INFORMATION TECHNOLOGY SUPPORT FOR KNOWLEDGE MANAGEMENT IN COOPERATIONS

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Abstract

Cooperative structures of product development and production are gaining more and more importance. In the following paper, we will examine how organizational structures spanning multiple companies influence the use of information technology in knowledge management. We will identify requirements to information technology used for knowledge management in cooperations and evaluate the suitability of the existing software tools. We will point out the major weaknesses of the existing implementations and introduce technical solutions.

Keywords: knowledge management, cooperations, corporate networks, information technology.

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Cooperative structures of product development and production are gaining more and more importance. In the following paper, we will examine how organizational structures spanning multiple companies influence the use of information technology in knowledge management. We will identify requirements to information technology used for knowledge management in cooperations and evaluate the suitability of the existing software tools. We will point out the major weaknesses of the existing implementations and introduce technical solutions.

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Suggested track: L Practitioner's Track

1 Introduction

Very complex goods, such as cars, aircrafts, but also semiconductor technologies are frequently developed in cooperations (such as corporate networks) by several manufacturers in order to reduce the risks and share the high costs. Complex research and development activities usually include knowledge management (KM) activities aiming at an efficient use of know how and intellectual capital. If R&D and production are conducted in cooperations, knowledge management should be extended across the borders of the participating enterprises as well in order to leverage the experience and competencies of the participants. However, the general conditions and structures in cooperations differ significantly from those in integrated enterprises. Differences concerning the organization, the structures of knowledge and the structure of the existing information technology (IT) influence the tools used in knowledge management.

In this context the question arises, whether the information technology used in knowledge management today is up to the challenges posed by these dynamic usage scenarios spanning multiple companies. We will evaluate requirements to the IT-

support for knowledge management based on the characteristics of cooperations. After that, we will systematically examine how far existing tools comply with these requirements. The tools' main deficits will be identified and approaches to alleviate these shortcomings will be pointed out.

2 Specifics of knowledge management in cooperations

From an economic point of view, there are two characteristic features of cooperations: First of all, several market partners are jointly responsible for the creation of a product or service. They have a mutual economic objective and a common creation of value is carried out, which is coordinated by agreements or formal regulations. Secondly, cooperations consist of at least three legally and economically independent enterprises. The economic independence is characterized by the fact that each enterprise accepts individual economic risks, defines its own goals and plans independently. The legal independence, on the other hand, is characterized by a lack of hierarchical control mechanisms and the voluntary nature of the cooperation (Veil and Hess 2002). There are cooperations within enterprises if formally independent subsidies, profit centres or modules cooperate, as well as cooperations between enterprises. They mainly differ in the degree of hierarchical control (high in intra-company cooperations and inter-company cooperations with focal partners, low in networks of equals such as virtual enterprises) and in stability (ranging from very stable, long term relationships to networks which are reconfigured for every order). In the following, we will focus on dynamic networks with changing configurations.

In this context, the borders between knowledge and information are blurred. Some authors argue that knowledge can only exist in connection with a human mind and that only data transfer is possible (Maier 2002: 61). As the information systems used to transfer data, information and knowledge cannot be separated either, we will not distinguish sharply between knowledge and information in the following text.

The investigation of the activities of knowledge management (KM) in cooperations reveals a number of specifics which can not be found in traditional, integrated enterprises. Some of these specifics, such as the limitations to the use of hierarchical coordination and the necessity of an intrinsical motivation for each partner's participation in knowledge management activities, have to be met on an organizational level. Others, however, can be accounted for during the design and implementation of IT systems for knowledge management.

It is possible to identify five key requirements which have to be met in order to successfully employ knowledge management tools in cooperations. The first of them are determined by the particularities of the use of IT. It may be characterized by heterogeneous systems which may – in the worst case – be different for every partner involved, and the necessity to react to changes in the structure of the cooperation, which may be frequent. Therefore, the ability to access other systems across platforms, the flexibility of the integration and the variability of the presentation are important success factors. The other requirements are determined by the structure of knowledge in cooperations. The main difference to integrated cooperations is the fact that knowledge in cooperations is distributed among the different participants. This leads to two further requirements to IT support: the ability to bridge differences in terminology and language and the possibility of detailed access controls.

1. *Cross-platform accessibility*: In cooperations spanning multiple independent organizational units (e.g. companies, divisions or departments), it is likely that there will be a number of heterogeneous IT systems, particularly databases (Garita 2002). Comprehensive knowledge management systems will have to provide interfaces to various databases and file systems, if they are to access data on the storage level. Besides, they require interfaces to applications used to store information and knowledge, particularly document- and content management systems. Tools used for KM in cooperations will have to be able to bridge the technological gaps between the participants.

