KnowFlow - A Hybrid Approach to Identifying and Visualizing Distributed Knowledge Work Practices

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Abstract

Understanding collaborative work practices represents a critical factor in and a necessary fundament for the development of effective Computer Supported Collaborative Work (CSCW) systems. In today's economies, collaborative work is increasingly knowledge intensive, distributed *and workers are more and more conceptualized as* knowledge workers*. This yields to the question how especially* distributed knowledge work practices *can be identified and visualized as a basis for the development of CSCW systems. This contribution 1) investigates how a traditional knowledge work analysis approach can be adapted for application in distributed settings and 2) reports on the preliminary findings of an explorative case study.*

1 Background and Motivation

Understanding the way a group of workers interacts with each other represents a major challenge and a prerequisite for the design and development of computer systems that aim to support collaborative work. Today, collaborative work increasingly takes place in a distributed fashion, with actors being dispersed across geographic locations. In the past, comprehensive research has been conducted to analyze roles and relations among a network of actors. On one hand, this has led to the emergence of the field of Social Network Analysis (SNA) and the development of supporting software tools [23, 22, 31] to visualize and analyze especially *distributed* social networks. Evidence for the relevance of SNA in the context of designing Computer Supported Collaborative Work (CSCW) systems can be found, for example, in the initiation and organization of the workshop on *social networks* during CSCW 2004 ([34, 32, 7] in Chicago. However, utilizing social network models as a basis for the development of CSCW systems has turned out to be difficult because of some challenges: First, SNA approaches that rely on analysis of available data (such as [7] on the basis of e-mail logs) struggle to provide appropriate visualizations that can present the huge amount of resulting data in a way that aid analysts in understanding the networks [34]. Also, because SNA predominately focuses on social aspects, other aspects that are relevant in the context of system design, such as *organizational or technological* factors, are not covered adequately.

On the other hand, knowledge management (KM) as a research domain emerged during the last decade to investigate and manage knowledge as the most critical resource of organizations [17]. To a certain extent, knowledge management is concerned with understanding social relations within communities [25], but also introduces complementary modeling dimensions, such as knowledge-, organizational and technological aspects [29]. Within the knowledge management domain, *knowledge work analysis* can be regarded a research branch of its own which is concerned with the descriptive modeling of socio-technological real world systems (or ”object systems” [5]). Key issues in this domain include the multi-dimensional *identification* and *visualization* of knowledge work practices. However, approaches in this domain typically are *labor-intensive* and rely on a *co-location of analysts and investigated actors* (such as B-KIDE [29, 30] or ARIS(KM) [2]) and therefore are not well equipped for being applied in distributed settings.

So while social network analysis on one hand provides suitable concepts for conducting analysis among a set of distributed actors (through e.g. *automated log analysis*), it lacks consideration of necessary modeling dimensions and appropriate mechanisms to handle the huge amount of data to successfully aid the process of developing CSCW systems. On the other hand, knowledge work analysis typically develops '*hand-crafted*' models (vs. network models automatically derived from logs) and provides modeling languages and techniques with a comprehensive set of modeling dimensions, but lacks effective tools to be applied in distributed settings. As a result, this contribution investigates the degree to which an existing, traditional knowledge work analysis approach can be adapted for and applied in distributed settings as a basis for developing effective CSCW systems, thereby aiming to reap the benefits of both SNA and knowledge work analysis approaches.

In order to achieve that, we first briefly introduce the context (key roles and activities) of knowledge work analysis in organizational settings. Subsequently, we introduce a framework and a tool that is based on a traditional approach for knowledge work analysis, but was modified to be applicable in distributed settings. We illustrate how the framework and tool was designed to aid the distributed *identification* and *visualization* of collaborative knowledge work practices based on *web-based interviews* and the concept of *knowledge flows*. To investigate the feasibility of the introduced concepts, we report on the results of an explorative case study that focused on the development of knowledge infrastructures. We conclude with a discussion of our achievements and draw conclusions for future research.

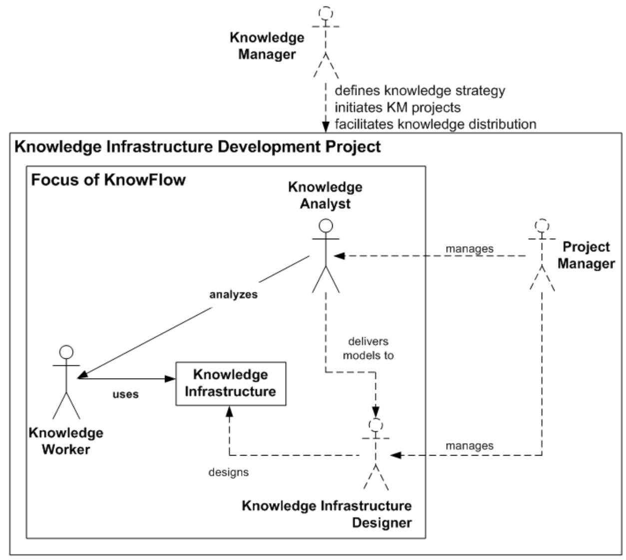

Figure 1. Organization of Knowledge Infrastructure Development Projects [29]

