Communication Workflow Perspective on Engineering Work

Žiga Turk[1] and Berndt Lundgren[2]

ABSTRACT

Information technology can only support concurrent engineering if engineering works are well understood. The prevailing approach to do this is process modeling. We found, however, that traditional process modeling techniques such as IDEF0 obscure some aspects of human works, such as communication, collaboration, coordination, client-worker relations and client satisfaction and suggest an idealized, problem free view on the engineering works. We find that the communication workflow approach addresses these problems. In the paper we provide the theoretical background of this approach and compare a tool that implements it - Action Workflow - to traditional IDEF0 modeling approach. We found that the observation of the workflow loops between customers and performers provides a good overview of what is going on and enables the study of optimization and paralelisation of the works while at the same time maintaining and improving the quality of the services and client satisfaction.

Keywords - process modeling, workflow, coordination workflow, Action Workflow, IDEF, computer integrated construction

1. INTRODUCTION

Construction[3] is characterized by complex, one-of-a kind products, designed, built and maintained by many different consultants, companies and contractors (Teicholz, 1997). The disintegration of the construction industry is the result of the complexity (in time, space and technology) of construction products. Since the industrial revolution, disintegration has been enabled by information and communication technologies that allowed for the collaboration between the specialists. In the last few decades information technologies include electronic equipment, also computers.

One of the main tasks of applying information technology to construction has been to integrate the profession, to enable collaboration and automate some of the activities. It has been believed by most of the researchers as well as the industry, that the agreement on the standardized product models and information exchange protocols is the way to achieve CIC. Standards for the representation of building product information and the exchange of product

[1] Assoc.Prof., University of Ljubljana, Slovenia; zturk@fagg.uni-lj.si; www.fagg.uni-lj.si/~zturk/
[2] PhD. Student, KTH, Stockholm, Sweden; berndt@recm.kth.se.
[3] We use the term construction as a broad term to denote civil and structural engineering products or activities.
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data are developed by International Standards Organization (STEP) and Industry Alliance of Interoperability (IFC). Both focus on product information.

Indeed, computers must know about buildings, in order to assist humans making them, however, we believe that it is also very important to know and understand what engineers do while designing, planning or building a construction product. Ultimately any software will support the human works. A very popular school of computer science would argue, that problem solving is one such activity, and that computers should at least assist, if not replace humans in solving problems (e.g. Kalay, 1985). Another school is arguing, that what we do is give, accept and fulfill commitments, and that the communication between the performer of the task and the customer of the task is very important (Wingrad and Flores, 1986). This second approach places the activities or processes as the top level concept and understand all other kinds of information, like product data, as something that is associated with those activities and only makes sense within the context of these activities.

The shift of focus product models to process models has been noted since the works of Sanvido et al. (1989) and in the IRMA model (Luiten et al., 1993). Several different process modeling techniques have been compared (Koskela, 1995), however, we find most of the approaches tried so far as being based towards understanding human work as processing and flows. This proved to be a useful paradigm to model works on an assembly line, but is it also appropriate for the modeling of intellectually demanding engineering work?

1.1 About the paper

In the last century some new theories on how humans think, work and collaborate appeared. They are the background of the so-called "workflow" software and are briefly presented in Section 2. Process modeling and workflow concepts are introduced in Section 3. The difference between traditional workflow and communication workflow is explained. The prevailing way of modeling engineering processes has been the IDEF0 methodology. We compare Action Workflow with IDEF0 in Section 4.

2. THEORETICAL BACKGROUND

Rooted in he works of Greek philosophers, the western philosophical tradition claimed that humans act rationally and that they think in terms of symbolic representations of the real world and that communication is an exchange of information about these concepts. Cognitive science believes that cognitive mechanisms in computers, humans and animals are following similar principles (Gardner, 1987). The traditional understanding of cognition, language, and intelligence has been challenged by Martin Heidegger and other philosophers (Gadamer), linguists (Austin and Searle), and neurobiologists (Maturana). Winograd and Flores (1997) summarised the effects that these ideas should have on our understanding of the role of computers. They exposed the role a computer has as a tool and media, as opposed to a more ambitious role of an assistant, envisioned by pioneers of AI. Their work, first published in 1986, is one of the landmark works in the evolution of the workflow paradigm. In construction context it was used as a baseline for an analysis of some trends of construction IT in general (Turk, 1998) and product and process modelling in particular (Turk, 1999).