2. *Flexibility of integration*: The integration of partners' IT systems has to be as flexible as possible and must not require extensive programming efforts. This is due to the fact that the pool of partners involves may change dynamically, particularly in modern organizational forms, such as virtual enterprises (Veil and Hess 2002). In order to be able to react to these changes efficiently, new systems and users have to be incorporated quickly with little manual programming involved. The technical integration mentioned above is a prerequisite of the flexibility of integration. However, the flexibility will be investigated separately, as it significantly influences the usability of IT in highly dynamic settings.

3. *Variability of presentation*: Information access is one of the primary roles of IT in knowledge management. In order to avoid information overload and poorly structured, complex access structures, it is particularly important to adapt the information supply to the tasks they support. Particularly in dynamic forms of cooperations, in which the partners and the systems used to create services and products may change frequently,

the systems used in knowledge management have to allow flexible changes to the presentation layer. It is necessary to include and exclude functions and data sources as needed without large-scale programming in order to tailor the system's contents to the needs of the users.

4. *Overcoming language differences*: In different companies, or even in different parts of large, distributed enterprises, different ways of speaking about identical things may develop. This will lead to misunderstandings and wrong interpretations, particularly in the case of explicit knowledge, which are referred to as information pathologies (Wigand et al. 1999). Knowledge management systems should help to overcome or reduce these communication problems and reduce language ambiguities.

5. *Access control*: Due to the distributed nature of knowledge, total access for all users may not be desirable. When independent companies cooperate, they may want to protect some of their knowledge in order to prevent an imitation of their core competencies. Besides, it may be necessary to restrict access to knowledge which accounts for competitive advantages to prevent espionage. Therefore, knowledge management systems have to integrate access control mechanisms and role concepts which allow access restrictions for users or groups of users on a document or data source level.

One may also name the creation of transparency by comprehensive access to all knowledge sources as a knowledge-related criterion. However, this may well be subsumed under the technical integration described above, as it essentially leads to the same technical requirements, namely interfaces to all relevant storage systems.

3 Classification and evaluation of existing tools

In the following chapter, we will classify the existing tools for knowledge management and evaluate whether they are suitable for use in cooperative settings. It has to be noted that there is no such thing as "the knowledge management system" as a monolithic, integrated application. Instead, a knowledge management system is a more or less tightly integrated combination of various applications, some of which are used in other contexts as well.

3.1 Classification of knowledge management tools

There are numerous attempts at classifying the software used in knowledge management in the literature. In fact, almost every author uses his own classification, since the classification is usually closely linked to the subject treated and the insights desired. In the following, we will adapt the system proposed by Maier (Maier 2002) which classifies the IT tools based on the functions they serve in the knowledge management system. It is based on current research and covers all fields of technology used in practice. Besides, it is free from overlaps between the categories. It offers a higher degree of clarity than categorizations which use only two categories based on dichotomies or strategies such as codification/ personalization.

In this classification, the tools which are combined to form the knowledge management system are grouped into seven categories (cf. fig. 1). These are the input-oriented functions of publication, structuring and linking as well as integration of knowledge from external sources. The output-oriented functions include search and retrieval as well as presentation of knowledge. These groups are supported by infrastructure functions categorized as communication/cooperation and administration. The seventh group, imparting knowledge, which mainly consists of e-learning and related concepts, will not be examined in detail in this paper, as it mainly belongs to personnel development and not primarily to knowledge management.

