FORMAL LANGUAGES FOR CONSTRUCTION PROCESS MODELLING

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ABSTRACT: Numerous modelling methods and languages have been developed for describing different aspects of industrial and other processes. Each method, for instance the widely used scheduling method as used in project planning software, has a specific scope (i.e. the modelling of the sequence in time of interdependent activities) for which it has been designed and for which it is well suited. Used outside this scope the method may prove quite inadequate. A number of such methods have either been used or proposed for the modelling of construction processes. In order to create the basis for a next generation of more general purpose process modelling tools an analysis has been made of six such methods. In order to illustrate the concepts and graphical notation of each method a simple example of making the foundation of a summerhouse with a sauna is used. Additionally the concepts of each method have been modelled using a uniform methodology, the EXPRESS information modelling language. Based on the analysis a synthesis method, called GEPM is proposed and defined in EXPRESS. The method is defined on the semantic level, as its main purpose would be to enable the storing of process descriptions in a database format, enabling multiple user views to the same information. A prototype application is developed to demonstrate different views.

KEYWORDS: process, modelling, conceptual, model, generic

1. INTRODUCTION

Process modelling methodologies have been developed for business process re-engineering purposes but these methods are usually of limited scope, and need be developed further. Methods like in the IDEF family, in scheduling software, and for computer systems have all their scope and some of them have been used in describing the building construction process.

The construction process may be characterised as a process that consists of many stages and is a joint effort of many parties such as architect, structural engineer, building services engineer, geotechnical engineer, general contractor, authority, client, etc. The process has a number of iterations, feedback, concurrent activities, temporal restrictions, etc.

A model is a representation of a set of components of a system or subject area [IDEF0 1993]. A process is a bounded group of interrelated work activities providing output of greater value than the inputs by means of one or more transformations [Melan 1992]. The transformations are physical, locational, transactional, or informational. Process modelling is a means to systematically describe the activities, their relationships and information flows of a process. Mayer defines process modelling as a mechanism for constructing a simplified or ideal view of the process that is suitable for quantitative analysis such as consistency, completeness, simulation, and cost and benefit analysis [Mayer et al 1998].

A generic modelling method should be suitable for all process descriptions. It should be able to be tailored to suit specific need.

1.1. Background

In construction process modelling research construction activities have typically been described as activities, material and information flows between the activities, actors performing the activities, etc. A number of such construction process models have been defined using formalised modelling methods such as IDEF0 [Sanvido et al. 1990, Karhu et al. 1997]. These models have had a limited scope that has been due to, for instance company specific restrictions, and thus, cannot be used as generic models.

The multi-disciplinary nature of construction projects, the increasing complexity of project organisation, as well as the technology push from concurrent engineering and information technology developments, impose new requirements for construction process planning and management. It seems that the industry today uses quite sophisticated IT-tools for the design and analysis of its products (CAD-systems, structural analysis) whereas the tools for analysis and planning of its fundamental working procedures still lacking.

Recently, there has been a need for the development of process modelling concepts, in particular in terms of how IT is used and could be used to support the overall life-cycle process. A generic process modelling method would be suitable for describing the building construction process from different points of view.

1.2. Perspectives and purposes of process modelling

Processes may be analysed from different perspectives: functional, behavioural, organisational, and informational [Curtis et al. 1992]. The functional perspective concentrates on process elements that are being processed, and on flows of information entities such as data, artefacts and products. The behavioural perspective represents performing of process elements, for instance sequencing, and how these are performed though iteration, feedback, decision-making, etc. Also, entry and exit criteria are included. The organisational point of view takes into account the performer, i.e. who performs the process elements in the organisation. It also represents the physical communication mechanisms and the physical media locations as well as storage entities. The fourth perspective, informational perspective, represents the information entities of the process. The information entities are such as data, artefacts, products, and also objects. In addition to these, the informational perspective includes the structure and relationship of entities.

Models and modelling may facilitate human understanding and communication, support process improvement and support process management. The concepts are described in the following.

Human understanding and communication is facilitated because:

- A process is represented in a form understandable to humans and thus, communication about and agreement on the process is easier.
- The process is formalised so that people can work together more effectively.
- Models provide sufficient information to allow an individual or team to perform the intended process.

Process improvement is supported since:

- Necessary components of process development can be identified more easily.
- Effective and well-defined construction processes can be reused in future projects, and alternative construction processes and technologies can be compared.

- The impacts of potential changes to a construction process can be estimated without putting them into actual practice.

Process management is supported since:

- Project-specific processes and project plans can be developed and progress can be forecasted.
- The process can be monitored, managed, and co-ordinated more easily.
- Models provide a basis for process measurement, such as definition of measurement points within the context of a specific process.