1.1 State of the Art

Today, knowledge management initiatives in organizations, such as knowledge work analysis and the development of knowledge infrastructures, are largely organized as a project [19]. Based on [29] and [28], figure 1 introduces relevant *roles* and respective *tasks* of knowledge infrastructure development projects. Knowledge infrastructures here are regarded to represent computer systems that support the execution of collaborative, knowledge intensive work.

In figure 1, the *knowledge manager* (or CKO - Chief Knowledge Officer) develops and implements knowledge management strategies [28, p. 22], [21, p.107]. The *project manager* (or knowledge project manager [21]) is in charge of running knowledge management projects from an administrative perspective [28, p. 22]. *Knowledge workers* are the primary target group of knowledge infrastructure development projects [17, p. 150]. These projects typically aim to improve knowledge worker's productivity. The *knowledge analyst* analyzes collaborative knowledge work practices as a basis for the design of supportive systems. Similar to the role of a system analyst [35, p. 56], he investigates a complex object system (collaborative knowledge work practices) and develops models (often with the help of supporting modeling systems) that highlight certain aspects of the system, while neglecting others. In doing so, the knowledge analyst provides specific views on the system that represent a fundament for subsequent activities of knowledge infrastructure designers. The *knowledge infrastructure designer* transforms the developed models of knowledge work into a design that aims to represent a supportive technological environment for knowledge workers. The knowledge infrastructure designer (or an implementation team) finally implements the final design and accompanies the validation of the solution with knowledge workers.

Early research in the domain of **knowledge work analysis** focused on modeling knowledge work (as e.g. [2]) as a basis for the *design of knowledge based systems* [28] and *workflow management systems* [24]. Subsequent research increasingly focussed on developing *theories of knowledge modeling* in organizational contexts, including approaches such as [26, 9]. Current research aims to *bridge* the modeling of knowledge work with the concrete development of knowledge infrastructures [20, 29, 18]. Concrete modeling approaches include B-KIDE [29], KMDL [9], KODA [1], extensions to ARIS [2], or the concept of knowledge stance [18]. Empirical evidence for the feasibility of these approaches already exists [13, 11, 29] and motivates further research into that direction.

Social network analysis has been utilized for analyzing especially distributed social networks [23, 22, 31]. First approaches for leveraging SNA for the design of CSCW systems already exist [34, 32, 7]. Typically, such approaches rely on the availability of *logs* to identify, visualize and analyze relationships between *individuals* (such as [3, 4]). The resulting social networks are typically visualized as complex graphs. Indicators that are used to analyze such graphs include *network density*, *degree centrality* and *network degree centralisation* [4].

Some concrete drawbacks of existing knowledge work analysis approaches were identified in earlier case studies [29], including: 1) the time and resources needed for interviewing knowledge workers as a basis for modeling *(low modeling productivity)* 2) the necessary geographic co-location of interviewers and interviewees *(location dependency of the modeling process)* 3) the influence of varying skill levels of analysts on the analysis results *(subjectivity)* and 4) the limited analysis options available in existing tools (*lack of analytical power*). For investigating how the advantages of SNA and knowledge work analysis can be brought together, we adapted the existing B-KIDE[1] Framework and Tool [29] to be applicable in distributed settings. The *KnowFlow® Framework and Tool* represents the outcome of this effort, and is introduced in greater detail in the following sections.

2 The KnowFlow Framework

The focus of the KnowFlow Framework is on supporting *knowledge analysts* in *understanding distributed knowledge work practices* based on *investigating and interviewing* a set of *distributed knowledge workers*. The KnowFlow Framework addresses the drawbacks identified in existing approaches and consists of a *method and a tool*[2] for the *identification and visualization* of distributed knowledge work practices in organizations. It is thereby applied in *early analysis phases* of knowledge infrastructure development projects. It builds upon and evolves the B-KIDE Framework that proved itself successful in supporting the development of business process oriented knowledge infrastructures [29].