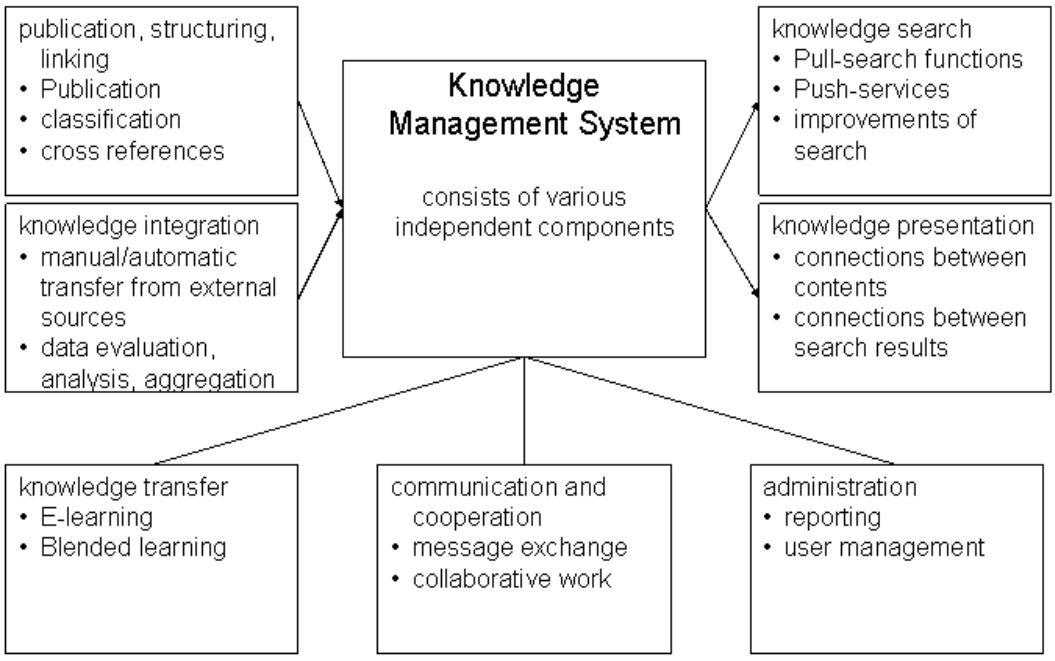

Fig. 1. Groups of IT tools for knowledge management

In the following paragraphs, we will examine the tools based on the criteria introduced in chapter 2. The evaluation is based on a literature survey conducted in (Schmaltz and

Hagenhoff 2003). We will introduce the results in the form of tables and discuss the main results, including tools which are particularly well- or ill-suited for use in cooperations. Blank fields in the tables indicate that the criterion in question is not applicable to the respective tool. The + sign denotes that the tool in question complies with the requirement in question, the O means neutrality or limited support and – means that the tool conflicts with the requirement. Since we will not be able to treat all tools in depth, we will focus on the aspects which are particularly positive or negative.

3.2 evaluation of tools

3.2.1 Publication, structuring, linking

In this category, we will discuss tools and specific functions of tools which enable the users to publish new contents within the system and to add links and structures to the contents. Table 1 shows the tools and their particular strengths and weaknesses. Regarding their use in cooperations

Table 1. Publication, structuring and linking tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
Content Management	+	O	+	O	O
Unstructured documents	+	+	-	-	-
(Semi-) structured documents	O	-	+	O	O
Keywords/abstracts		O		O	
Hyperlinks	+	O		O	O
Integration with taxonomy/ontology		-		+	
Categorization/clustering	O	+	+	O	
Meta knowledge base	-	-	O		O

Most tools used in publication originate from the area of web publishing, usually standard content management systems are used. Generally, content management systems support integration and access to data sources, since most commercial

products are able to access numerous data formats and storage systems, making distributed contents easily accessible to all users involved. The flexibility is limited, though, because there are no interchange standards which allow exchange of contents between systems. Presentation is variable, as contents are stored independent of the output formats, and in some products there is support for formal descriptions (which may help to overcome language differences, cf. Chapter 4.3) as well as access control.

Content management systems are able to manage both unstructured (plain text) documents, in which the elements of the text do not carry any machine-readable information, and (semi-) structured documents, in which some or all of the elements have a specific meaning (such as carrying information about the author, date of publication etc.). Unstructured documents poorly support the requirements in cooperations. While they are easy to import and integrate, they do not support different forms of presentation, nor do they allow the storage of descriptive metadata or access control information within the document.

Therefore semi-structured documents should be used, which may be augmented with information concerning formatting (e.g. headlines) for presentation, metadata for understanding and access restrictions for security. Integrating different semi-structured or structured document formats may be challenging, though.

Keywords and abstracts are added at the time of publication in order to describe the contents of the text using natural language. They only require format conversions during integration, as no controlled vocabulary is used. This goes along with limited descriptive powers in environments which use a different “corp-speak”. Abstracts are more helpful here, but their expressiveness is still limited.

Hyperlinks between contents are the most straightforward way to connect contents. Being a part of basic internet technology, they are platform independent, but it is necessary to ensure their consistency if contents are moved or removed. They may help to attenuate language differences, as they can provide an easy way to retrieve further information. Access control has to be guaranteed by other means, e.g. the respective repository.

Another tool which is frequently mentioned in the context of structuring knowledge is the integration with formalized description systems such as taxonomies and ontologies. The main advantage of these systems is the fact that they are an efficient way of overcoming problems of understanding. If contents are annotated with metadata related to a system of unambiguous categories or subjects which is shared among the

partners, relevant documents can be found regardless of the specific terminology used. These content-related meta data are, however, a significant hindrance to the flexibility of integration. Especially if new participants in the value creation use different description systems, a laborious manual mapping of concepts has to be conducted. Annotating contents retroactively is also very costly. As an alternative or complement, one may use automatic clustering or categorization tools, which group similar documents. They have to access the repositories in which the documents are stored. Some text mining tools on the market are already able to access a wide variety of storage systems and formats, but they will fail if unsupported (e.g. very exotic or proprietary) formats are used. They are positively related to the aspect of flexibility, as they can easily process and thus integrate large quantities of data. Besides, they can support a flexible presentation as they can be used to build task-specific categorizations or to suppress irrelevant contents. As these methods use only a statistical analysis and no semantic understanding, their benefit for the bridging of language gaps is limited.

