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Modeling Approaches in the Early Phases of Information Systems Development

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Abstract

Modelling the real life plays a significant role in Information Systems Development (ISD). There are several approaches that can be utilized, with different emphases on methods and notations. Some of them are well-known, like the traditional process modelling approach, while some newer ones are not widely known, like the Activity Driven Approach. In this paper we study modelling approaches in the early phases of ISD with two dimensions – the scope (technical – social) and the degree of structure – and create a map of modelling approaches. Traditional process modelling, socio-technical and Activity Driven approaches are located on the map in order to provide an overview of the approaches and their relations with each other.

Keywords: Information Systems Development, Analytical Modelling, Socio-technical approach, Systems analysis and design/development.

1 INTRODUCTION

Information systems (IS) serve as instruments or tools for work activities. By IS we mean a socio-technical system that consist of information, technology, system, communication, organization and people. In order to create appropriate, sustainable and usable information systems in organizations, adequate understanding of the business activities of the target domain of IS development (ISD) should be achieved as a starting point to further ISD activities. (Mursu et al., 2007)

In the analysis phase, modelling is an important activity that has a high contribution as a success factor in ISD projects (Bandara et al., 2005). Business processes modelling is one of the most common approaches in the early ISD phases (e.g. Sommerville, 2001). We adopt the definition by Bandara et al. (2005) for business process modelling: "*term 'Business Process Modelling' encompasses all graphical representations of business processes, and related elements such as data, resources, etc., as employed for diverse purposes including process documentation, process improvement, compliance, software implementation or quality certification, among others.*" Several notations are widely utilized to support modelling, e.g. UML and BPMN.

Business processes are complex organizational phenomena, which are influenced by human factors and thus sensitive to situations and context realities. Traditional notation-based process modelling has met critique for being partially insufficient to cover human aspects, dynamics and contextual realities (e.g., Lindsay et al., 2003; Melão & Pidd, 2000). To overcome those limitations, there is a variety of extensions to process modelling (e.g., Nurcan et al., 2005; Lunn et al., 2003; Arsanjani, 2002). Alternative approaches, e.g. socio-technical approaches, with a wider organizational scope of models, are embracing the social dimension and enabling the integration of human and technological practices (Atkinson, 2000; Alter, 2008; Checkland, 2000).

We argue that the basic object of analysis in the early phases of ISD should be *work activity system* instead of separate processes. The Activity Driven (AD) approach provides analytical models for work-oriented ISD. It is based on Activity Theory (e.g., Hedegaard et al., 1999) and Developmental Work Research (Engeström, 1999). It has been elaborated on and tested for more than a decade in several research and pilot projects in the University of Kuopio, resulting in the Activity Analysis and Development (ActAD) framework (Korpela et al., 2004) and the Activity-driven ISD Model (Mursu et al., 2007) for analysis and descriptions; and our research group have encouraging experiences of the practical applicability of the approach. AD approach, however, is not very familiar to large audience. At this stage of method development it is important to position the AD approach in relation with other approaches, and we start this exercise with positioning it in the field of modelling.

The objective of this paper is to sketch a map of modelling approaches which can be used in the early phases of ISD and to position the AD approach within it. To create a map of modelling approaches, we review modelling literature and study the features of different modelling methods and approaches. We study (1) examples of 'traditional' process modelling, (2) goal-driven methods as extensions to traditional process modelling, and (3) socio-technical approaches as examples of alternative approaches. The objective of this paper is not to present an in-depth literature survey on modelling, but rather grasp the essence of different approaches to locate them in the map of modeling field.

The rest of this paper is organized as follows. In chapter 2 we clarify the research question and research approach of the paper. In chapter 3 we review literature concerning modelling quality and model features in order to create a basic map for modelling approaches. In chapters 4, 5 and 6 we locate traditional process modelling, socio-technical approaches, and the AD approach, respectively within the map. In chapter 7 we discuss the mapping and in chapter 8 conclude the paper.