The *KnowFlow Framework* consists of the following principle components: The *KnowFlow Context* describes the basic application context: The development of knowledge infrastructures based on analyses of distributed knowledge work practices. The *KnowFlow Model Architecture* is concerned with the modeling of distributed knowledge work. In modeling theory, model architectures typically consist of 1) modeling processes and techniques (*the way of working*) and 2) modeling structures (*the way of modeling*) [12]. Within the *KnowFlow Model Architecture*, the *Modeling Structure* is defined as a UML[3] diagram based on the existing B-KIDE modeling structure, which is introduced in [29].

The KnowFlow modeling structure consists of six reference models that conceptualize distributed knowledge work practices. The reference models that are organized in a hierarchical structure include: a *business process-, knowledge domain-, organizational roles-, knowledge storage object-, knowledge transfer object* and a *location reference model*. These reference models fulfill the purpose of ensuring uniqueness of elements (such as knowledge domains, business processes, etc.) which is regarded to represent a critical factor in validating models [14]. The reference models are pre-modeled by the knowledge analyst before interview execution, in order to provide a controlled vocabulary for the distributed modeling process. This is expected to decrease the complexity and increase the usability of the resulting models. The *KnowFlow Method* is concerned with analyzing the developed models of distributed knowledge work practices and developing supportive knowledge infrastructures with the support of *Knowledge Infrastructure Template Architectures*. The next section introduces the tools that accompany the KnowFlow framework to aid in developing models of distributed knowledge work practices.

3 The KnowFlow Toolset

The KnowFlow Toolset represent an implementation of the modeling structure and a collection of functionalities that aim to support the application of the KnowFlow Framework. It represents a distributed approach to the modeling knowledge work practices that aims to address the identified problems. Figure 2 characterizes the KnowFlow approach by relating it to knowledge work analysis and social network analysis approaches.

Approach	Knowledge Work Analysis	KnowFlow	Social Network Analysis
Mode of Model Development	Hand-Crafted Models	Hybrid Model Development	Algorithmic Model Development

Figure 2. Comparing the Different Modes of Model Development

The KnowFlow Toolset takes the following novel approach to knowledge work analysis: 1) Instead of relying on co-located modelers, the KnowFlow Framework proposes a *de-centralized mode* of modeling through the utilization of web-based interviews and 2) The KnowFlow Toolset aims to support *graph-based visualization and analyses* of distributed knowledge work practices that reveal knowledge interactions between a set of collaborating knowledge workers across geographical locations in a *formal yet intuitive* way.

The KnowFlow Toolset consists of two basic tools: The KnowFlow *Interview Tool* and the KnowFlow *Report Tool*. While the KnowFlow *Interview Tool* predominately supports the distributed process of gathering empirical data about dispersed knowledge work practices through interviews, the KnowFlow *Report Tool* focuses on the visualization of identified knowledge work practices by means of

[1] B-KIDE...Business Process Oriented Knowledge Infrastructure Development

[2] similar to [33], who defines that as a method-tool companionship

[3] Unified Modeling Language [10]

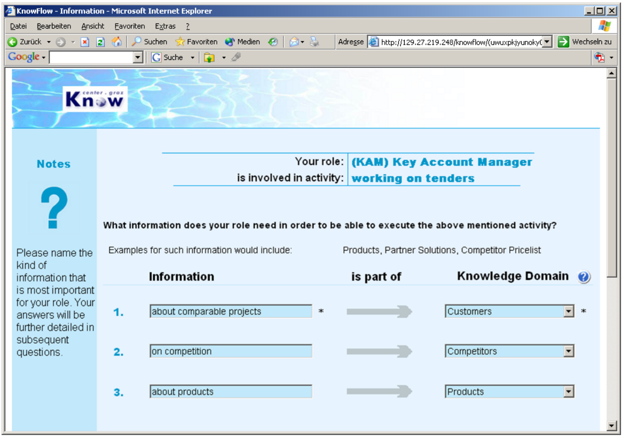

Figure 3. Screenshot of the KnowFlow Interview User Interface

graph-based visualizations. By providing software integration between these two tools, the process of collecting and visualizing analytical data is unified.

3.1 Identification of Collaborative Knowledge Work Practices

The KnowFlow *Interview Tool* provides support for gathering data about distributed knowledge work practices. In order to address the identified drawbacks of knowledge work analysis approaches, it aims at (largely) eliminating the need for co-located modelers. To achieve that, the KnowFlow Interview Tool facilitates web-based interviews. The screenshot in figure 3 illustrates a fragment of the user interface. Knowledge workers are invited by e-mail to fill out a questionnaire about their basic knowledge needs, business processes, interactions and means of knowledge storage and -transfer. They are interviewed in their respective roles, that means they are required to give answers from a certain perspective. Questions that are raised during the interviews include "*What are the most critical business activities of your role?*", "*What information does your role need in order to be able to execute these activities?, What kind of information do others need from your role?*" and "*Which role delivers that kind of information, in which way?*". These questions are rooted in existing approaches to knowledge work analysis [29] and aim for the development of multi-dimensional models of knowledge work. By giving answers that consist of a combination of free-text and controlled vocabulary[4], the KnowFlow Interview Tool collects data about distributed knowledge work practices that are subsequently visualized with the help of the KnowFlow *Report Tool*. By following such a new approach, we aim to investigate how a series of potential advantages over traditional knowledge work analysis approaches can be achieved, including: 1) the *virtualization* of the modeling process, avoiding the need for co-location of knowledge workers and facilitating modelers 2) a *broader involvement* of knowledge workers in modeling activities and 3) an increase of *inter-subjectivity* (and thus, traceability through the models developed in the modeling process).