A meta knowledge base, which is used as a central repository for the description of knowledge sources and their properties, appears to be a useful part of the knowledge management system. However, working implementations of this concept are rarely reported in the literature and standards for the technical and semantic description of the data sources are mostly missing. As data sources have to be described manually, the use of meta knowledge bases is rather inflexible. They are potentially valuable for the construction of task-adequate information supply, as they allow an easy combination of relevant sources if the respective descriptions are available. Besides, the repository could be used to facilitate access control, as it may be used as a central storage for restrictions.

Among the publication functions, one has to balance the lacking descriptive powers of unstructured documents with the lesser flexibility of semi-structured formats. Besides, the problem of integrating descriptive systems remains unsolved. Furthermore, solutions for access control and rights management are weakly supported by the existing tools.

3.2.2 Integration of external knowledge

When attempting to integrate knowledge and information from external sources into the KM system, one has to face two tasks: the first one is transferring external knowledge into internal storage systems, the second one is evaluating, analysing and aggregating external knowledge prior to importing it (cf Tab. 2).

Table 2. knowledge integration tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
transfer from external sources	O	+		-	-
evaluation, analysis, aggregation	O	-	+		O

Transferring knowledge from external sources may be done manually. Since this process is identical to the publication, it will not be treated in detail here. Automatic integration may not only be used in connection with sources external to the cooperation, but also with systems which are not directly connected to the knowledge management system. Using scripts or crawlers, relevant contents may be discovered and taken over without having to construct complex interfaces. This will increase the flexibility, even though the import mechanisms will have to be adapted to the respective sources. Semantic metadata may be imported as well. Due to the current lack of commonly accepted description systematics, however, this will only be of limited use. Besides, access restrictions have to be included, since the owners of restricted contents will not allow them to be transferred unless a comprehensive security architecture is in place. This will probably limit automatic imports to freely accessible contents.

The tools used for reporting and data analysis in cooperations do not differ significantly from those used in integrated enterprises. They require interfaces to the partners' operational databases and/or to data gathered on the level of the cooperation. Due to the existence of widespread database access standards (e.g. ODBC as an Interface or SQL as a query language), this does not pose a great technological challenge. It may however be necessary to adapt or transform data models, which may be very complex (Garita 2002). Due to the necessity of data model integration, reporting and data mining tools tend to be inflexible with regard to the integration of new partners. Depending on the features of the systems used, reporting and analysis offer large potential for user- or task-specific aggregation of data and therefore improve the flexibility of the presentation. If commercial analysis tools (e.g. from ERP suites) are

used, there will be access control mechanisms which limit access to the tool's data base to authorized personnel. Restrictions from the partners' systems have to be imported manually, though.

The knowledge integration tools are generally suited for use in cooperations, but there are deficits regarding rights management and the integration of description mechanisms.

3.2.3 Search and retrieval

On the output-side of the system, search and retrieval are the most important functions, since they are a widely used, simple way to access information stored within the KM system (Maier 2002:207). They comprise push- and pull search functions and background technologies which are used to improve search results.

Table 3. search and retrieval tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
Search engines	+	+			
Search filters			+		
Navigation	-	-	-		
Push tools	O	O	+		O
Semantic metadata	-	-	O	+	
Usage statistics	O	O			

During the use of pull search functions, the user takes on an active role by requesting and downloading contents relevant to his information needs. The tool most commonly used in this context is search engines, which are based on the same technologies as the widely-known WWW search tools. Their ability to access heterogeneous systems depends on the storage systems used, but state of the art enterprise search solutions (e.g. offered by Verity, Autonomy and others) offer interfaces to a wide variety of file formats and databases. Setting up interfaces to new sources is usually simple, which

makes a common search engine a good starting point for cooperative KM. Filters are commonly integrated in the search engine and allow users to restrict their search by limiting it to specified data sources, file types etc. This way, results may be easily adapted to user demands, although simple filters are usually restricted to technical criteria which can be detected automatically.

Aside of search engines, pull search may be conducted using navigation structures which group contents into tree-like structures. Navigation structures may be seen as simple taxonomies which group contents into hierarchical categories. Integrating navigation structures is difficult, as they are usually company specific. There is no commonly accepted set of categories for e.g. corporate intranets. Therefore, a manual mapping of the classification or a re-grouping of contents has to be conducted. Navigation structures are generally static; they do not support task-specific adaptation of the contents.

Push tools automatically deliver relevant contents to the user, usually by email or personalized web pages. They are usually based on search engine technology. Hence, the same restrictions concerning data source access apply. Integration of new users is flexible (only the desired method of delivery and a profile of interests have to be specified), whereas the integration of new data sources may prove difficult if they are not supported by the tool. The biggest advantage of push services is their ability to deliver tailor-made content packages. They will have to be integrated with access control mechanisms, as the contents delivered should only include resources the user is allowed to view.