1.3. Criteria for modelling

Common concepts and interpretation form the basis to define issues and contexts clearly and create mutual understanding between people and parties with different experiences. The standardisation of certain interfaces and the support to the classification of information and development of information and control systems is also significant. Development of processes and the analysis of models can yield new and more efficient operational procedures for construction. Models and computerized tools facilitate the design, construction and testing of various means of improving efficiency and new types of operational processes without real risks. They also allow rating alternative implementation solutions against each other.

For the process control and management the models can be used to plan and control construction, to match and synchronize the work of various parties and to set intermediate goals. Models can be used, for instance, to define the information needs and material flows of a process and to fix the corresponding temporal goals with respect to various activities and the various parties.

Criteria for modelling power and decision power have been recognised [Konchikar et al. 1994]. For modelling power the criteria are sufficient number of features, abstraction ability of levels, hierarchical modelling, verifiability and system evolution ability. For decision power the criteria are computational efficiency, quality, interactive tools, data requirements, and the easiness to understand and use. Koskela [Koskela 1995] adds to the above that the requirements for a general model of construction concerning the modelling power are construction focus, breadth and depth.

1.4. Scope and objectives

The scope of this paper is

- to study formal methods that have been used in modelling construction process.
- to suggest preliminary requirements for a generic modelling method.

The paper is restricted to the preliminary results of a project called MoPo (Models for the construction process) that started in the beginning of 1999 and thus, only a limited number of methods have been studied so far [MoPo 2000].

2. METHODS STUDIED

The methods discussed in this paper are

- Scheduling method
- IDEF0
- Simple flow method

The conceptual model of each method is presented in EXPRESS-G, which is the graphical counterpart of EXPRESS language [ISO 1994]. In addition, each method is described using a

common example of building a basement for a Finnish summerhouse. All methods use a graphical representation that also plays an important role for analysing the developed process models. A Finnish summerhouse has a main building and a separate sauna. In this example concrete is used as the main building material for the basement. Before casting the concrete it is necessary to make a mould and place reinforcement, which creates a sequence of activities. The main activities are "Make mould", "Place reinforcement", and "Cast concrete". It is assumed that two construction workers make the mould, two persons place the reinforcement, and one person casts the concrete. It is then assumed that the moulds for the house and for the sauna be built simultaneously. One worker casts the basements, first for the house and then for the sauna. It means that casting the basement for house must be finished before casting the basement for the sauna. Instructions are design drawings and work specifications.

2.1. Scheduling method

Scheduling software tools are available for process description. These software tools usually enable to define activities, called tasks in the tools, and resources. The conceptual model of the scheduling method is shown in Figure 1. A task has attributes as start date, end date, and duration that could be a derived attribute. The temporal relationships form constraints between the tasks. Other typical constraints often refer to a date, for instance finish-before-certain-date.

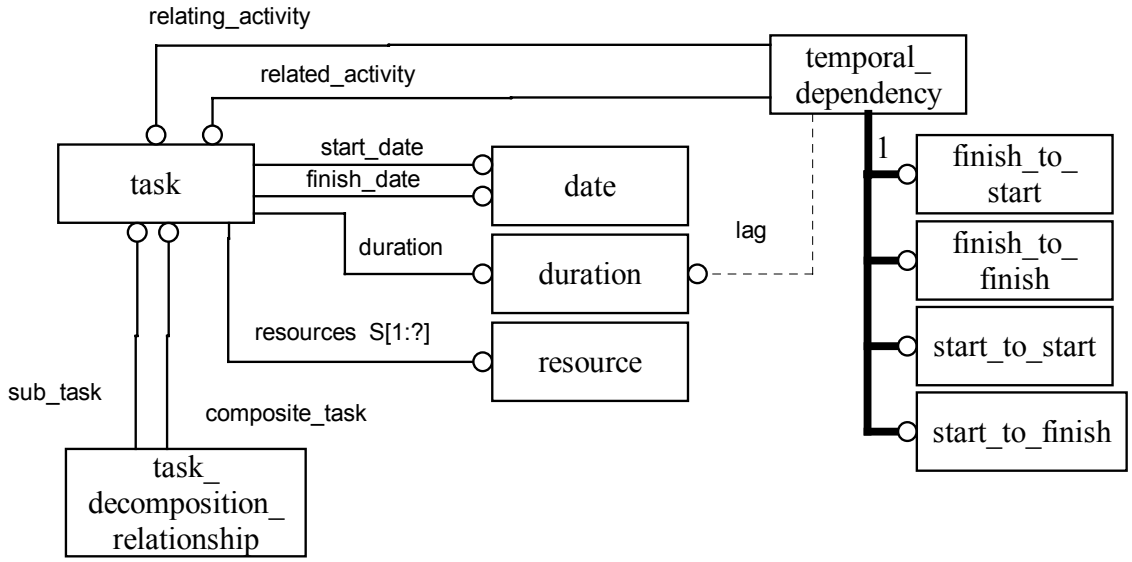

Figure 1. The conceptual model of scheduling method.

