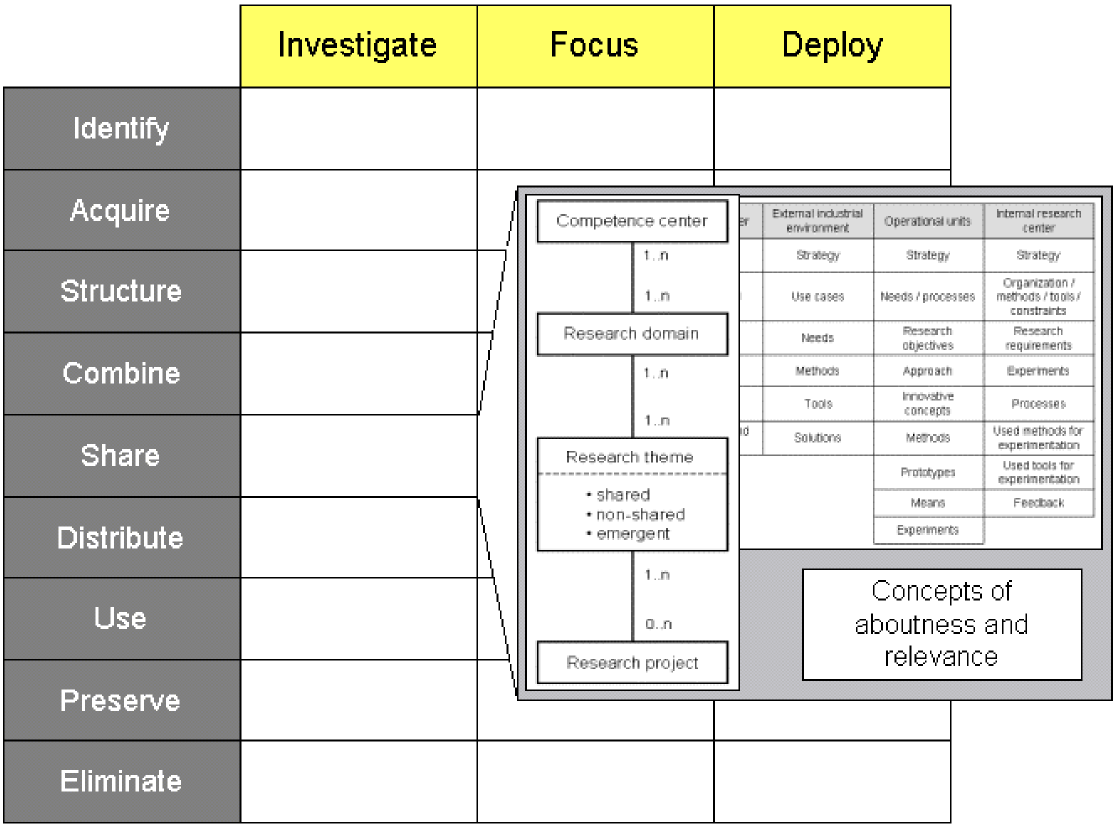

Figure 6.1 - General knowledge and information management relevant framework architecture for an industrial research center – a synthesis

This framework allows to structure and analyze existing practices, methods and used tools but also helps to structure the needs of an industrial researcher concerning the activities in this framework. We used the framework to make these analyses and identified crucial needs to improve the management and exploitation of written information content.

This leads us to a prototype proposition, specification and realization. The A.N.I.T.A. tool, based on the framework and therefore based on research activity structures, common practices, shared ontology, etc., supports in particular certain activities for written information content (especially for document zones) (Figure 6.2):

	Investigate	Focus	Deploy
Identify		Access and visualization	Access and visualization
Acquire			
Structure	Attribution points of views	Attribution points of views	Attribution points of views
Combine	Visualization, annotation, assembling	Visualization, annotation, assembling	Visualization, annotation, assembling
Share	Annotation and access	Annotation and access	Annotation and access
Distribute			
Use	Assembling	Assembling	Assembling
Preserve	Attribution points of views	Attribution points of views	Attribution points of views
Eliminate			

Figure 6.2 – Contribution of A.N.I.T.A. tool to general framework architecture

- The re-identification and re-access functions for already structured information from the previous research process phases,
- Structuring functions with points of views (shared ontology),
- The combination with the help of annotation, visualization and assembling functions,
- The sharing with the help of annotation and access (according shared ontology) functions,
- The using of information content to produce new research results with assembling functions,
- Facilitate preserving based on structuring functions with points of views.

The shared ontology with the concepts of aboutness and relevance supports the management and exploitation of information content according to the different research process phases.

The use and validation of the A.N.I.T.A. tool with researchers showed, that the different functions correspond to the user needs structured with the framework architecture. However, as the practices and activities of the researcher as individual and as acting in a group are very complex, it would be impossible to say that the solution corresponds to every need. We only can make a general statement based on the validation feedback. It is important to mention that this framework constitutes only one point of view for structuring industrial research. Other structures might be possible and could be the objective for further research on the subject.

6.3 CONCLUSION ON CULTURAL ASPECTS – SOME PRACTICAL EXPERIENCES

Our thesis took place in departments of two research centers in two different countries: France and Germany. Therefore, we included a study concerning possible knowledge management relevant differences between different cultures. We analyzed the possible effects on our general architectural framework and prototype proposition.

In section 1.5, we discussed some cultural differences from a literature point of view. We focused on knowledge identification, knowledge development and knowledge sharing and transfer. The analysis concerning these points included a more general analysis concerning the differences and common aspects between the two departments.

The comparative analysis shows that the organization and structure of research projects is similar. The different steps include the same activities and similar document structures. At the end of a research project, both sides have similar forms representing their research results. During the research projects, both sides hold review meetings which are documented with minutes of meetings and presentations. Even if the German side does not have an ISO 9000 certification, processes and structures of the research projects are similar.