There are a number of means to improve the results of traditional full-text search. One of them is the inclusion of semantic metadata, which contains machine-readable information about the contents of resources. Unfortunately, there are hardly any standard thesauri or ontologies of widespread acceptance. Usually, companies develop their own ontologies. This leads to severe integration problems. Since computers cannot analyze the meaning of the description tags automatically, an integration of different ontologies requires a mapping of meanings by a human editor. This process is complex and time consuming. Besides, it has to be repeated every time the ontologies change (Noy and Musen 2002). Both access to partners' systems and flexibility of integration are poor. Semantic metadata offers great potential, however, to find task-specific contents, and, most importantly, to bridge the gaps of corporate languages.

Usage statistics offer further possibilities to improve search results. They may be used to point at unread articles or to judge relevance by recommending the most-read

articles. A central system which monitors all access to contents is required to gather valid usage data. This function may be integrated into a portal system. Otherwise, it is necessary to evaluate a large number of web server or database statistics which may not contain the required information (particularly concerning the users).

It is also possible to evaluate user profiles to identify relevant contents. User profiles will be treated in chapter 3.2.5, as they are primarily used for administrative purposes.

While search engines offer high potential for rapid integration, they have very limited potential to bridge language gaps. This may be done by semantic metadata, a technology flawed with severe integration problems. Company-specific navigation structures are another hindrance to integration.

3.2.4 Presentation of knowledge

One may either present knowledge independent from a specific search request in order to give an overview of the available contents, or process search results to improve the quality of knowledge access.

Table 4. Knowledge presentation tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
Visualization of structures	O		O		
Knowledge maps		-	-	O	
Mining-based visualization	O	+	O	O	
Related documents	O	-		-	
Links to communication software	+	O		+	
Direct access	O	O			

There are a number of tools for the presentation of contents which may be added to conventional navigation structures (cf. Tab. 4). Contents and their structure can be visualized not only in trees, but also using three-dimensional or non-euclidic geometry, e.g. in hyperbolic browsers. The integration requirements are the same as for search

engines, as the visualization tools will require interfaces to all relevant data sources. Again, the flexibility and completeness of results are limited by the interfaces provided. They will suffer if proprietary storage systems and formats are used. The main benefit of these visualizations is their ability to provide intuitive, clear access to complex structures of contents. Some tools allow user specific configurations, especially concerning the depth and complexity of the visualization.

Knowledge Maps are another form of visualisation. They include contents as well as organizational units and people. Hyperlinks enable direct access to documents or contact to people. Building and evolving knowledge maps requires a lot of manual work (Kim et al. 2003). While creating links to resources is not technically challenging, the need for manual integration of new (and removal of resigning) partners and the lack of interchange formats make the use of knowledge maps difficult. It has to be noted, though, that the integration of links to people is an interesting way to improve the accessibility and to bridge differences in the terminologies used.

The third form of knowledge presentation discussed here is visualization based on text mining. It uses statistical correlations between the terms in documents to create networks, landscapes or other graphical representations of their connections. As is the case with all search-related tools, the ability to access knowledge sources depends on the tools used. The flexibility of mining-based tools is generally high, as they can process large quantities of data automatically. Thus, they are well-suited to provide an overview of large collections of new documents. They can be adapted to the task at hand by specifying the terms displayed at the centre of the visualization. Text mining is, however, not very well suited to bridge linguistic differences, as it cannot analyse the actual meaning of the terms. There is only a limited ability to discover e.g. synonyms.

In order to improve the quality of the presentation in connection with search results, some other tools may be employed. Recommending related documents is one of these functions. If a user requests a document (or any other content) he is presented with a selection of resources which are similar to the one selected. These recommendations are determined either by collaborative filtering or by content based filtering (Melville et al. 2001). The same restrictions concerning access and flexibility that were mentioned in connection with usage statistics apply here as well. Besides, these filtering methods are not well suited to ease problems of understanding. Collaborative filtering requires that an article has been read and rated by at least one user in order to discover a connection. This means that some users will have to find the relevant articles in the partners' databases by themselves before the system is able to recommend them.

Content-based filtering is not likely to discover similarities if the terms used in the documents do not match. Therefore, filtering mechanisms are not very helpful in this scenario.

The contents retrieved by the search component may also be augmented by direct links to communication software. It is possible to enable direct access to commentary functions, discussion groups and the author's email or instant messaging system. As these functions are based on standard internet technology, they are simple to realize. They do, however, require a centralized delivery platform which allows the addition of the links. If they can be added automatically, new contents may be added flexibly. The integration of communication software and content delivery will help users to understand contents from different contexts, because it enables users to smooth out problems of understanding in personal contact.