In relation to studying construction processes, the speech act theory of Austin and Searle provides a different insight. It claims that communication is not information exchange but negotiation of commitments. We shall use this observation to claim that engineers are not processors in engineering processes, but nodes in commitment networks.

2.1 Tradition: work[4] is processing

Describing human activities as processes has proven very efficient for the traditional optimisation of work at the assembly lines, pioneered by Taylor in the early 20th century. The idea that the essential human activity is some kind of an involvement in processes has been adopted to model not only human manual operations, such as work at the assembly line, but intellectual processes, such as design, as well. The current understanding of the building process is:

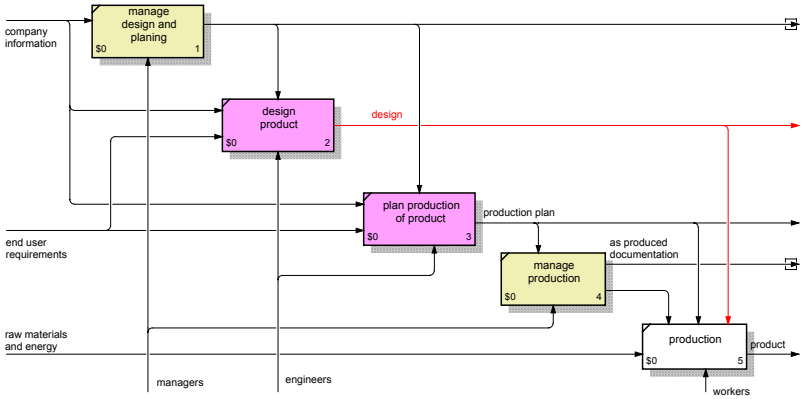

Figure 1: IDEF0 diagram of an abstract building process.

1. Building is a set of process (inception, design, construction etc.) that results in a building product (house, bridge, dam etc.).
2. Building product goes through many life-cycle phases, from feasibility study through construction to the demolition.
3. There is a consistent flow of information, from investor's specification to the detailed design drafts. The flow carries the information through the various processes.
4. Similarly to the workers at the assembly line, engineers take inputs, contribute some information, and create outputs that are passed on to the follow-up process.
5. In perspective, information will be in product models. Engineer's problem solving activities will be increasingly supported by design tools which will at first assist and finally replace him.

Information flow diagrams, such as one in the Figure 1 above, are used to describe such processes. Each of the processes (boxes) can be broken into several sub-processes. Typical activity within a process would be problem solving, that would, based on the inputs, create some added value in the outputs. The input-processing-output paradigm is also the prevailing paradigm in modelling computer software.

From this perspective, processes can be broken into material processes, information processes and business processes (Medina Mora et al, 1993) and this has been used as a top level process model for construction (Bjoerk, 1997). Information technology should support problem solving activities, as well as editing, recording, distribution, searching, retrieving and converting and converting of information (Turk, 1997).

[4] Term "work" is used as the most generic term denoting what people do. Work may happen during processes, activities, tasks etc..

2.2 Alternative: work is participation in commitment networks

The input-processing-output paradigm is well suited to describe works of a machine for grinding meat for burgers or a computer program, but is it really best suited to describe human activities?

The speech act theory would argue that the most important human activity is not "processing" like problem solving or decision making, but maintaining a network of conversations for action – *"conversations in which requests and commitments lead to successful completion of the work*". This also holds true for collaborative engineering activities in the construction business. Organizations, such as construction companies, are understood as networks of commitments between customers and performers. The customers require, and the performers fulfil certain tasks in the construction process.

The baseline for such understanding of work is the speech act theory. A speech act is something like a message, but the term "speech act" has been used by the linguists (Austin, Searle) to stress the "action" perspective of language. The speech act theory does not understand messages as transmissions of information but as the basis for action. The theory claims that the essential feature of speech acts is that they create commitments. We do not send messages and information from one engineer to another to let him know about some design information but to request his action and that he would either accept or reject a commitment.

For example, a statement that a structural engineer sends to a foundation designer, that the expected load of the structure is 500 tons means more than just that fact. It attempts to commit the foundation designer that he would design the foundation in such a way that they could carry the 500 tons. An action - act - is in the result of the speech. Austin and Searle examined different types of speech-acts and classified them into:

- assertives that commit the speaker to the truth of expressed position,
- directives which commit the hearer to do something,
- commissives which commit the speaker to some action,
- expressives and
- declarations.