Concerning the research result production, the focus lies on the elaboration of new information technology and systems engineering concepts which are validated and simulated with prototypes. As the research domains are similar, both sides have similar information and knowledge resources and networks.

As both sides have a similar project organization and structure, their practices are also similar. This includes the use of internal and external information resources as well as the support to acquire the information. Therefore, from our point of view, it was possible to propose the same solution propositions for both sides.

Concerning the global framework architecture, there were no significant cultural differences. However, for the use of the A.N.I.T.A. tool, we observed some differences. The differences were mainly based on the aspects of low-context or high-context knowledge transfer as described with the corresponding concept in section 1.5.

On the German side, the attribution of points of views was more exhaustive. German researchers used more points of views in order to describe a written information content. Furthermore, the annotations are longer and more detailed. The French side used fewer points of views to describe an information and annotations were shorter. This could confirm the fact that the German culture belongs to the low-context knowledge transfer side and the French culture to the high-context knowledge transfer side. However, these differences did not affect the use of the prototype as the users among one team had the same cultural background.

We did not make an experimentation with teams including French and German researchers. Therefore, we cannot make a conclusion on a negative or positive effect concerning these differences. Furthermore, these differences are observations and need to be deepened in order to make further conclusion of the use of the prototype in multi-cultural teams. However, we think that a use in mixed teams is not only possible but can favor the information exchange between the team members. This could be examined in future research work and being part of the perspectives of this thesis.

6.4 PERSPECTIVES

The experimentation of the architectural framework and of the A.N.I.T.A. tool leads to the conclusion that the different propositions correspond to a great extent to the expressed needs. On the one side, we structured the different practices, activities, organizational frameworks, etc. to an overall framework for industrial research activities. On the other side, based on this framework, we provide means for the management and exploitation of written information content supporting the researchers in their daily activities. However, at least six major themes emerged for potential further discussion and even research work:

1. Application of the general framework architecture and A.N.I.T.A. tool in other domains:

   The framework architecture and the A.N.I.T.A. tool have been experimented mainly in IT research domains. However, an adaptation to other domains is possible. Concerning other domains, we can make the distinction between other industrial research domains, academic research structures, and other industrial environments.

   – Other industrial research domains: other industrial research domains might have other research result development cycles. For example for material research or structural research, development cycles can be longer. This might imply different activities and practices. The research process framework and the activity framework of the general framework architecture might be relatively stable for the different industrial research domains. However, it might be necessary to elaborate additional or other elements concerning the shared ontology framework: as the domain is different, the information content structure will be different. An interesting question here could be: to what extend an ontology varies according to the research domain or is the proposed ontology general enough to be applied for all research domains?

     Concerning the use of the A.N.I.T.A. tool, a change of the general framework will have influences on the prototype, especially on the fixed points of views. Another aspect concerns the possible use of the A.N.I.T.A. tool in other industrial research domains. Other research activities might change the identified practices of section 3.4. Changed practices might influence the management and exploitation of written information content and therefore changes the use of the A.N.I.T.A. tool. In the field of material research, there is for example a lot of experimentation with new materials. Measurement results in different formats are analyzed in order to make conclusions. The different activities and content structures of written information might therefore influence the use.

   – Academic research: academic research activities are less oriented towards concrete industrial needs (operational unit needs for industrial research). Therefore, certain research activities and the research products are different. One objective of academic research activities is to publish new research results. The objective of industrial research activities is more oriented towards solution production for operational unit requirements. The differences between industrial and academic research activities might influence the general framework architecture. For example for the research process framework, the deploy phase might be less important for academic research then for industrial research. Furthermore, knowledge and information resources might be different. This might have an influence on the shared ontology among academic researchers. Therefore, further research activities could deal with the elaboration of a general framework for academic research and the comparison between industrial and academic.

Concerning the use of the A.N.I.T.A. tool for the academic research environment, we think that it is especially necessary to adapt the shared ontology. The different focus on the research products (strong focus on publications for academic research) might also play a role for the use of the A.N.I.T.A. tool.

- Other industrial activity domains: The general framework architecture might be applicable for other industrial activity domains. However, we think that the framework is limited to activity domains dealing with innovative development cycles (design office, etc.). The process framework might vary according to the different tasks of the different teams. As for other research domains, we think that there is the need to review the proposed shared ontology and to adapt it to the existing environment. However, there might be further research necessary in order to adapt the overall framework architecture.

  Concerning the A.N.I.T.A. tool proposition, we think that there is less adaptation necessary. The basic tool functions like attributing points of views, annotations, visualization, could be used for in several contexts where people work together on similar problem environments. However, a further analysis might be necessary in order to confirm or reject this assumption. At least an adaptation of the shared ontology might be necessary.

  We think that our approach can be used in a more generic context since we used the CIMOSA framework for the framework architecture. Consequently, the functions of the tools will remain as proposed. Only the shared ontology needs to be adapted to the specific activity domain of the users.

2. Use of A.N.I.T.A. tool in large teams:

   The experimentation of the A.N.I.T.A. tool took place in a small group of industrial researchers (five people). The participants knew each other and they were working on similar or same research projects. In a perspective of generalization, it would be necessary to study the constraints of a use in large teams (several tens or hundreds of people). Is the A.N.I.T.A. tool applicable for large teams? If this is the case, what are the necessary modifications? We think that in large teams there exist a larger diversity of job functions, practices and objectives. Therefore this might have an influence on the different functions as well as on the constitution of a large shared ontology. A large ontology might cause problems for the attribution of points of views. The users would have a large choice between different attributes which could have an impact on a shared information content structure (different use of different attributes could have an impact on information retrieval). Furthermore, it would be necessary to examine the impact of the possibility to create document zones in large teams as more information items might be available for retrieval and visualization. Does the creation of document zones influences the use of the tool in large teams?