Direct access to contents allows users to view the resources they have requested at once, without the need to download them or start other applications. This function accelerates the delivery process and reduces the number of applications needed on the client computers. In most cases, modern content management systems are able to transform files into HTML pages which can be viewed in the user's browser. It the members of the cooperation use exotic storage systems or formats, this may require considerable efforts to convert the resources, which will also affect the flexibility of the system.

In this group of systems, knowledge maps display strong deficits, as they are lacking in flexibility and exchangeability. Automatic recommender systems are of limited use because they cannot bridge language gaps, whereas direct links to communication instruments, which will be treated in the next chapter, are a simple and straightforward instrument to facilitate direct contact between users.

3.2.5 Communication and cooperation

The tools used for communication and cooperation are provided by conventional intranet and groupware software which is used in the knowledge management context (cf. Tab. 5). They can be divided into tools for synchronous and asynchronous communication.

Table 5. Communication and cooperation tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
Email	+	+		+	
Newsgroups		+		+	O
Shared documents	O	O			O
Ad-hoc Workflows	-	O	+		
Group databases	-	O	+		O
Chat/IM/audio- and video conferencing	O	O		+	
Shared screen tools	O	O		+	O

Tools for asynchronous communication enable interaction with a time shift, meaning that the users do not have to be present at the same time. Email is the most widely used tool for asynchronous communication. As it uses standard protocols, it can be used to connect partners easily. The functions offered are limited, though. Newsgroups, which may be web-based or use specialized reader programs, are another simple, standard tool which does not require integration efforts. While they allow personal discussions about shared problems, they usually offer only simple role models and limited potential to include access controls.

Shared documents offer support for joint editing of documents by providing mechanisms such as check out/check in, versioning and revising. They may be very simple, browser-based implementations, but more sophisticated alternatives require specialized client software and servers (which add integration expenses). They usually include rights management systems. Further support for asynchronous collaboration can be given by ad-hoc workflows, which are offered of many groupware systems. This way, users can define simple processes and documents or tasks will be automatically routed to the person in charge. As these workflow tools are integrated into groupware packages and use proprietary client software and protocols, it is difficult to integrate systems across company borders. Their main benefit is the possibility to adapt

workflows to changing processes and configurations quickly. Group databases, which also originate from traditional groupware systems, pose the same problems concerning integration. They are usually integrated into the groupware system's access control mechanisms. While they are easy to set up and flexible, their use has to be observed critically from a knowledge management point of view. The more separate, distributed storage systems there are, the higher the risk of creating information islands which are not accessible to central search tools.

It is also possible to use a number of tools for synchronous communication. The main tools, which are chat, instant messaging, audio conferencing and video conferencing, can be treated together. They use different types of media (text, speech and video) to support a very similar communication process, namely the synchronous interaction between one or more participants. Generally, these tools do not need a large amount of integration with other systems, but client-side software is required in some cases. Particularly instant messaging has proven useful in the workplace (Isaacs et al. 2002), as it helps to resolve problems, misunderstandings and questions quickly.

Shared screen tools are the last piece of software treated in this group. They allow two users to use one application at the same time. Like other communication tools, shared screen tools don't require tight integration with other applications and can be used flexibly if the required software is installed. For security reasons, it may be necessary to establish login mechanisms and restrictions. If the tools are part of the architecture of a groupware package, they will be integrated into its security concept.

Particularly simple groupware tools which are based on open standards are a capable means to facilitate communication between employees in different parts of the cooperation, particularly if they are integrated with the presentation of the contents. Tools which originate from proprietary groupware architectures suffer from deficits concerning cross-platform applicability.

3.2.6 Administration

The most important administrative functions are reporting and user management. Reports may be generated with respect to contents and to user behaviour. User management includes the management of role concept as well as the generation and evaluation of user profiles (cf. Tab. 6).

Table 6. Administration tools

requirements / functions	Cross-platform accessibility	Flexibility of integration	Variability of presentation	Overcoming language differences	Access control
Content analysis	O	-	+		
User analysis	-	-	+		O
Roles	-	-	O		O
Profiles	-	O	+	O	O

Content related analysis can be used to identify the most relevant contents, contents which are frequently used in connection, and parts of the system which are rarely used. Ii is also possible to detect trends and knowledge gaps by evaluating search requests and results. Technically, these evaluations are a demanding task, as access protocols from all systems involved have to be evaluated. This will also affect the flexibility of reporting and analysis tools. Statistical evaluation tools are generally configurable and allow the flexible design of the reports generated. They can be used to detect weaknesses of the existing system. If the users regularly overlook large portions of the contents, this may hint at poor usability or information pathologies. User-related analysis aggravates the technical difficulties, as the data from the content sources has to be integrated with user data. It is possible to use these evaluations to detect user groups with low system usage, as well as very active users. However, the appropriate legal restrictions concerning the use of personal data have to be observed.