2.3 Role of information technology

From this perspective, information technology should primarily support conversations for action among the participants in the project and computerise the following operations:

- **The exchange of speech acts**, possibly treating them as such, and not as simple information exchange.
- **Monitoring of completion.** The system assists in supervising the fulfilment of the commitments and for example issues warnings when a part of design is not finished in time.
- **Keeping temporal relations.** The system assists in managing the time available to each participant in the network.
- **Examination of the network.** An engineer or manager should be able to see a clear overview of his commitments and their relation to other commitments.
- **Automated application of recurrence.** Certain parts of the commitment network are often recurring – for example a change in the structural load always triggers the need for speech acts to the foundation engineer, structural engineer ... the system should be able to automate the generation of such sub-networks.

We could find some of the features listed above in the time management software (e.g. Microsoft Outlook, Netscape Calendar, and Lotus Notes). A whole family of software, called "workflow software", is specializing in exactly these kinds of systems (e.g. Action Workflow). What distinguishes the workflow software from other kinds of management or planning software is that it understands the networks of commitments, the speech acts and the messages between the people involved as the main and topmost integration mechanism of a business process.

3. PROCESS MODELLING AND WORKFLOW MODELLING

Today, the prevailing method to do process analysis in AEC is using functional analysis, usually IDEF0 process modeling technique. In this section we compare it to a communication workflow modeling technique Action Workflow.

3.1 Business process modeling

Process modeling is a process in which a description of one's understanding of a phenomenon is created, in order that his understanding could be shared by and agreed upon, by other people, particularly managers, process re-engineers and programmers. In business process modeling, a model of organization's business processes is created. Such models are basis for computer support of the processes, process-reengineering etc. A modeling technique provides:

- A synthetic language in which models can be defined more precisely than in a natural language.
- The symbolic representation of the language that can be graphical, textual or both.
- Basic constructs from which models can be constructed. Typically, these constructs are some kind of objects with properties and relations. There is a limited set of predefined attributes and a predefined set of relations that can be used to relate them with one another. The predefined relations include abstractions such as "part-of" or "is-a".
- A set of guidelines that define how to use the methodology.
- Computerized tools that implement the above.

Numerous techniques for business process modeling are available:

- **Functional analysis** (e.g. SADT, IDEF0-IDEF4) employs a graphical hierarchical representation and data flow-like diagrams.
- **Entity process modeling** provides three coherent views on a business process: the functional view (usually shown using data flow diagrams), the behavioral view (usually shown by state transition notation) and the structural view (showing which elements of the process are performed by which entities).
- **Process programming** approaches for describing software processes.
- **System dynamics** models apply the principles and techniques of feedback control systems to managerial, organizational, and socio-economic systems.
- **Petri net** models use a mathematically based graphical notation (Petri Nets) for the modeling of dynamic and distributed processes.
- **Object oriented** techniques model dynamic features of software as state transitions on lower level and scenarios on higher levels.
- **Workflow** (next section).

3.2 Workflow

Workflow Management Coalition (WFMC, 1996) defines workflow as "the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules." More broadly, workflow can be defined as a collection of tasks organized to accomplish some business process (e.g. designing a facility). A task can be performed by software systems, humans, or a combination of these.

Two different perspectives on workflow exist:

- **Activity based workflow** models focuses in modeling the work that needs to be done and breaks it up into a series of interrelated tasks. A task or an activity is a typical smallest entity out of which complex models are built. This is the prevailing view on workflow and is not fundamentally different from business process modeling.
- **Communication based workflow** focuses on the relations and communications between the people involved in the work. A relation between two persons, one ordering work and the other performing it, and the communication between them, are the main building block. Medina-Mora et al (1993) define workflow management as a "systematic organizational communication, coordination and actions among people".

In a communication workflow all work is performed in the context of a transaction between two people, one who requests it (the **customer**) and one who does it (the **performer**). What is to be done is stated in the mutually agreed conditions of satisfaction, which include a time by when work will be completed. The transaction between customer and performer has four stages:

1. **Preparation**. The performer makes an offer to provide service to the customer. Work to be done is proposed by the customer or by the performer.
2. **Negotiation**. Conditions of satisfaction are negotiated: an agreement about what is to be done is reached by the customer and performer
3. **Performance**. Work is performed and progress is communicated during completion
4. **Acceptance**. Work performed is evaluated and satisfaction or dissatisfaction is declared

This can be represented with a loop notation shown in Figure 2. Traditional process modeling techniques model only the performance stage. The best-known communication workflow technique and tool is Action Workflow, produced by Action Technologies (www.actiontech.com).