   The question of the use in large teams could include an experimentation in large multi-cultural teams. This could include the study of cultural influences in the use of the prototype.

3. Integration of the A.N.I.T.A. tool in existing tool environment:

   An integration of the A.N.I.T.A. tool in existing tool environments could provide additional functions for the users. As the chosen technology of the A.N.I.T.A. tool is very flexible (XML based), interfaces are probably easy to create and to adapt to other tool environments. XML is here the key technology which is also used by more and more other tools. The tool could be integrated in environments, where people have to manage and exploit an important quantity of written information content. We see three main tool environments for our prototype:

- Collaborative tool environment: the A.N.I.T.A. tool could play an important role for information exchange based on the shared ontology. Functions like forums, chats, etc. could have an interface with our prototype proposition.
- Document management: the A.N.I.T.A. tool proposition could be integrated in a document management system. The document management system could manage the documents from an administrative point of view whereas the tool could support the exploitation of the document content of the stored documents in the document management system.
- Portal solution: the A.N.I.T.A. tool could be part of a knowledge management portal solution. There could be several links to different functions of the portal solution. The role of the A.N.I.T.A. tool could be the exploitation of the information content which would be integrated in the portal.

Other links with other tool environments are certainly possible.

4. Use of new information technologies:

   Certain new information technologies could play a significant role for a support of the different functions of the A.N.I.T.A. tool:

   - An automatic content analysis could support the users with the proposition of points of views according to the information content. This is in fact an index proposition based on content analysis. The user could mark a document zone and the system proposes him a selection of points of views to describe the information content (concept of aboutness).
   - The analysis of information content and the analysis of the attribution of points of views could help to bring people automatically together having similar interests. This automatic analysis could be based on user profiles.
   - In stead of written annotations, the user could make oral annotations. These oral annotations could be transcribed into written annotations. Therefore, there would be the need for an integration of a transcription module into the annotation module of the prototype. Oral annotations could reduce the barrier to write annotations (time consuming).
   - Computers with interactive screens where the user has the possibility to select document zones manually and makes hand written annotations (without typing). This could be a significant support for the attribution of points of views and annotations as it would correspond to the actual practices with information in paper format.

   The above list of technologies is not exhaustive. Other technologies could play an important support for the prototype.

5. Support for strategy definition:

   Research managers have to participate to the strategy definition of an industrial research center. This strategy definition is based in the information the research manager has in order to get an impression, where the research centers stand according to the external environment and to the needs of the operational units and what is coming up to the research center. As the researchers characterize the information content with points of views, the research managers could use this characterization for their strategy definition. The information visualization module with its cross structured representation could be helpful to analyze the existing information content according to the needs of the research managers.

According to our ontology, the researchers can characterize information content according to the needs of the operational units, new external concepts and technologies, etc. With the cross-structured information content visualization, the researcher manager could see, how much information is available concerning the needs for certain research objectives or how much information is available concerning new technologies for certain research objectives. In fact, the research manager crosses information content structured according to the concept of aboutness with information content structured according the concept of relevance.

However, the question here could be, to what extent the prototype proposition supports decision making for research managers? What are supplementary features to support decision making based on information content analysis? What are the risks for decision making? What are the benefits of the use of the prototype?

6. Analyze ROI (Return On Investment):

   An analysis about ROI calculations could concern the examination about a better and more effective knowledge production. This examination could include an analysis of the quality of the research products such as research reports. The question could be: does the tool A.N.I.T.A. contribute to a better quality of research results. Another aspect of ROI analysis could also concern aspects about user satisfaction or more general satisfaction concerning a better handling of written information content.

This list of six themes is not exhaustive. But these are themes and reflections which could be interesting to take into account for further experimentation and further development.

7 GENERAL CONCLUSION

Knowledge management can support various activities in industrial organizations. Especially activities, which can be characterized with intensive knowledge and information flows, can be of interest for a knowledge management support. Industrial research activities of an industrial researcher center, being part of an industrial group, belong to the sort of activities with intensive knowledge and information flows.

One major objective of the industrial research center is to produce new research results for a direct application in the operational units. The research results consist in fact of new knowledge: new knowledge models (concepts) accompanied with experimentation knowledge and implementation knowledge. In order to produce new research results, the industrial researcher uses knowledge and information from various resources: external, internal and operational unit resources. In order to structure and optimize the knowledge and information flows and the exploitation of existing knowledge and information resources we propose a general framework architecture for industrial researcher processes. This proposition is based on an analysis of the industrial research center structure and organizational elements as well as an analysis the different common practices, existing technical support, and different activities among the researchers.

We used part of the CIMOSA model to structure the general framework architecture. The architecture is based on three layers:

- The general objective oriented research process framework describing the research activity as a research process in three phases: investigate, focus and deploy.
- The general activity management framework describing the principle knowledge and information relevant activities based on conceptual knowledge management models.
- The resource element content knowledge typology and the research activity content structure describing a shared ontology among the researchers based on the theoretical concepts of aboutness and relevance.

The framework architecture allows to structure the different analyzed needs for a better knowledge and information management and exploitation. We also used the framework architecture to structure the existing and used tools, and the possible tool structure with available operational tools. This analysis showed that actual tools do not support sufficiently the management and exploitation of written information content for the context of industrial research activities.

Therefore we propose A.N.I.T.A. (annotation tool for industrial teams), based on the general framework architecture, supporting researchers with functions to identify, structure, combine, share, use and preserve written information content. The A.N.I.T.A. tool proposition includes three different modules:

- An attribution of points of views (based on the shared ontology) and annotation module. The attribution is possible for documents and document zones.