3.2 Visualization of Collaborative Knowledge Work Practices

The generation of multiple perspectives (or *views*) on a single model is regarded to represent an effective way of handling complexity of complex models [27]. The KnowFlow *Report Tool* provides seven different perspectives on the developed models of distributed knowledge work practices, and a set of instruments to generate additional perspectives easily. The readily available perspectives include *Role-Based Knowledge Flow*[5], *Process-based Knowledge Flow*, *Location-based Knowledge Flow*, *Knowledge Community*, *Role-based Knowledge Requirement*, *Transfer-Object* and *Storage-Object reports*. With respect to the design of knowledge infrastructures that support the execution of collaborative knowledge work practices, the *Role-Based Knowledge Flow* report is of special interest. The reason to that is because this report reflects important aspects of collaborative knowledge work practices including *organizational roles* and the *knowledge flows* between them, representing interactions and dependencies between knowledge workers from a knowledge management perspective. Therefore, *the KnowFlow Framework conceptualizes distributed knowledge work practices as a collection of geographically dispersed knowledge workers connected by a set of knowledge flows. A knowledge flow represents a directed transfer of business-relevant information between two or more roles.* In addition to that, the Role-Based Knowledge Flow report maintains relations to related business locations (such as London, New York), utilized knowledge transfer instruments (such as e-mail, meetings, etc), knowledge storage instruments (intranets, hard discs, archives, etc) and communication characteristics such as frequency or regularity. Thereby, knowledge work is modeled via a multi-dimensional approach. Analyzing the knowledge flows between knowledge workers and applying the KnowFlow Framework can now represent the basis for identifying *requirements for the design of supportive systems*. Figure 4 introduces the basic syntax and semantics of

[4] as mentioned before, the controlled vocabulary is defined prior to interview execution by the analyst by pre-modeling the above-mentioned reference models

[5] Although we take a constructivist perspective [6] on knowledge that implies that knowledge is constantly (re)constructed by individuals and thus can not flow [26, page 122], we use the term knowledge flow here, and in our reports, to denote the directed nature of knowledge transfer