In user management, roles and profiles may be used. Roles define the rights and characteristics of user groups. They may include information about organisational affiliations, fields of activity, rights to edit and view contents, relevant sources etc. based on the organizational unit and/or the position in the hierarchy. As most tools used in knowledge management employ role concepts to differentiate between user groups (e.g. readers, editors etc.) it is useful to centralize these administrative functions. This way, new users have to be created only once and it is easy to implement changes of status. In integrated groupware packages, centralized role management functions usually exist. It is doubtful, however, if an integration of role

concept across various platforms and storage mechanisms is feasible, particularly it new systems have to be included frequently. On the other hand, centralized role concepts facilitate the adaptation of the system to the needs of user groups. Besides, they can serve as a foundation for access control without the necessity to maintain user data at each source.

A user's profile is an extension of the role concept, as it contains user information on a personal level. Profiles include data such as special interests, personal system configurations, frequently used contents etc. They pose the same technical challenges as role management systems. They offer, however, unique benefits concerning flexible, task-specific information supply, as they allow user-level personalization of contents, data sources and presentation. They may also be used to access implicit knowledge by serving as an expert location tool.

The administrative tools share a common weakness. They all require a large integration effort, especially if content storage and delivery is done using multiple different systems. Therefore, it may not be economically reasonable to aim at full scale integration.

4 Approaches to improve cooperative knowledge management

An overview of the evaluation of the tools reveals that some of the requirements defined in chapter 2 are not well supported by the existing solutions. There are problems on three different levels. The first problem is of technical nature. The systems used in knowledge management are distributed across different companies and use different formats and interfaces. Yet, it is necessary to access all of them. Thus, an integration infrastructure which enables data transfer between the different systems is required. The second problem, on the organizational level, is due to the fact that the organizational structures of the network have to be reflected by the knowledge management system, most notably by defining users' rights to view and manipulate contents. The third problem arises on the content level. The existing technologies do not provide sufficient means to deal with the problem of different corporate languages.

In the following chapter, we will briefly introduce approaches to alleviate these shortcomings. In all cases, it is possible to use either a top-down or a bottom-up approach. In a top-down procedure, the solution is developed centrally and has to be implemented by all participants. If a bottom-up approach is used, the partners' existing

systems remain intact. In that case, they have to be integrated into a common architecture. We will examine whether the former case, in which a central system is implemented on the part of the participants is beneficial, or the latter, in which the different systems are aggregated to enable their use across corporate borders.

4.1 Cross-platform accessibility

The applications used in knowledge management have to be integrated to be used effectively (search tools have to access content repositories, visualization tools have to access search results etc.). However, the tools examined in the preceding chapter are ill-suited for this purpose. There are no standard interfaces designed for knowledge management purposes and a wide variety of standards and proprietary formats have to be taken into account. There are different variants of integration which may be employed to deal with this problem. Taking the three-tier architecture of modern application systems (Jain 2001) into account, integration may be done on three different levels: data, application logic and interface. If data-level integration is desired, the partners have to agree on commonly used data structures. They use one or more common databases for all relevant data which serve as a central repository for all applications. This approach may be considered a top-down solution as a centrally developed standard is forced on all participants. It appears unlikely (and unaffordable) that the partners will convert their existing systems to a centralized design. Therefore, a bottom-up solution, which leaves the existing infrastructure intact, is needed. A portal system (Collins 2001) can provide access to numerous systems by either integrating them on the interface level (which will only show their user interface within the portal), or preferably at an application logic level. Integration on that level can be achieved using connectors provided by software vendors (e.g. of search engines) or application programming interfaces, which allow access to an application's functions by external programs. Connecting software tools will always involve considerable work. Therefore, it may sometimes be easier to establish a central storage mechanism for contents related to ongoing projects and add documents from other systems manually as needed.

4.2 Rights management

Another weak spot of the existing knowledge management tools is the fact that they do not include a comprehensive access control system. One has to assume that many participants have different user management systems, directory services etc. in place which contain user data and access rights. There are numerous variants of these systems of differing granularity. Users may be grouped on an individual level or by the

organizational unit they belong to and contents may be freely available to all users or restricted on a data source, category or document level. Aggregating and evaluating these restrictions is a demanding task. In order to avoid the necessity of maintaining multiple instances of the user data, a centralized storage for user data and access restrictions is required. The rights management component has to be integrated with search and delivery tools as well. In search, results have to match the user's rights. Contents which are not accessible are not relevant to the user; therefore they should be excluded from the result list. The same is true for navigation hierarchies or visualizations.