- An access and visualization module.
- An analyzing and assembling module.

The A.N.I.T.A. tool responds to the needs and supports the different individual practices of the researchers and the emergence of common practices shared among the researcher. Besides the different practices, it supports the capitalization of lineage knowledge and the active tracking of the knowledge maturity process. The experimentation showed that it can be used in a multi-cultural environment.

The results of this thesis could lead to further research in order to extent the approaches to other research domains or other industrial domains. Therefore, the results could be used as basis for other projects working on one or several themes identified in the perspectives:

- Application of the general framework architecture and A.N.I.T.A. tool in other domains.
- Use of the A.N.I.T.A. tool for large teams.
- Integration of the A.N.I.T.A. tool in exiting tool environment.
- Use of new information technologies.
- Support for strategy definition.
- Analysis of ROI results.

These different themes could be considered from different points of views: from an information technology point of view, an organizational science point of view, an ergonomic point of view, etc. We therefore suggest to work on the different themes with a multi-disciplinary team covering these different aspects. Besides continuing the research work of this these, such a team could use the approach and A.N.I.T.A. for their own purpose in order to manage their written information content.

APPENDIX

A.1 KNOWLEDGE MANAGEMENT MODELS

We distinguish between holistic knowledge management models and explanatory knowledge management frameworks.

A.1.1 HOLISTIC KNOWLEDGE MANAGEMENT MODELS

The models are discussed in a chronological order. This order gives also a short impression about the development of the different knowledge management frameworks during the last decade.

- The framework of knowledge management pillars:

  Wiig's (Wiig, 1993) knowledge management framework involves what he calls the three knowledge management pillars. These pillars represent the major functions needed to manage knowledge. As shown in Figure A.1 the pillars are based on a broad understanding of knowledge creation, manifestation, use, and transfer. Pillar one is concerned with exploring knowledge and its adequacy. The framework identifies several components of this function – survey and categorize knowledge; analyze knowledge and knowledge related activities; elicit, codify, and organize knowledge. Pillar two involves appraising and evaluating the value of knowledge and knowledge-related activities. The third pillar focuses on governing knowledge management activity. This function has three components – synthesize knowledge-related activities; handle, use, and control knowledge; and leverage distribute, and automate knowledge. The three pillars are built on a knowledge management foundation which constitutes the broad understanding of knowledge.

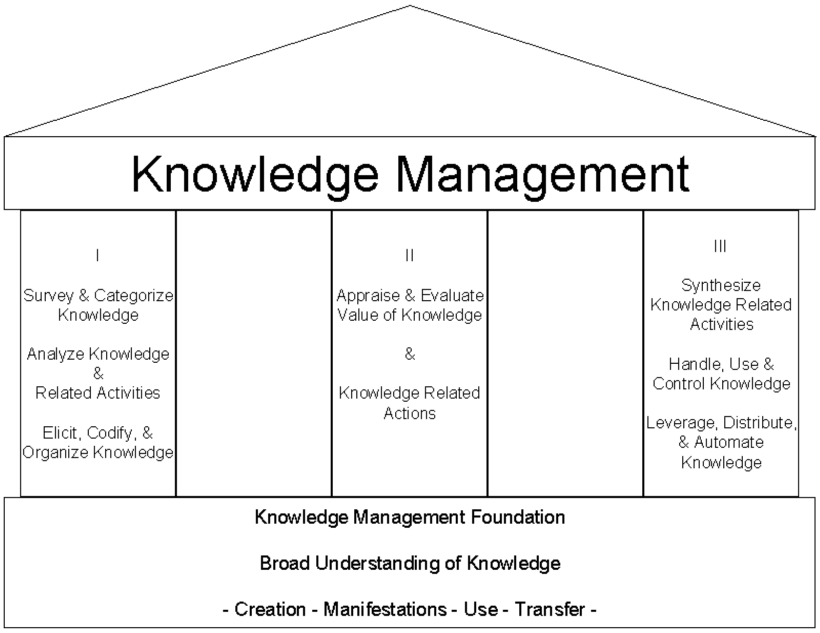

Figure A.1 – Pillars of knowledge management according to Wiig

- Framework of core capabilities and knowledge building:

  Leonard-Barton (Leonard-Barton, 1995) has introduced a knowledge management framework including four core capabilities and four knowledge building activities. As Figure A.2 shows, there are four knowledge-building activities that surround the core capabilities. The knowledge-building activities are: shared and creative problem solving (to produce current products), implementing and integrating new methodologies and tools (to enhance internal operations), experimenting and prototyping (to build capabilities for the future), and importing and absorbing technologies from outside of the firm's knowledge. These are knowledge creating and diffusing activities.

  According to Leonard-Barton, the core capabilities "constitute a competitive advantage for the firm: they have been built up over time and cannot be easily imitated" (Leonard-Barton, 1995). The four core capabilities in this framework are physical systems (competencies accumulated in material systems that are built over time such as databases, machinery, software), employee knowledge and skills, managerial systems (organized routines directing resources accumulating and deployment creating the channels through which knowledge is accessed and flows (for example education, reward, and incentive systems)), and the organization's values and norms.