3.3 Engineering workflow

How much workflow is there in an engineer's work and what is particular about it? The most successful applications of workflow technology are reported from services and businesses with intense contacts with the end-client and where customer satisfaction is a high priority. Building is in many ways special:

- The workflow does not happen within one organization but typically involves several companies with varying levels of IT expertise.
- Engineering workflow is unpredictable; improvisation is the rule, not an exception.
- Important parts of the engineering workflow mostly "work" and not much "flow". For example engineering design process activities are performed by an engineer autonomously, at his desk, for days, with not much information flowing in or out for a long time. At least

this is the traditional understanding of it. A further analysis should show how much external communication, now improvised, done informally and ad-hoc actually happens.

4. IDEF0 VS. ACTION WORKFLOW

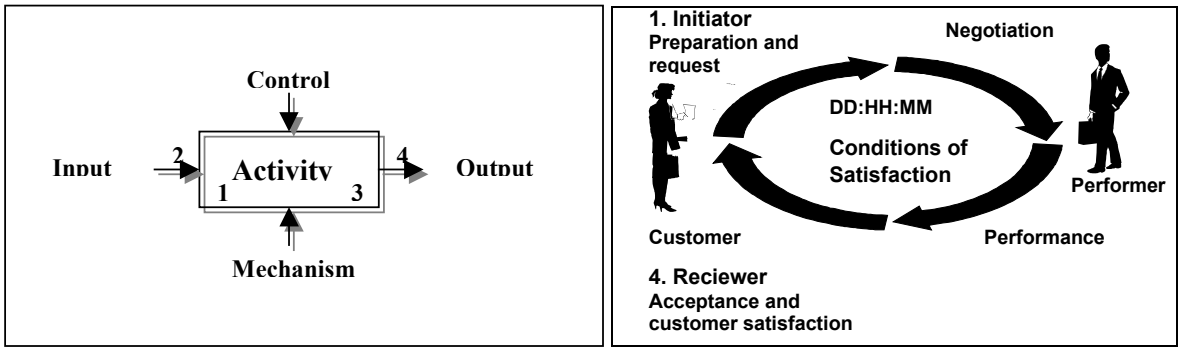

Figure 2: Basic building blocks of IDEF0 (left) and ActionWorkflow (right).

Criteria	IDEF0	ActionWorkflow
Language	Graphical only, additional attributes through forms.	Graphical only, additional attributes through forms.
Basic building block	Activity that has input, output, control and mechanism.	Loop between customer and performer.
What is modelled	Only work (performance).	Preparation, negotiation, performance, and acceptance.
Readability of language	Semantics of the IDEF0 model is fairly easy to interpret when users are trained. Practitioners tend to be reluctant when faced with more complex models. Ambiguity of control arrows vs. input arrows!	*Action Workflow* has a more simple and straightforward syntax but the view on work is different to the customary input-processing-output paradigm most people are used to.
Goal	Not explicit. Controls can be used to state demand and goal for a process.	Explicit. Demand and goal is decided by the customer and the performer. This process is called ”conditions of satisfaction” and clarifies customer's requirements. These requirements have to be fulfilled to complete the process. Time consumed is another prominent object of control as time is part of the ”conditions for satisfaction”.
Grouping	Processes are interrelated sequentially.	Activities are grouped into loops. There are 4 predefined activity types.
Cycles	No.	Yes.
Timing.	No.	Yes. Including the definition of alarms, follow up actions, reminders ...
Decomposition	IDEF0 models are coordinated sets of diagrams. The top diagram can be decomposed into hierarchically lower level diagrams with increased complexity. The purpose is to reveal the meaning of a particular activity and to show the kind of information, material or energy, which is conveyed through the interfaces (ie arrows) of the activity.	A two level decomposition: business process has several workflows. The workflow starts in one loop and each of the 4 components can be broken into another loop or initiate another workflow, which is shown in another window. This encourages thinking of a business process as a series of loosely connected workflows, as opposed to one big coherent process that IDEF encourages. If too many graphical items are in one window, several can be collapsed into one.
Links between items	Unconditional.	Conditional. Possibility to define flow splitters and rendezvous (joins).
Activity typing	Reuse of processes is difficult. Typing of processing or creation templates of typical interrelated processes is not possible.	Creation of process templates - reoccurring patterns of processes is supported and encouraged.