2 RESEARCH QUESTIONS AND RESEARCH APPROACH

The research question of this paper is three-folded:

1. What kind of map is needed to position modelling approaches that are used in the early phases of ISD in relation to each other?
2. How are the commonly known approaches positioned?
3. What is the position of the AD approach?

We draw from previously reported studies; both literature surveys and individual studies. Since there are many surveys and evaluations concerning modelling approaches, techniques, and methods as well as the quality and the purpose of models, reported by different authors, we avoid repeating that kind of surveys. Instead we appreciate the previous work of the authors and highlight their findings.

We use logical analysis to extract dimensions for the map of modelling in order to position different approaches in relation with each other. Next we position commonly known approaches on the map by locating some well-known representatives of process modelling and alternative approaches. In metaphorical sense, the examples serve as “landmarks” for the map. Then we discuss the features of the activity driven approach against the map dimensions, and accordingly position it on the map. In other words, we use a metaphorical map to describe the field of modelling, and use examples of commonly known approaches as “landmarks on the map” to clarify how different approaches are positioned on the map and with each other.

3 MODELLING CONSIDERATIONS IN THE EARLY PHASES OF ISD

Modeling is a way of grasping an idea of real world phenomena into a simplified illustration, i.e. a *model*, showing what is essential in order to reach the goal of modelling (Curtis et al.,1992). A model is expressed with a more or less organized notation; often graphical diagrams, but also text or tables can be used. The modelling process and the desired outcomes vary according to the purpose of modelling (Recker, 2007). Choosing right approach and notation for a specific purpose, increase chances for success (Bider, 2005).

The purpose of a process modelling exercise can be, e.g., business improvement, documentation, automation or simulation (Recker, 2007); or learning a business process, making decisions on the process or developing business process software (Aguilar-Savén, 2003). Software process modelling purposes according to Curtis et al. (1992) are to facilitate human communication and understanding, to support process management and improvement, to support automated guidance in performing process and automated execution.

Regarding the guidance and methods of modelling in ISD, there are a few methods guiding the early analysis phase (Dorn et al., 2007). Especially regarding the communication between the IT and domain experts, the feature “understandability” is highlighted (Aguilar-Saven, 2007; Tuomainen et al., 2007). Models should be descriptive for IS developers, but also facilitate learning and actions within the working environment (Krogstie et al. 2006; Giaglis, 2000). We emphasize that getting started with a modelling exercise for some specific purpose is often a fuzzy phase.

Since there are lots of modelling approaches, methods, and tools, each having their own emphasis, it might be difficult to select one. There are several studies that result in evaluation or classification frameworks aiming to make the selection easier. Heeks (2006) and Sedera et al. (2004) study the success factors of ISD projects and Iden et al. (2007) study the success factors of modelling in general. Some studies focus on the features of process modelling, e.g., process *modelling quality* (Hommes & van Reijswoud, 2000), *techniques* (Hommes & van Reijswoud, 2000; Aguilar-Saven, 2007; Giaglis, 2001), process *model quality* (Recker 2007), and business process modelling *languages* for health care (Rad et al., 2007). All these studies provide lots of detailed information.

Factors impacting the quality of modelling can be associated with the models themselves (scope, form and tool support), the project (way of working, purpose, planning) and the modeller (knowledge of models and the target domain) (Bandara et al., 2005; Hommes & van Reijswoud, 2000). In the beginning of a modelling exercise, two main considerations will be the modelling concepts and the modelling procedure (Aguilar-Savén, 2003). These considerations will be dependent on the purpose of modelling and the modeller's expertise (Aguilar-Savén, 2003; Hommes & van Reijswoud, 2000, Bider,2005). Model quality is one of the success measures of a modelling exercise, together with user satisfaction, individual impact, process impact and project efficiency (Sedera et al., 2004). Documented models and templates are quite stabile features within different approaches, compared to e.g. ways of working, which can be considered as a situation sensitive feature.