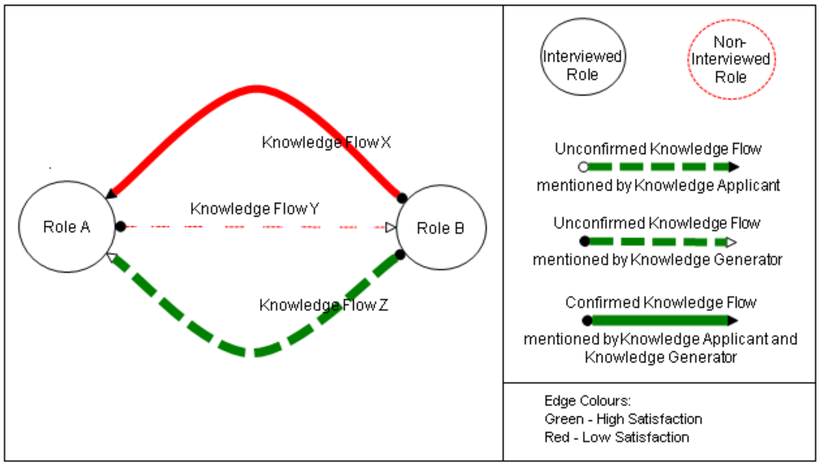

Figure 4. Syntax and Semantics of the Role-Based Knowledge Flow Report

the *Role-Based Knowledge Flow* report. Here, the answers given in interviews are *algorithmically aggregated* into a common model of the domain *based on 1) the relations defined in the KnowFlow modeling structure and 2) on generating the union set of the provided interview data*. *Thereby, inconsistencies and conflicts are maintained and become visible later in the process*. The report visualizes knowledge interactions between roles based on a directed graph representation. While *nodes* represent *organizational roles*, directed *edges* represent the *knowledge flows* between them. The technological dimensions of knowledge work analysis (including e.g. knowledge transfer- and storage elements) are related to the elements through the modeling structure, but are not included in this specific report. This information can be accessed via complementary *knowledge transfer* and *knowledge storage object report*. In figure 4, varying *edge width* of directed edges denotes varying numbers of interviewees that mentioned the respective knowledge flow. For example: The thick line of knowledge flow X in figure 4 indicates that a large number of knowledge workers mentioned knowledge flow X in their interviews (high number of *nominations*). Knowledge flow Y was hardly mentioned. The *thickness* of edges is normalized on a specified set of width values, so the visualization scales with increasing number of interviewees. Both ends of directed edges have a meaning as well: *circles* depict the generation of the knowledge in question, while *arrows* depict the application - together constituting a "knowledge flow". In addition, *black ends* denote that the attached role made statements regarding the respective knowledge flow, while *white ends* denote that the attached role did not make any statement regarding the knowledge flow. So in figure 4, Role A made statements regarding knowledge flow X and Y, while role B made statements about knowledge flow X and Z. Because each interviewee is asked about the generators of needed knowledge respectively the applicants (users) of provided knowledge, knowledge flows can be inferred even in cases where only one of the two participating roles makes statements about it. However, in such cases the knowledge flow is represented via a dotted edge to denote that the knowledge flow is *unconfirmed*. Thus, knowledge flow Y represents a knowledge flow from Role A to Role B that was stated by Role A and not by Role B (therefore *unconfirmed*) and was mentioned only by a small amount of knowledge workers (denoted by the thin edge width). Such situations can represent a starting point for the identification of inconsistencies and conflicts in the perspectives of knowledge workers.

Additionally, the color of edges denotes the degree of satisfaction regarding the respective knowledge flow as stated by interviewees. Red edges denote unsatisfactory knowledge flows (calculated on the basis of the average of individual interviewee ratings) while green edges denote a high degree of satisfaction. The introduced syntax and semantics allows for identifying and visualizing a set of knowledge flow constellations that promise to be of interest when analyzing collaborative knowledge work practices, including: unconfirmed vs. confirmed *knowledge flows*, popular vs. unpopular *knowledge transfer* and *knowledge storage instruments*, satisfactory vs. unsatisfactory *knowledge flows*, closely vs. weakly *collaborating groups* of knowledge workers, collaborative *structures* such as representatives and/or liaisons [15], collaboration *roles* such as coordinators, brokers and/or gatekeepers [15], collaborative *processes* such as reviewing or forwarding and knowledge intensity of *knowledge work*. By visualizing interview input from knowledge workers in an unbiased and non-synthesized way, KnowFlow *maintains and aids the identification of inconsistencies and conflicts* between the way different knowledge workers perceive their environment. Identifying such knowledge work constellations help in gaining an understanding about knowledge work practices, and therefore can represent a basis for subsequent analysis and negotiation of new ways of collaboration.

4 Analyzing Social Network Structures

Because the KnowFlow Report Tool generates graph-based visualizations of knowledge work, existing work in the area of *electronic knowledge brokering* and *sociological methodology* can be utilized for analyzing the resulting models. The contribution of [15] for example introduces a set of graph-based network structures that represent specific knowledge work constellations. [15] argues that for different distributed knowledge work practices (e.g. demand or supply driven), different network structures need to be employed. The KnowFlow Report Tool aids in identifying network structures, such as brokers, by visualizing knowledge flows between knowledge workers based on graph visualizations. Because such network structures are often implicit, and sub-consciously executed, KnowFlow represents an aid for knowledge analysts to make these aspects of collaborative knowledge work practices visible. In addition to different types of network structures, [15][6] identifies different types of brokerage relations in networks. Figure 5 introduces the five different structural types of brokerage relations defined by graph-based characterizations, which makes these characterizations especially interesting in the context of this work. KnowFlow might for example automatically infer such brokerage relations inherent in distributed knowledge work practices from a generated *Role-Based Knowledge Flow* report. The brokerage relations depicted in Figure 5 include the following types [15]. *Coordinator*: The brokerage relation is completely internal to the group, *Itinerant broker*: Two principals belong to the same subgroup while the broker belongs to a different group. *Gatekeeper*: Broker and knowledge user belong to the same subgroup while the knowledge generator belongs to a different group. *Representative*: Broker and knowledge generator belong to the same subgroup while the knowledge user belongs to a different group. *Liaison*: Broker, knowledge generator and knowledge user belong to different groups. The broker links distinct groups together.