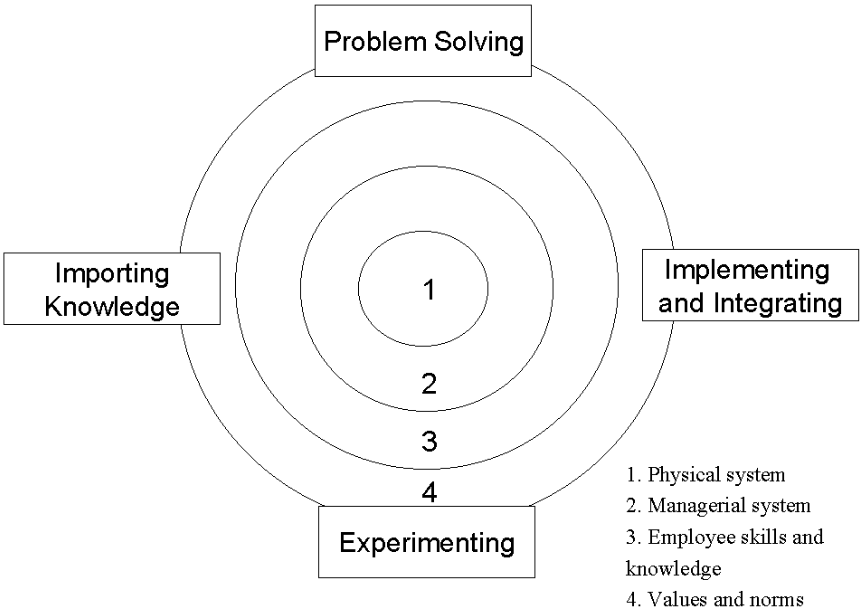

Figure A.2 – Core capabilities and knowledge building according to Leonard-Barton

- Model and organizational knowledge management:

  Arthur Andersen and APQC (APQC and Arthur Andersen, 1996), propose a model including seven knowledge management processes that can operate on an organization's knowledge. As illustrated in Figure A.3 these processes or also described as activities are create, identify, collect, adapt, organize, apply, and share. The nature of the organizational knowledge that they handle in these activities is not characterized. The model identifies four organizational enablers that facilitate the workings of the knowledge management activities: leadership, measurement, culture, and technology. The model does not detail these enablers anymore.

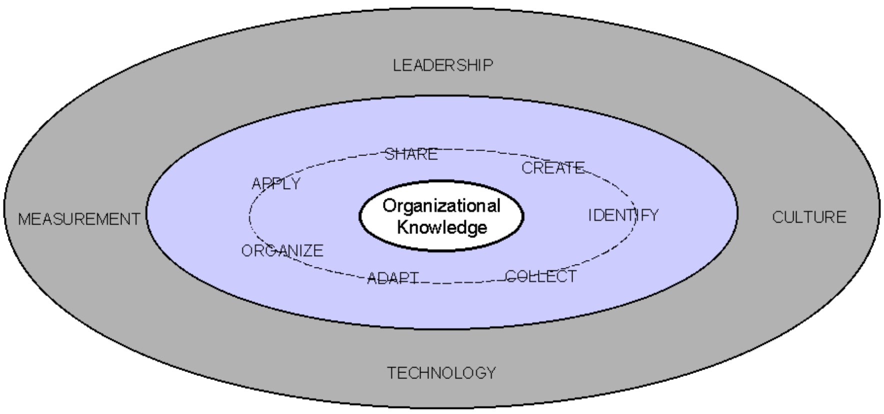

Figure A.3 – Model of organizational knowledge management according to Arthur Andersen and APCQ

- Framework of the knowing organization:

According to the “knowing organization framework” presented by Choo (Choo, 1996), an organization uses information strategically for sensemaking, knowledge creation, and decision making (Figure A.4). These three processes are “linked as a continuum of nested information activities that define an organization which posses the information and knowledge to act intelligently” (Choo, 1996). The model uses the terms “knowledge” and “information” without clarifying the distinction between them.

During sensemaking, an organization tries to make sense of its changing environment. This process is concerned with understanding how people in the organization interpret information in order to cope with environmental uncertainty. During knowledge creation, an organization creates new knowledge in the course of innovation. This process is concerned with understanding how information is transformed into new knowledge in an organization. The model views decision making as a process concerned with understanding how organization processes information to resolve task uncertainty.

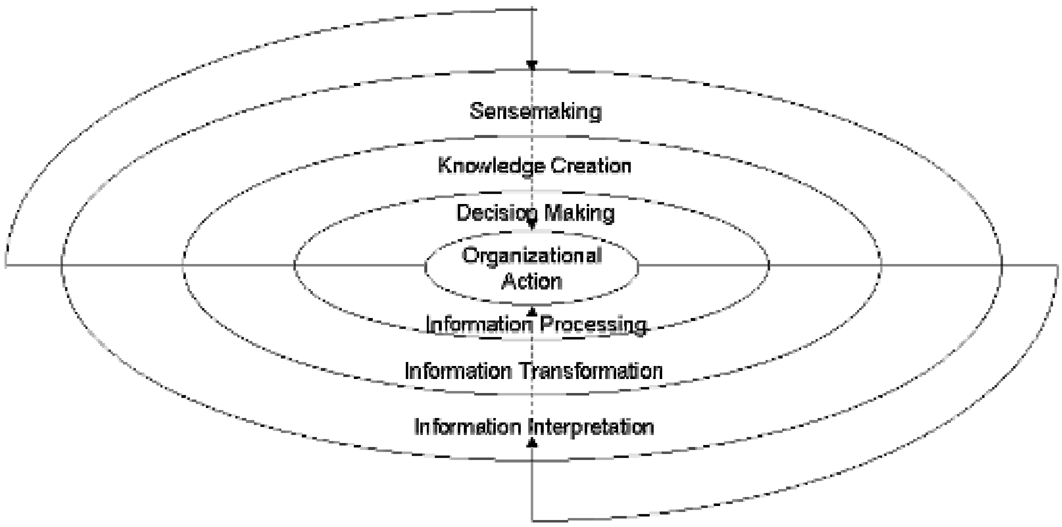

Figure A.4 – Framework of knowing organization according to Choo

- Framework knowledge management media reference model:

Eppler (Eppler, and Sukowski, 2001) introduces a knowledge cycle describing different knowledge management activities and four different enabler views for these activities. The knowledge cycle activities concern the identification, the evaluation, the allocation and the application of knowledge. These activities are supported by the four different views: the community view, the implementation view, the services view and the infrastructure view (Figure A.5).