Recker (2007) has a quality framework for models with three levels: syntactic, semantic and pragmatic level quality. On the syntax layer, the formal relations between the signs of the model are described. On the semantic layer, the relations between real world entities and their representations (the signs of the model) are described. On the pragmatic layer the human aspect is brought in by addressing the question of the usefulness of the model for its users and their particular purposes. Thus pragmatic quality can be seen as a subjective matter and dependable on the needs of the users.

3.1 The map of modelling approaches

We intend to characterize different approaches with the models used within each. In order to create a map of modelling we utilize model quality aspects to sketch the map itself. We use two independent dimensions describing the features of the approaches, namely the *scope* and the *degree of structure* of the models. We define the scope of a model as follows: *the set of real world phenomena which are represented by the elements in the model*. We define the structure of a model as follows: *the definitions of relations and rules between the elements and sets of elements*. The scope is related to the semantic and pragmatic aspects, and the degree of structure is related to the syntactic aspect of a model.

We use the scope of the models as the horizontal axis of a two-dimensional map of modelling approaches (Figure 1). Along this axis, the scope of models varies as follows. Approaches focusing on technical issues only are at the left end and ones focusing only on human, social and organizational issues are at the right end. A holistic approach covering a wide range of issues spans across the axis.

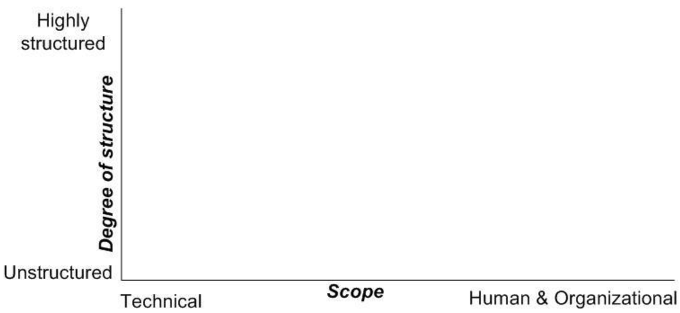

Figure 1. Initial map of modelling approaches with two dimensions: degree of structure as vertical axis and scope as horizontal axis.

Correspondingly we use the degree of structure as the vertical axis of the map as follows. The bottom end represents ad-hoc intuitive structures, like free text, boxes and arrows, and the top end represents highly structured, formally defined languages with theoretically based and organized elements. An approach that includes formal specifications of the models is thus positioned high on the axis.

The purpose of the map it is not to evaluate existing approaches, but rather to give a comprehensible overview on the field of modelling approaches. Moreover, the dimensions are qualitative and heuristic rather than quantitative. Therefore, there are no explicitly defined scales on the axes.

4 PROCESS MODELLING

In this chapter we position process modelling approaches on the map. From the literature, critical reviews and research papers concerning process modelling we can draw phenomena that are included in the models, or should be included but are lacking. In subsection 4.1 we discuss notation-based approaches and in subsection 4.2 goal-driven approaches.

4.1 Notation based process modelling approaches

Dorn et al. (2007) categorize approaches to business process modelling in five categories: pure UML (particularly Activity Diagrams), UML based approaches, Business Process Modelling Notation (BPMN), Event Driven Process Chains and Integrated Definition Languages (IDEF). All these traditional process modelling approaches share the feature of well defined notation, but lack a clearly defined method for the use of the notations. The notations can be used together with several methods defined within e.g. goal-driven or other approaches. Thus we call traditional process modelling approaches *notation-based approaches*.

In order to define their location on the horizontal axis, we need to study the scope of the models. For that purpose we draw from critical reviews on lacking features and elements in the notation based approaches. Most of the above mentioned notations support the “mechanistic view” to processes (Melão & Pidd, 2000), neglecting the human, social and organizational factors (Lindsay et al., 2003). There is a weak support for modeling:

- collaborative processes, seen as a combination of different viewpoints of the participants or work distribution (Dorn et al., 2007; Russel et al., 2006),
- communication and information flows with satisfactory linkages with the processes (Lunn et al., 2003; Danesh & Kock, 2005; Tuomainen et al., 2007),
- controlling human-driven processes (deMan, 2009),
- business goals, roles of the stakeholders, and stakeholders’ goals (Lindsay et al., 2003; Lunn et al., 2003; Nurcan et al., 2005), and furthermore, traceability from goals to IT functionality (Lunn et al., 2003; Nurcan et al., 2005; Arsanjani, 2002),
- resource related and organizational aspects linking processes with respective resources needed (Tuomainen et al., 2007; Russel et al., 2006; Mentzas et al., 2001),
- traceability and interdependencies of tasks and processes (Lunn et al., 2003; Mykkänen et al., 2006),
- handling of uncertainty (Mentzas et al., 2001).