The identification of such groups is facilitated by the KnowFlow *model architecture*, the availability of *role hierarchies* (the organizational roles reference model) and available *role-location associations*. Analyzing brokerage relations and network structures can lay the basis for a conceptual reorganization of distributed knowledge work practices. On a technological level, the definition of to-be relations can lay the basis for design. By modeling distributed knowledge work practices along organizational (business process- and roles reference model) as well as cultural and technological dimensions (location-, knowledge transfer- and storage reference models), the KnowFlow Framework illustrates how knowledge work analysis approaches can be integrated with social network analysis. To explore the viability of the introduced concepts we have applied the KnowFlow Framework and Tool to a real-world setting.

[6] based on [8]

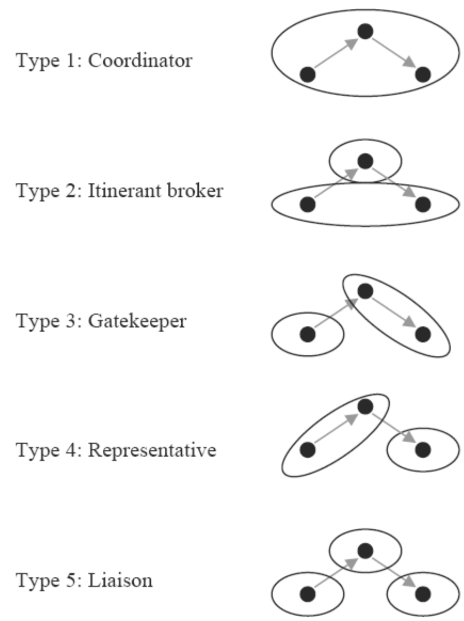

Figure 5. Types of Brokerage Relations [15]

5 An Explorative Case Study

We have conducted an explorative case study employing the KnowFlow Framework and Toolset for identifying and analyzing distributed knowledge work practices in a geographically dispersed software development organization. In this section, we report on preliminary results obtained from the case study and give an outlook on the potentials of the KnowFlow Toolset in the context of this study. The main epistemological driver for this explorative case study was investigating the *feasibility of distributed knowledge work analysis approaches*. By applying the KnowFlow Framework and Toolset in a real world scenario, we aimed to elicit potentials and obstacles by conducting *qualitative analysis*. Because in this case study traditional knowledge work analysis approaches were not considered to be feasible by the case study company, no comparative analysis could be conducted.

5.1 The Case

In a software development company, the framework and the tool introduced in this paper were used to identify distributed knowledge work practices based on the execution of KnowFlow facilitated, web-based interviews. The main focus of this case study was to identify knowledge flows between organizational roles and between business locations in order to redesign and support ongoing distributed knowledge work practices. Employing new or adapting existing information technologies to improve collaboration among these roles was among the most pressing project goals of representatives of the case study organization. The case study took place in the sales division of a software development company, which in total employs 100 individuals. The case study focused on investigations of collaborative knowledge work practices among a group of *Key Account Managers (KAM), Partner Account Managers (PAM), Telesales (TS) and Pre-Sales (PS) persons* in *four different locations* spanning *three different countries*. To obtain the necessary empirical information, six employees (3 KAM, 1 PAM, 1 TS, 1 PS) were interviewed with the help of the KnowFlow Interview Tool. Before conducting the interviews, the necessary KnowFlow reference models were set up by the analyst as a controlled vocabulary for the interviews in cooperation with the project manager of the case study company. Figure 6 depicts a result fragment of the conducted interviews and gives a more complex example of knowledge flows identified with the KnowFlow Framework and Tool. In this example, the knowledge domain descriptions were replaced by numbers to anonymize the obtained results.

The complexity that emerges from KnowFlow interviews turned out to be considerably high, and demonstrated the need for algorithms to manage the complexity of distributed knowledge work practice models in an effective way. This issue was addressed by the KnowFlow Toolset on two levels: While *pre-modeling reference models* within the KnowFlow Interview Tool narrowed the scope of investigations, the KnowFlow Report Tool provides a *series of functionality* to deal with the complexity on a visualization level (thereby addressing some of the issues of SNA highlighted by [34]), including: 1) generation of different views on the gathered data (*different reports*) 2) *parameter based filtering* of graph elements (including statistical parameters such as threshold filtering to hide knowledge flows with only few nominations) 3) *auto-layouting* of graphs 4) *graphical reorganization and manipulation* by knowledge analysts and 5) *color coding* of the introduced reference elements. Figure 6 was manipulated by means of this functionality to reduce the complexity inherent in these models to a level that is cognitively manageable.