Criteria	IDEF0	ActionWorkflow
Involvement of people	Nothing predefined.	Concepts of customer, performer and observer built in. Separation between roles (e.g. "architect") and actors (e.g. John Doe). Distinction between business process roles ("designer of architecture") and organizational roles = job titles ("architect").
State	Concept of process state not supported.	Supported.
Conditions	Implicit, using controls.	Explicit.
Consistency checking	?	Elaborate. Tool checks for logical consistency, so that no definition created contradicts the effect of another definition; Simplicity, so that maps are not unnecessarily complex. Avoiding redundancy, so that map elements that serve no function are eliminated; Completeness, so that all essential elements of the business-process definition are included.
Resources	The mechanism in IDEF0 specify what a process need to transform inputs to output, examples of mechanisms are machines or people. Input itself is also a resource for the process, example of input are material and energy.	Time is a resource and the length of time required to perform a workflow is crucial. Reduce the "cycle time" for a process is a primary goal. Information needed to fulfil "conditions of satisfaction" is also a resource in the workflow model. (AT 1994). Data structures of the information passing through workflow can be defined.
Guidelines	The book (Marca and McGowan, 1993) is the definitive guided to IDEF0. Deeper or theoretical background is missing.	ActionWorkflow is now marketed by Cincom. The manuals and trial version are available from www.cincom.com. Winograd and Flores (1997) book provides the theoretical background.
Tools	A few commercial tools for modeling are available. Perhaps the most popular is the BPWin (www.blueice.com/).	In addition to the above, the same methodology is available in products from ActionTechnologies (www.actiontech.com) such as Web based workflow solution ActionWorks Metro.
Programming language	Not built into tool.	Scripting in the built-in Basic possible.

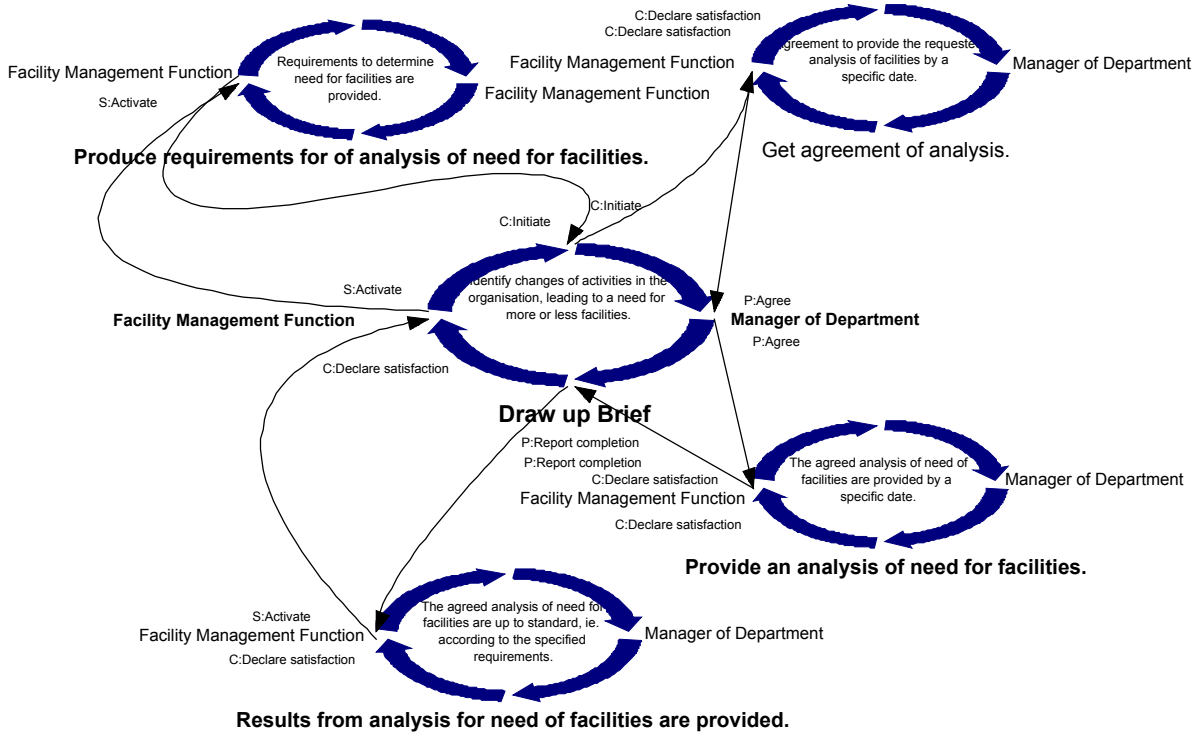

Figure 3: An example of an ActionWorkflow diagram.