The scope of the notation based approaches is quire narrow, and the position on the horizontal axis is accordingly at the left end (Figure 2). Because they feature well defined structured notations we can position notation based approaches in high into the vertical axis.

Despite the existence of plenty of formal methods, *ad-hoc flowcharts* are still used in practice (Tremblay, 2004). In flowcharts, boxes and arrows are used creatively depending on situational needs without explicit formalism. Therefore we locate them also on the map, at the bottom left corner.

4.2 Examples of goal-driven approaches

Goal driven approaches are widely spread to process modelling in order to capture the relations between business processes and business goals; thus expanding the scope. There are several different approaches that we briefly refer to, in order to achieve an understanding of the elements extending traditional process modelling. After that we can use goal driven approaches as an example of an extension to traditional process modelling as a landmark on the map.

A well grounded example of a goal driven method is described by Arsanjani (2002). Arsanjani's method combines business goals with core business processes in order to find use cases, and proceeds to component design. Lunn et al. (2003) define a 6-step method starting from the identification of stakeholders and their goals and proceeding to a detailed elaboration of the desired systems functionality. The identification of the different stakeholders and their goals is the starting point of the analysis. Another novel goal driven approach is provided by Nurcan et al. (2005). They present a method for modelling processes with a notation of directed graphs. The processes are defined in terms of goals and strategies to reach the goals. The form of the directed graph serves better than the traditional flowchart in capturing dynamic processes.

From these examples we can conclude that goal driven methods provide models and means to define and analyse goals and to identify stakeholders, thus to some extent to identify interaction and human factors also. Despite of clear descriptions of the methods provided in the articles, the extensional elements are not formally structured. Thus we can locate goal driven approaches a little lower than traditional methods along the axis of the degree of structure, and a little further right along the axis of scope (Figure 2).

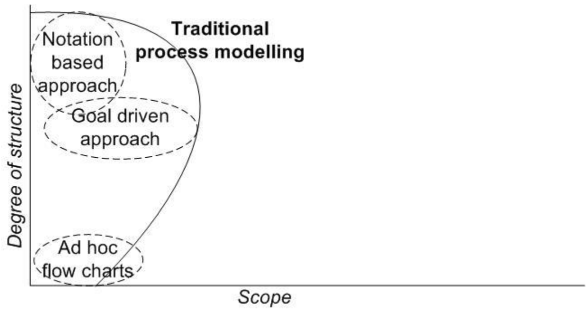

Figure 2. Process modelling approaches positioned on the map.

5 SOCIO-TECHNICAL APPROACHES AS EXAMPLES OF ALTERNATIVE APPROACHES

In order to take technical, organizational, economic and social aspects into account in modelling, several socio-technical approaches have emerged. Work System Method (WSM) (Alter, 2008) and Soft Systems Methodology (SSM) (Checkland, 2000) are examples of well established socio-technical approaches. There are also other such methods, like ETHICS (Mumford, 2000), but due to the space limitations, only WSM and SSM are used as landmarks in order to locate socio-technical approaches on the map in this paper.

The methods have a communicative and participatory emphasis on data collection and validation activities. It is also common to them that their major concerns include human and social aspects, thus expanding the scope of modelling towards a holistic view on ISD. This may also cause a reduced emphasis on technological issues. The structure of the models is not as strictly defined and the notations are not as explicit as in process modelling approaches.