Using a portal as a single point of access will help to integrate user data and access control. Users are identified by login mechanisms and presented with a personalized view of relevant, accessible contents (Maier 2002:218). It depends on the implementation, however, if access and user data can be automatically imported from the partners' systems. Aside of problems caused by formats and interfaces, it is also necessary to do a mapping of different authorization hierarchies to a common system. This makes a bottom-up solution a demanding project. For use in cooperations, a pragmatic, lightweight solution deployed top-down seems to be more realistic. Rights may be managed at the level of the integration platform a simple system. An example is grouping the users by company affiliation and project membership. This way, every content supplier is able to define at least three levels of accessibility (only his own employees, all project participants or no restriction). Assigning contents to these categories is simple, as the company in charge can be identified by the data source (if the document is stored at a partners system) or by the editor (if it is stored on the network level). The project affiliation can be determined automatically if companies/editors participate in one project only, otherwise it will have to be set manually.

4.3 Overcoming language differences

Judging from the evaluation, there are few technological solutions to the problem of information pathologies arising from different terminologies in cooperating companies. Aside of tools which facilitate personal communication, the only possible solution provided is semantic metadata in connection with taxonomies/ontologies. However, the semantic metadata created by the participants of a cooperation is of little value if it isn't interchangeable. If one partner is to interpret the others' descriptions correctly, there is a need for standardized metadata formats and description systems. Standards for semantic metadata have received a lot of scientific attention lately, particularly in

connection with the semantic web. The vision of the semantic web (cf. Berners-Lee et al. 2001) is based on machine readable metadata which makes the contents of web resources understandable by machines.

Technically, the standards required for successful metadata interchange are in place: XML is used as a common syntax. RDF, the resource description framework, and RDF Schema are used to define the structure of the descriptive elements, but they do not specify specific descriptions. The descriptions are taken from an ontology, which is a formal representation of reality. The conceptualization of reality expressed by the ontology has to be shared by its users (Studer et al. 2003). Ontologies may be exchanged in the Web Ontology Language OWL which has just become a W3C recommendation (http://www.w3.org/TR/2004/REC-owl-features-20040210).

In the context of knowledge management, the proponents of ontology-based semantic metadata promise a number of benefits, mainly in the area of search and presentation. The main advantage of ontology use is due to the fact that search engines will not only be able to search inside documents for text strings. Instead, they can assure that the contents retrieved actually treat the subject the searcher has specified, thereby improving relevance. Besides, it is possible to find documents about relevant subjects even if the search terms do not appear in the full text, which improves the recall of the search. It is also possible to display related contents which treat superordinate, subordinate or neighboring concepts. By using inferencing mechanisms, it is even possible to detect connections which have not been specified explicitly (Staab and Maedche 2001). Further proposed benefits include the automatic generation of navigational structures and automatic categorization of contents.

There are, however, limitations to the use of ontologies. The existing software support for the creation and maintenance of ontologies is limited at best (cf. OntoWeb Consortium 2002). The construction and maintenance of these formalizations is a complex, time consuming process and requires the participation of the potential users (Staab et al. 2001). The integration of existing ontologies is difficult as well, as the mapping or merging of relationships between the terms in the respective ontologies requires a lot of manual interventions. This will make it difficult to use a bottom-up approach which exploits existing structures. Due to the complexity of the ontology integration, the costs of this approach have to be weighted against the potential benefits. Therefore, semantic web technologies can only provide a partial solution to the problems posed by differing linguistic customs. If there are standardized ontologies which have industry-wide support (which don’t exist in the field of business or

engineering), using them for the creation of semantic metadata could be a long-term solution. It appears unrealistic, however, that all contents accessible within the knowledge management system can be annotated ex post, and even the creation of metadata at the time of publication is often shunned by users (Kogut and Holmes 2001). Hence, metadata-based search should be tightly integrated with full text search instruments. Additionally, face-to-face contacts between the employees involved, e.g. in regular meetings, will improve mutual understanding significantly.

5 Conclusion

Establishing a coherent IT infrastructure for knowledge management in distributed environments is a complex task. Tools which may be employed without difficulties in integrated enterprises display notable deficits in supporting inter-company knowledge management. There is a three-fold integration challenge, on the technical, the organizational and on the content level which cannot be solved by technology completely. The integration on the technical level may be done using a portal system. Portals enable the integration of functions such as knowledge repositories, publication, retrieval and user management. A large number of portal systems have been developed by commercial software vendors. They are ready to be deployed, and while the task at hand is complex, there is a technological solution. As far as the organizational level is concerned, the challenges posed by the need for a rights management architecture can be tackled by IT as well. It has to be noted, though, this will require a trusting relationship between the partners which can’t be generated by technological means. On the content level, however, a technological solution is not likely to be available in the near future. In the area of semantic metadata, the solutions offered so far are still in development. While there is a large number of (mainly scientific) prototypes, commercial solutions based on W3C standards have not yet emerged. Besides, the cost-benefit relationship has to be analyzed critically. As far as problems of mutual understanding are concerned, it appears that non-technological solutions are superior, at least at the present state of development. It becomes clear that, while IT plays an important role in inter-company knowledge management, it does not offer solutions to all problems.

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