5. CONCLUSIONS

Hibberd and Djebarni (1996) claim that changing requirements, teamwork communication, identification of responsibilities and supply of information, contribute a total of 77,4% towards the problems associated with construction projects in the UK construction industry. Communication workflow is addressing exactly these issues. The goal of the workflow analysis is to improve the business process and focus is on investigating the interaction between people. Most of these problems with current procurement methods can be analyzed using the Action Workflow methodology and tools.

Modeling is a subjective endeavor that, if successful, ends up with models that are found agreeable by several people and application programmers. In the end, however, the users of the programs and the readers of the models are intelligent human beings that will interpret the models in the context of their education, cultural background, current problems and their intimate understanding of the modeled topic. Having said all that, very different modeling techniques can be used to document an engineering process in a useful way. However, by choosing a modeling technique, the modeler accepts certain paradigms and abstraction mechanisms that influence his perspective on the topic being modeled.

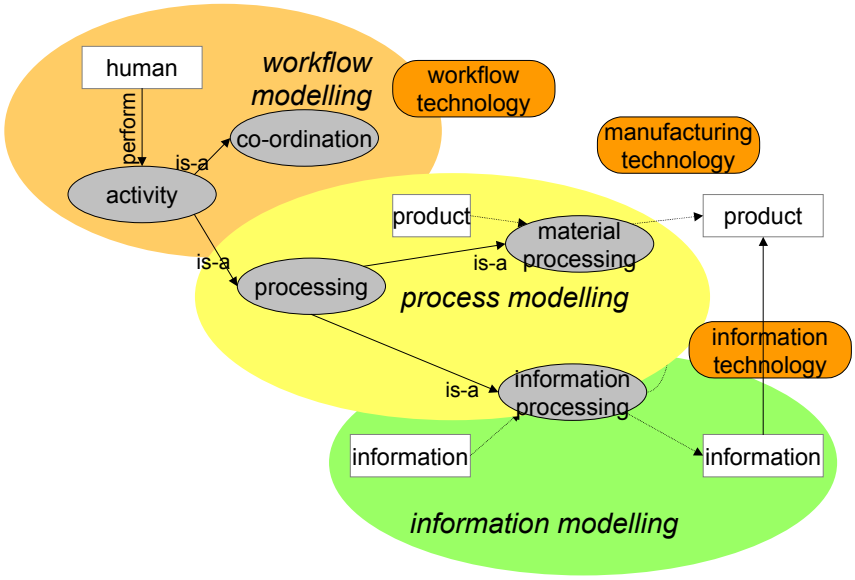

Figure 4: Possible top level semantic network of construction.

Action Workflow methodology shifts the focus towards the relations and communications between two humans involved in each process - the customer (client) and the performer (server). IDEF only covers a fourth of a loop between them, the performance. Communication workflow forces us to think about questions like "Why are we doing this?", "How did we negotiate it", "Who asked for it?", "How to make him satisfied?" etc. In all these questions, the concern for the client is evident. Action workflow has been particularly popular in fields where client satisfaction is a top priority. It should be so in construction as well. By doing all work in a loop between customer and performer, Action Workflow explicitly leaves a lot of control with the humans. Therefore, improvised activities with known customers, less known performers and even lesser understood processes, inputs and outputs, can be modeled in Action Workflow and can be tackled by software that implements the workflow models. This is very well suited to a profession - construction - where improvisation persists to be a way of life. Action Workflow is more than a modeling methodology - tools that implement the models are available and the mapping from the model into an implementation is almost automatic.

A realistic scenario is therefore to model processes with simple human to human relations as flows while resorting to Action Workflow techniques for works where customer-performer relations are of greater importance. A possible top level model of construction, bringing together workflow, process modeling and product modeling is shown in Figure 4.

This initial study revealed Action Workflow as superior to IDEF0. Further work using it to model construction works would therefore be justified.

6. ACKNOWLEDGEMENT

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