The Work System Method moves the focus of ISD from the IT artefact to *work system* as the unit of analysis and modelling within ISD (Alter, 2008). Alter defines work system as "a system in which human participants and/or machines perform business processes using information, technologies, and other resources to produce products and/or services for internal or external customers." The methodology offers a static view (work system framework) and a dynamic view (work system life cycle model) to the work system. The work system framework defines nine elements of work system facilitating the modelling activities. *Business processes* are described in relation to *participants*, *information* and *technology* on the one hand, and with *products and services* on the other hand. Products and services are related to *customer*s. These elements are surrounded by e*nvironment*, *strategies* and *infrastructure*). Work system life-cycle model provides elements to facilitate the management of change. (Alter, 2008)

Soft Systems Methodology, SSM, can be expressed in seven stages. It starts by creating a current state description and continues with design activities and implementation. The method provides a useful checklist (CATWOE) to capture an understanding of the problem under study. CATWOE stands for Customers, Actors, Transformation process, World view, Owner, and Environmental constraints. The methods utilize rich pictures and informal notations in descriptions in order to make communication between designers and users easier, improving the understandability of models. (Checkland, 2000)

The socio-technical approaches differ from notation based process modelling in that they emphasize the ways and guidelines of analysis, i.e. methods versus notations. They provide lists of relevant phenomena what should be modelled, yet allowing liberties in the selection and use of notations. Therefore WSM and SSM can be situated on the middle level of the vertical axis on the map. WSM provides more structured models than SSM, thus WSM is positioned a bit higher than SSM. As seen from the examples above, in order to achieve a holistic view, the amount of considerations (the scope of the models) is richer than in the process modelling approaches. Detailed technical descriptions do not belong to the models. Therefore we position WSM and SSM covering an area near the right end of the horizontal axis (Figure 3).

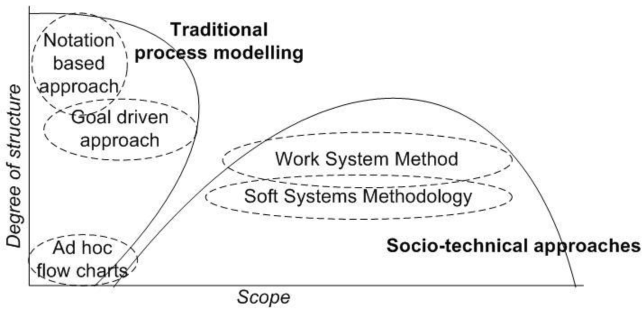

Figure 3. Examples of socio-technical approaches located on the map of modelling approaches.

6 THE ACTIVITY DRIVEN APPROACH

Activity Theory (AT) is a socio-cultural theory which has been applied mostly in the fields of learning and education, and work development and since the 1980’s in the field of software development and ISD (e.g. Kuutti, 1991; Nardi, 1996, Bødker 1991), mostly in Human Computer Interaction and Computer Supported Cooperative Work research. In this paper we focus on Activity Driven (AD) approach based on ActAD framework (Korpela et al., 2004) and the Activity-driven ISD Model (Mursu et al., 2007).

According to the AD approach the starting point and the focus of ISD activities should be work itself, not just plain IS or software requirements. This differentiates AD from traditional process modeling, but stands in line with socio-technical approaches. The basic unit of analysis within AD is *systemic work activity* (Korpela et al., 2004), in which the elements and the structure are based on Activity Theory, AT (e.g. Hedegaard et al., 1999) in general and the ActAD framework particular. The theoretical basis differentiates AD from other socio-technical approaches.

In order to provide the reader with a basic understanding of the principles of the activity driven approach, we discuss it in relation to the scope and structure of the models it provides: the ActAD framework (Korpela et al., 2004), Activity-driven ISD Model (Mursu et al., 2007) and the “landscape” framework (Korpela et al., 2008).