The different views are related with each other. The community view describes communities of experts creating and sharing experiences, insights and new concepts. The implementation view describes know-how –intensive processes and projects in which the community members apply their skills. The services view describe the means which enable the interaction of the members in communities. The services here are: content management-, collaboration-, retrieval-, aggregation-, and visualization-services. The infrastructure view provides the necessary infrastructure to support the functioning of the service view.

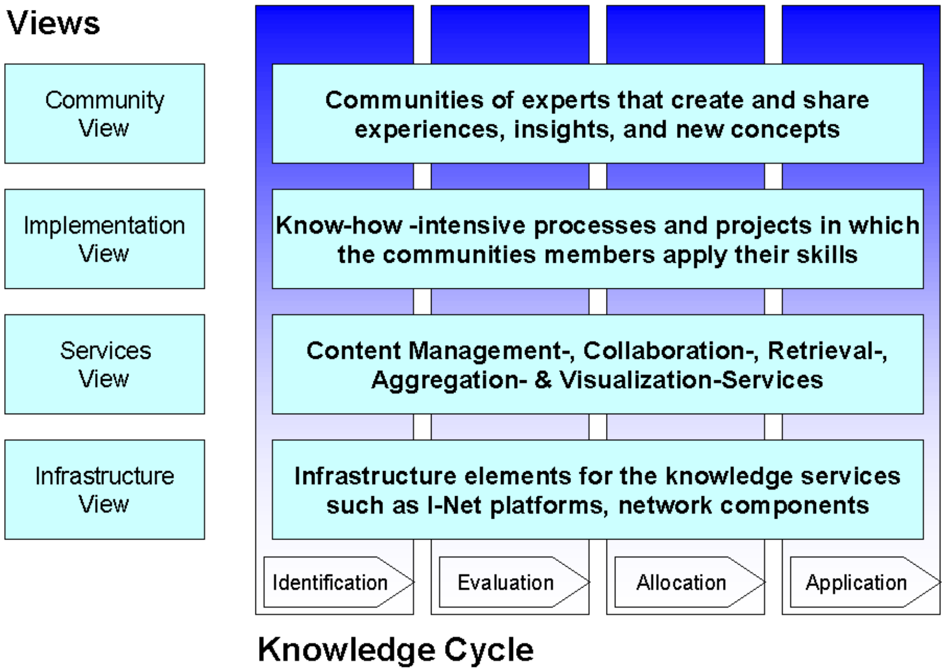

Figure A.5 – Knowledge management media reference model

A.1.2 EXPLANATORY KNOWLEDGE MANAGEMENT MODEL FRAMEWORKS

Besides the broad descriptive frameworks, the literature also contains some specialized descriptive frameworks. The following frameworks represent an overview of the variety of the existing frameworks.

- Framework of intangible assets:

  Sveiby (Sveiby, 1997) describes the notion of organizational knowledge as intangible assets. The framework describes three components: external structures, internal structures, and employee competence (Figure A.6). External structures include customer and supplier relationships, brand names, trademarks, and the company's image. Internal structures includes patents, concepts, models, computer and administrative systems, and organizational culture. Employee competence consists of skills and knowledge bases of individuals within an organization. Employees use their skills and knowledge base to act in a wide variety of situations in order to create tangible or intangible assets. When the employees' competencies are directed toward entities outside of the organization, then they are considered to yield external structures; if those efforts are directed inward, then they are considered to create internal structures.

Figure A.6 – Framework for intangible assets according to Sveiby

- Framework of knowledge conversion:

  Nonaka proposes a model which focuses on knowledge creation (Nonaka, 1994), (Nonaka and Takeuchi, 1995), (Nonaka and Konno, 1998) by converting existing knowledge (Figure A.7). The SECI (Socialization, Externalization, Combination, Internalization) model incorporates the following: two forms of knowledge (tacit and explicit), an interaction dynamic (transfer), three levels of social aggregation (individual, group, context), and four "knowledge creating" processes (socialization, externalization, combination and internalization).

  This is realized through systems and structures, and a corporate culture, which facilitate the interaction of the four following knowledge-creating processes:

  - Socialization: the sharing of tacit knowledge between individuals through joint activities, physical proximity.
  - Externalization: the expression of tacit knowledge in publicly comprehensible forms.
  - Combination: the conversion of explicit knowledge into more complex sets of explicit knowledge: communication, publication, systematization of explicit knowledge.
  - Internalization: the conversion of externalized knowledge into tacit knowledge on an individual or organizational scale. The embodiment of explicit knowledge into actions, practices, processes and strategic initiatives.

  Nonaka proposes that the spiral resulting from the exchange of tacit and explicit knowledge across different organizational levels is the key to knowledge creation and re-creation. The next figure illustrates these aspects.