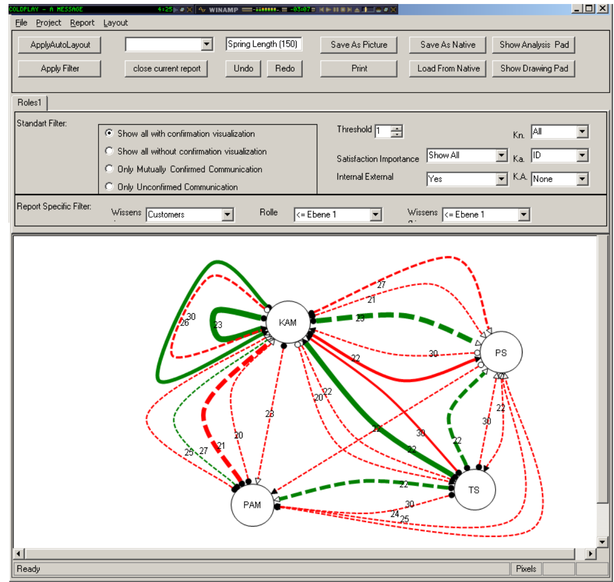

Figure 6. Case Study Results: A Role-Based Knowledge Flow Report

5.2 Preliminary Results

One of the main results obtained from this case study is the observation that the application of the introduced approach is feasible. The distributed knowledge workers were able to relate to and answer the questions of the KnowFlow Interview Tool while knowledge analysts were able to develop the reference models, and comprehend and make sense out of the graph visualiations provided by the KnowFlow Report Tool. The resulting models maintained a sufficient level of detail as judged by the analyst and a representative of the case study organization. The elicited role-based knowledge flow reports, *together with more detailed knowledge transfer and knowledge storage reports*, provided insights for the identification of, for example, *heterogenous usage of existing systems* and *conflicting views on work procedures*. In order to identify such situations, knowledge analysts discussed and *interactively explored* the resulting reports together with the project manager of the case study organization (co-located with the analyst) by searching for knowledge flow patterns, as introduced previously. Especially *unconfirmed* knowledge flows represented a basis for the identification of conflicts. During that process, the aforementioned complexity management functionality of the KnowFlow Report Tool (filtering, layouting, etc) proved itself to be helpful for interactively exploring the models of distributed knowledge work. In cases where the interpretation of the gathered data was ambiguous, the answers given were checked back with the interviewees via phone. During that process, the analyst and the project manager could develop a picture of how knowledge work is conducted in this distributed setting. This included finding answers to questions such as: *Which knowledge transfer and storage objects are used in the context of a specific knowledge flow? What kind of knowledge do two specific business locations exchange, and how? What are the most knowledge intensive business processes, and to which degree is the according knowledge dispersed across countries? Which technological systems are frequently used, which ones are largely abandoned? What kind of functionality does a new, improved knowledge infrastructure require?* Based on the insights gathered, the case study company was able to deduce coarse-grained implications for the underlying CSCW system (such as *implementation of technological support for "representative" brokerage relations* in the sales department). However, as KnowFlow is considered to be applied in early phases of analysis, complementary activities (following traditional systems design methods) were necessary to develop a complete and detailed design of the CSCW system.

Finally, the application of KnowFlow enabled the case study organization to conduct analysis of distributed knowledge work in an environment where there were no resources available to 1) get all relevant roles to a common location or 2) get the analyst to visit three different countries. So having KnowFlow allowed for conducting knowledge work analysis in a setting where the application of traditional knowledge work analysis approaches would have been *prohibitive* and existing SNA approaches would have been restrictive and would have lacked necessary modeling dimensions. Therefore, the productivity of the KnowFlow approach can be regarded to be *above the critical modeling productivity* of this specific case study setting, while traditional knowledge work analysis approaches were considered to be *below that threshold* because of limited resources for necessary co-location. The effects of distributed modeling on *modeling quality* could not be evaluated in detail in this case study because of a lack of comparative models. However, the informal feedback given by the case study organization provides anecdotal evidence that modeling quality was sufficient in that specific case. Future evaluations might include investigations of model quality including *pragmatic quality, perceived semantic quality or language quality* [16].

Visualizations of collaborative knowledge work practices as introduced in figure 6 can represent the basis for the design of knowledge infrastructures as it was demonstrated in earlier, non-distributed studies [29]. Based on analysis of interactions between knowledge workers, knowledge portals were developed and connected through an infrastructure based on the commercially available knowledge management system Hyperwave that effectively supports knowledge workers in the execution of their respective business processes [29].

5.3 Lessons Learned

During case study execution, the development of *appropriate* reference models has proven to be critical to the process of modeling. In this case study, the reference models were developed by the analyst in cooperation with the project manager of the case study organization. From the experiences gained, we learned that there might be iterations necessary for reference model development. Also, the web-based interview interface proved itself to be sufficiently usable for interview execution, based on informal feedback provided by the interviewees. Having a toolset available that *unifies the collection and visualization of analytical data* reduced the efforts of modeling (as opposed to approaches that rely separate tools). However, analyzing the developed models has proven to be labor-intensive and more algorithmic support (by, for example, implementing an algorithm for identifying the introduced patterns) would have been helpful to reduce the efforts for knowledge analysts. Also, motivating employees to participate in this new approach to modeling has turned out to be difficult, despite expected benefits such as reduced efforts and the absence of travel.