6.1 The scope of the AD approach and the degree of structure in the models in it

Within a systemic work activity, several people work upon a shared object in an organized way to produce a common outcome. The elements of a work activity are: *actors*, *object*, *work process*, *outcome*, *means of work*, *means of coordination and communication*, *collective actor* and the *mode of operation*. These elements are depicted in the ActAD framework (Korpela et al., 2004) which also provides a graphic notation illustrating the elements and the relations between them – the structure of work activity as a systemic entity.

The Activity-driven ISD Model is a holistic model which covers the different elements and levels of work activity and work processes (Mursu et al., 2007). With the model, the target domain is analyzed on three levels: actions on the *individual* level, collective activities on the *group* level, and networks of activities on the *organizational* level. The work activity system, illustrated by the ActAD framework, forms the basic unit of analysis and initiates the group level. Single activities can be linked with each other as a network of activities in one direction, and refined as actions by individuals in the other direction. On each level both intra and inter viewpoints (within and between units of analysis) are taken into account in analyses. The levels are traceable with each other and the higher level represents the context to the next lower level: an individual action can be seen as part of a group level activity which is further part of a network of activities on the organizational level.

Sometimes it is important to understand the broader socio-political context around the basic object under study. The AD approach provides a tentative methodology to depict the “landscape” around information systems, consisting of the geo-political “canvas” and four layers depicting flows of authority, financial flows, service flows, and information flows (Korpela et al., 2008). The layers help in balancing the amount of detail on the one hand, and the adequate understanding of issues affecting the target domain on the other hand. Especially the services and the information layers can be related to the work activity system. The “landscape” methodology broadens then the scope of the AD approach.

It is noticeable that the AD approach differs from approaches with e.g. management or IT emphasis by facilitating the analysis from the cooperative perspective of different kinds of workers and their information needs. Traditional BPM is often highlighting the managerial viewpoint to business activities, and UML traditionally highlights the software design and technical issues.

Activity driven needs analysis is intended to be used for ISD purposes, thus highlighting the information needs within work activities. The starting point is to analyze work activities, from the viewpoint of how different kinds of work tasks are *actually conducted* and what kind of information the actors need within those tasks. At each level the work is linked up with information system, and analyzed with different amount of detail. In early ISD phases especially linking the information elements with other activity elements (e.g. actor; workflow; location, time or event of use; and mediating information tool) supports the goal of achieving the information needs within work activities.

6.2 Positioning the Activity Driven Approach on the map

From sections 3, 4, 5 and 6 we can draw the following arguments:

1. Position on the vertical axis, representing the degree of structure: AD has not a formal language thus it should be located at a lower level than the notation-based approaches. However, it provides graphic notations with explicit theoretical foundations, which position it at a higher level than the previous socio-technical examples (Figure 4).
2. Position on the horizontal axis, representing the scope: AD does not strictly facilitate detailed technical descriptions, but rather has a high emphasis on work activity. AD has means to model information systems and information as tools within work activities, human and

organizational aspects and furthermore, a tentative "landscape" methodology to depict broader contexts. Thus we can position it on an area covering the right end of the axis and also some overlap with process modelling (Figure 4).

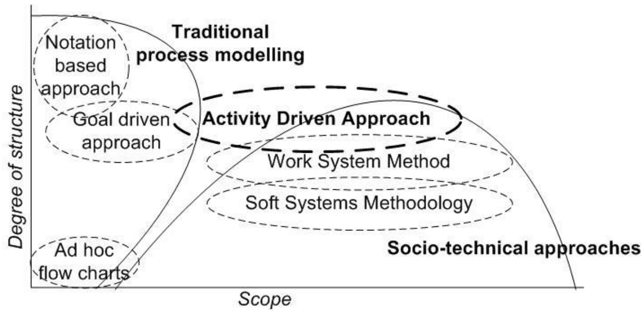

Figure 4. Positioning the AD approach within the modelling field.