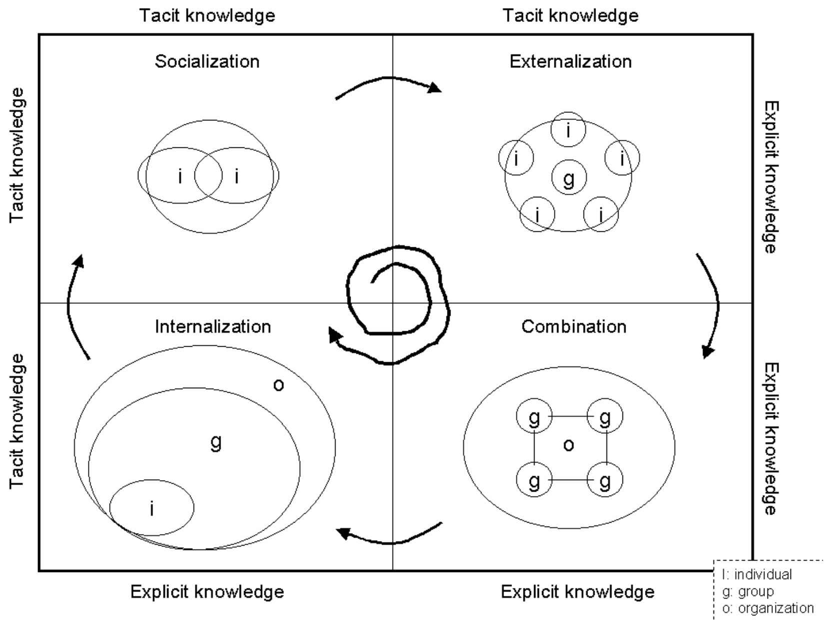

Figure A.7 – The SECI model according to Nonaka

To this model, Nonaka added the concept of Ba (Nonaka and Konno, 1998) which relates to the English concept of place. With Ba, Nonaka points out the fact that knowledge is context-dependent: it cannot be separated from its "place" in any meaningful way.

- The model of knowledge transfer:

  Szulanski (Szulanski, 1996) proposes a model for analyzing internal "stickiness" of knowledge transfer. Internal stickiness means the difficulty of transferring knowledge within an organization. The framework identifies four stages related to knowledge transfer: initiation, implementation, ramp-up, and integration. It also identifies four factors that have an impact on the difficulties of knowledge transfer: characteristics of knowledge transfer (causal ambiguity and unproveness), characteristics of the source of knowledge (lack of motivation and perceived unreliability), characteristics of the recipient of knowledge (lack of motivation, lack of absorptive capacity, and lack of retentive capacity), and characteristics of the context (barren organizational context and arduous relationship).

  The initiation stage is comprised of all events that lead to the decision to transfer. The implementation stage begins once a decision to transfer needed knowledge is taken. In this stage, the knowledge resources flow between the source and the recipient. During this phase, social aspects are developed between the source and the recipient and the transfer is adapted to the needs of the recipient. These activities terminate once the recipient starts using the received knowledge. In the ramp-up stage a recipient starts sing the received knowledge. The recipient tries to identify and resolve unexpected problems that arise during using the new knowledge. In the integration stage, transferred knowledge gradually becomes routinized and institutionalized.

- The knowledge management process cycle model:

  Romhardt (Romhardt, 1998) proposes a knowledge management process cycle model with "building blocks" for core knowledge management activities. He distinguishes between a control process and a core process. The control process guides the activities of the core process. The knowledge management process starts with the definition of objectives of knowledge in the core process. These activities initiate the activities of the core process. The definition is followed by the identification building block. The identification of knowledge helps an organization to get transparence about existing internal and external knowledge. The acquisition of knowledge describes the importation of knowledge from resources which are located in the external environment of an organization. The development of knowledge focalizes on the creation of new non-existent internal or external knowledge or capabilities. The distribution of knowledge concerns isolated non-accessible knowledge. The objective is to distribute this knowledge in order to make it accessible. The utilization of knowledge concerns the efforts of an organization to assure the usability of knowledge. The preservation of knowledge assures the preservation of critical knowledge or of knowledge necessary for future activities of the organization. The activities of the core process are linked between each other (Figure A.8). For Romhardt it makes no sense to consider the activities separately. The evaluation of knowledge is the last activity of the knowledge management process cycle model. This activity is part of the control process. The evaluation of knowledge allows to verify if the objectives have been fulfilled.

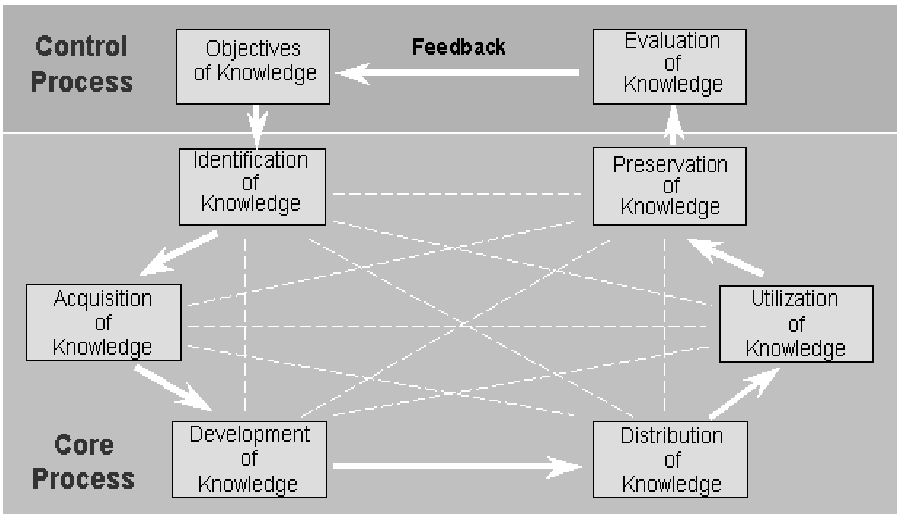

Figure A.8 – Knowledge management process cycle model according to Romhardt

A.2 TECHNICAL SUPPORT TO WORK ON DOCUMENT CONTENT – STRUCTURE INFORMATION CONTENT WITH XML

The content and logical structure of a document was inaccessible with common computer languages. The different formats and structures made it impossible to access the information content of documents or other data. XML has been developed to represent text documents and data. It is a standard language to favor the information exchange on the Internet.