5.4 Critical Discussion

Because only six individuals took part in the study, the ability to draw conclusions regarding the scalability of such approaches is limited. However, since introducing more interviewees to the process of modeling does not create much more efforts for knowledge analysts (as compared to traditional, co-located interview settings), it can be expected that a higher number of interviewees can be easily accommodated by the KnowFlow approach on a technical level. On a conceptual level, increasing the number of interviewees might make more complex reference models necessary - which could impair the usability of the web-based interview screens. Integrating different views of knowledge workers in an unbiased way aided increasing the level of intersubjectivity (compared to other approaches where analysts subjectively synthesize the results from modeling workshops). By maintaining individual interview results, inconsistencies and conflicts could be identified and traced back. However, the effects of our approach on modeling quality could not be investigated in greater detail, because of a lack of comparative modeling efforts. Nevertheless, the organization participating in the case study was willing to sacrifice model accuracy for a decrease of the costs of modeling, thereby clearly making a trade-off between model productivity and -quality. Traditional modeling approaches that require co-location of knowledge workers and analysts were ruled out by the organization because of the costs involved. Other approaches to modeling, such as phone-based interviews, would have had the drawback of necessary labor-intensive, hand-crafted post-processing and model development. In that sense, the introduced KnowFlow approach represents a new way of modeling under distributed conditions - through virtualizing the data collection process on one hand (and thereby increasing modeling productivity), but at the same time accepting a certain loss of modeling quality on the other.

6 Comparison to Existing Approaches

Figure 7 relates the KnowFlow framework to SNA and knowledge work analysis by comparing these approaches regarding the degree of automation during the model development process and the model quality (in terms of level of detail, accuracy, comprehensiveness). In contrast to many

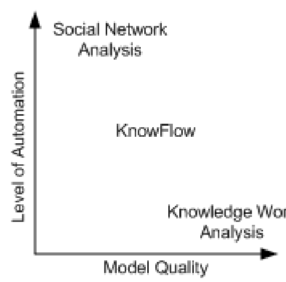

Figure 7. Illustrating the KnowFlow Approach in Relation to SNA and Knowledge Work Analysis

SNA approaches (such as [3, 4]), the KnowFlow Framework does not rely on the availability of logs / log files in order to identify social networks, but on web-based interviews. Thereby, KnowFlow can be applied in situations where log files might not be available, or the social network encompasses interactions that are critical, but are not represented in logged data. In other words, KnowFlow is able to capture what log files do not capture (such as conversations at the water cooler, i.e. informal, non-electronic communication). The rich model architecture of KnowFlow enables novel analysis of socio-technological systems. Similar to available approaches such as [3], KnowFlow is able to identify relations between *individuals*. But in addition, KnowFlow integrates informal social networks with the formal structures (such as organizational hierarchies, procedures, institutions) that can be found in organizations. Thereby, KnowFlow can identify and visualize relations between *roles*, *business processes*, *business locations* and *storage* and *transfer objects* in a level of detail that has not been available with traditional SNA approaches. On the downside, when compared to SNA, KnowFlow increases the efforts necessary for modeling by relying on interview data. However, these efforts are still significantly lower than available approaches from the domain of knowledge work analysis. By introducing web-based interview interfaces that enable knowledge workers to provide information about their environment in a self-directed way, KnowFlow decreases the efforts necessary for knowledge work modeling, while sacrificing a certain degree of model quality.

7 Conclusions

The observation that distributed knowledge work analysis could be applied in an explorative case study motivates further research and has some interesting implications: First, such new approaches have the potential to fill the gap between social network analysis and traditional knowledge work analysis approaches by being applicable in a distributed environment while still maintaining complementary modeling dimensions. Compared to SNA, approaches such as KnowFlow can lead to richer information about distributed knowledge work practices. Second, the influence of distributed approaches on modeling quality are currently not understood in detail and need further investigation. This also relates to understanding the *sufficient level of detail* that is necessary for developing effective CSCW systems. However, by following a "*Get Overview First - Add Detail later*" principle, the KnowFlow approach is applied in early stages of analysis, for focus setting of subsequent efforts. Third, questions of model evolution, that is the maintenance of model accuracy along time, need further investigation in distributed settings. While in traditional knowledge work analysis analysts are in charge of regularly maintaining models, knowledge workers might be more integrated into that process in the future - thereby potentially reducing efforts for analysts.

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