7 DISCUSSION

In the literature there are several ways to compare different modelling approaches. Some of them mixes features of models and methods in same comparison, or cover larger objects of study than modelling, e.g. IS development, or focus on comparing e.g. modelling tools. In one hand these thoroughgoing studies give a rich view to modelling, but in other hand the great amount of detailed information might blur the essence. In this paper we created a map of the modelling field, based on essential features of the *models* - the scope and the degree of structure- used in different approaches. A model which is used within a modelling approach can be considered as a relatively stabile feature, while project, modeller or tool can vary according to the situations. Thus we regard *the models of different approaches* as suitable basis for seeing the essential differences between different modelling approaches.

Because of the purpose-oriented nature of modelling, also quality aspects might vary according to the purpose of modelling. In the earliest ISD phase, analysis, the purpose of modelling is to grasp an understanding of the domain activities, and identify needs for development. In that phase models serve as means of communication and as means of analysis in order to achieve a shared understanding between the possible end users and the designers and implementers. In the design phase, models facilitate designing the to-be system, representing the processes of the solution, e.g. HCI and the functional principles; thus giving guidelines to the development phase, where the most fine-grained models of processes conducted by the application are needed presenting the inside logical algorithms of the application. In the implementation and deployment phases, the focus moves backwards toward the human aspects, where guidelines and training for the users may be facilitated by process models. Hence, requirements concerning the scope, granularity and formality of models vary in the different phases accordingly.

In the early phases of ISD, considering the models as means of communication and as means of analysis, the models should be pragmatic rather than formalistic (Lunn et al., 2003, Mykkänen et al., 2006), and clarity and visualization should be emphasized over syntactic rigor (Recker, 2007). The semantic aspect is important in all phases of ISD. The scope of modelling should be wide enough, and it is important that all participants and stakeholders share the same understanding and semantics. Formal (syntax) quality is highlighted in the design and implementation phases, when there is a need to e.g. realize business process models with executable process models or to perform transformations between different levels of models and executable code. Tool support for models is often related with high level of formal quality, but the existence of tool support also depends on the maturity of modelling approach.

Different approaches have different foci and different models with different degrees of structure. Most traditional process modelling notations (e.g., UML and BPMN) are associated with the mechanistic view of processes (Melão & Pidd, 2000; Lindsay et al., 2003). Goal-driven methods extend traditional process modelling by offering methods to link business goals to the processes. Socio-technical approaches provide means to take human and social aspects, like communication and the values of the stakeholders, into account in the analysis and modelling.

It is obvious that none of the approaches can fully support the whole ISD chain from target domain analysis to implementation. Traceability between domain requirements and implemented solutions is an important matter, and it should be supported by traceability between different models (Mykkänen et al., 2006; Henkel et al., 2004). Thus it is important to search for interfaces between the models and include such options into guidelines.

It seems that the further from a mechanistic viewpoint we go, adding complexity into the requirements for the methods by considering business goals, human aspects, and situation sensitive dynamics, the more ambiguous and fewer the methods become. The main object of modelling might be work that is basically not performed in the form of a process, but it is nevertheless bulldozed into process models in the descriptions. Thus some of the problems in process modelling might be rooted in that a 'process' is not the best concept for describing real life activities in all cases.

The AD approach has mostly been used in studies preceding different ISD phases, like requirements engineering phase in user organizations, implementation and deployment of new system, and decision making of integration principles of large regional system (Minkkinen & Eerola, 2007). Thus the approach can be located in the early phases of ISD activities preceding others. The approach is proven to be useful in gathering the information needs within work activities and the following analysis, suiting well in situations when there is a need for quickly clarify the essence of previously unknown target area.

8 CONCLUSION

In this paper we surveyed literature concerning modelling in the early phases of ISD, both process modelling and alternative approaches, and created a map with two dimensions: one dimension for the degree of structure in the models and the other for the scope of the models. Traditional process modelling and alternative approaches were positioned on the map. The features of the activity driven approach were discussed against the dimensions of the map and as a result, the AD approach was located on the map of modelling approaches, in relation to commonly used approaches.

To cover the whole chain of ISD phases, several modelling approaches are needed and a traceable modelling chain should be supported by integrating different models. The methods and approaches positioned on the map have been studied with a broad view in this paper, but in order to integrate models, more specific study is needed to define interfaces between the approaches.

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