XML (Extensible Markup Language) is a meta-language to describe and distribute on the Internet documents and structured data (Michard, 1999). It is a "light" version of the SGML (Standard Generalized Markup Language) standard, adapted for the Web.

XML allows to describe the structure of a document even if it is very complex. XML can also support the description and programming of data structures described with relations, as objects, graphs, etc.

The structure of a document is described with tags. Contrarily to HTML, the XML tags have no limit in terms of depth. The document structure can be formally specified in a DTD (Document Type Description) or XML schema. Two formalism complete XML: XLink and XPointer to define hypertext links and the paths in a XML document.

XML allows to define the logical structure of a document but does not allow a readable representation of the text. The solution to represent a XML document lies in the style sheet format XSL (Extensible Stylsheet Language). The XSL allows to associate a presentation format to a XML document.

The separation in XML of the logic structure of a document and its presentation allows defining several style sheets being associated to the same document. This allows having different representations modes for the same information. This can be useful if different user with different profiles access the same information. The representation of the information can be adapted to use user profile.

XML's ability to separate content from the presentation characteristics of a document is a key technology to access and manipulate the content of written information in a document. XML is central to content portability, display flexibility and extension of content shelf life.

XML constitutes therefore the technological background to exploit the written information content for knowledge management applications. With XML it is possible to characterize the information content according to ontologies and therefore also according to the concept of aboutness and relevance. As the exploitation and management of information content plays a sgnificant role for knowledge management introduction, XML will play a support role to access the information content in order to make it possible to transfer it into knowledge.

A.3 THE CIMOSA FRAMEWORK

The CIMOSA framework (Vernadat, 1996) supports enterprise modeling in the context of business process reengineering.

The CIMOSA architecture is based on three fundamental modeling principles (see also Figure A.9):

- The derivation principle which proposes to model according to three principle levels:
  - Level expression of the needs which models the needs of the users,
  - Level of concept specifications which transforms the needs of the users in conceptual models. These models should be formal and executable by the firm,
  - Level of detailed descriptions en terms of documentation, resources, operations, etc.
- The instantiation principle which is based on three generic levels:
  - Generic model which describes the used modeling formalism,
  - Partial model which contains model libraries which can be used to elaborate particular models,
  - Particular models, which describe the firm in a detailed level.

- The generation principle which recommends to model the firm according to four principal viewpoints:
  - Organizational view which represents the organizational structure, the hierarchical levels and the responsibilities,
  - Resource view which represent all the means of a firm (material or human), as well as their capacities and their administration,
  - Information view which represents the information necessaries for the functioning of the firm,
  - Function view which represents the functionality and the behavior of the firm en terms of events, activities, procedures and processes.

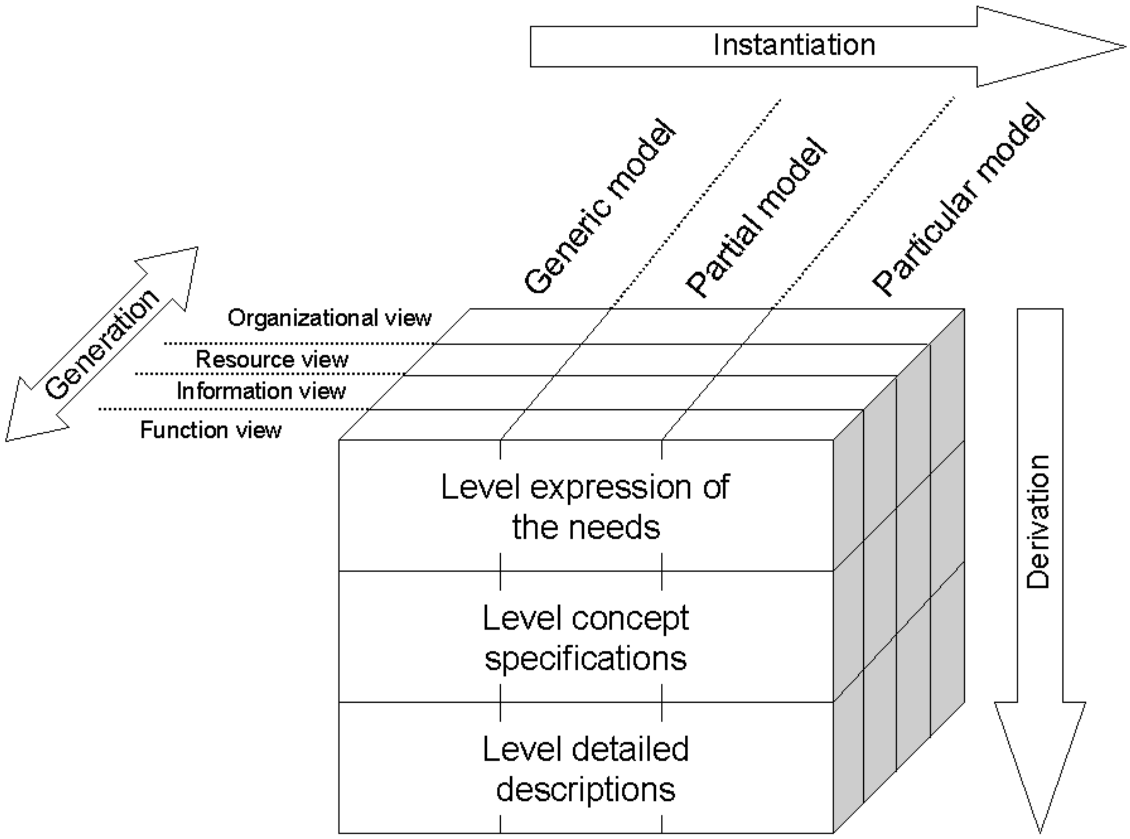

Figure A.9 – Modelling of a firm according to CIMOSA

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