An example of the process is shown in Figure 2. The tasks for making the mould for the house and the sauna may be proceeded in parallel but casting the concrete must be done in sequence. The task "Make reinforcement for the house" has a finish-to-start temporal relationship with the activity "Make mould for house" (shown as an arrow between the tasks). The decomposition of tasks is also possible as it is seen that the top most task "Build summer house basement" is a so called summary task, graphically depicted as a solid bar.

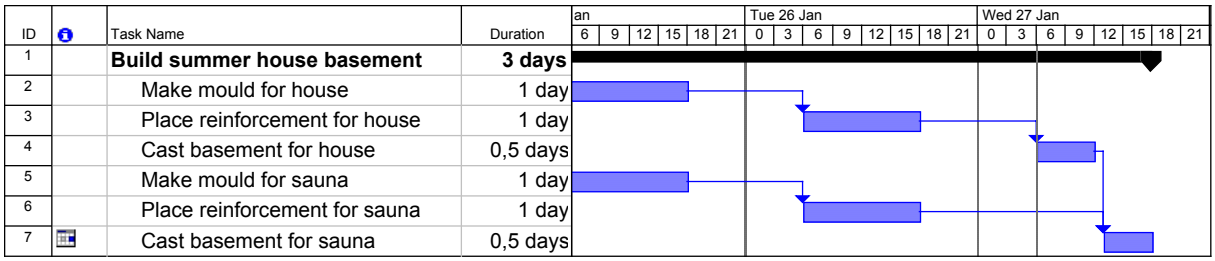

Figure 2. An example of a chart made with a scheduling software.

2.2. IDEF0

The IDEF methods were originally developed during the 1970s by the U.S. Air Force Program for Integrated Computer Aided Manufacturing (ICAM). This ICAM program developed the IDEF techniques IDEF0, IDEF1 and IDEF2. The IDEF family [IDEF 1998] has many methods for different purposes. The IDEF0 is used for functional modelling, IDEF1 for information modelling, IDEF2 for systems dynamic modelling, and IDEF3 for process flow and object state modelling. It may be noted that IDEF0 is a subset of a method called SADT (Structured Analysis and Design Technique). The SADT [Marca et al. 1986] method was originally developed by SofTech company in the beginning of the 70s. The basic idea for SADT was to develop a method to improve the quality of systems and the productivity of system work.

The IDEF0 is used to model the activities and actions of an organisation or system [IDEF0 1993]. A model has a clear subject, purpose and viewpoint, and it represents a process or a system. The activity models are independent of time. A box as shown in Figure 4 graphically represents the activities. Arrows represent the information or objects used by activities. These arrows are called input, output, control and mechanism. In an activity input is transformed to output by a mechanism under a constraint or control. Arrows that represent interfaces or interconnections between the activities connect the boxes. IDEF0 models are co-ordinated sets of diagrams in a hierarchic structure where the diagrams at the top of the model are less detailed than those at the bottom are.

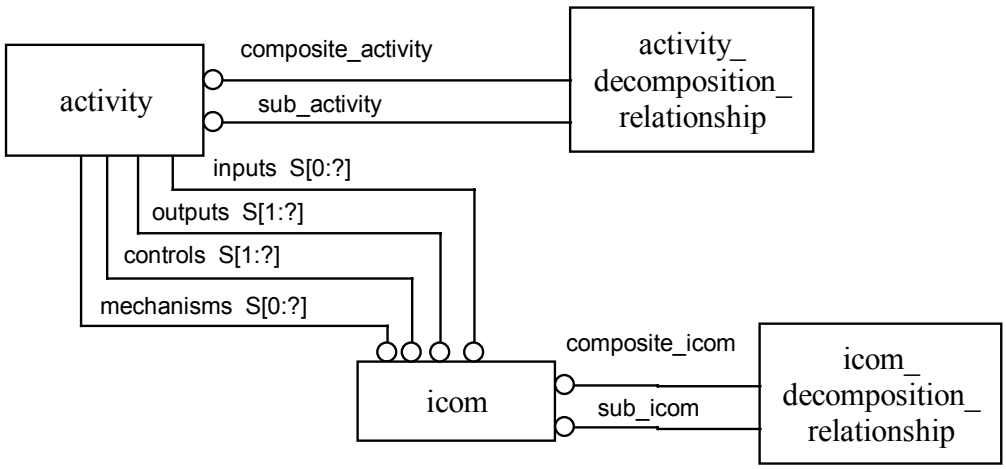

Figure 3. The conceptual model of IDEF0.

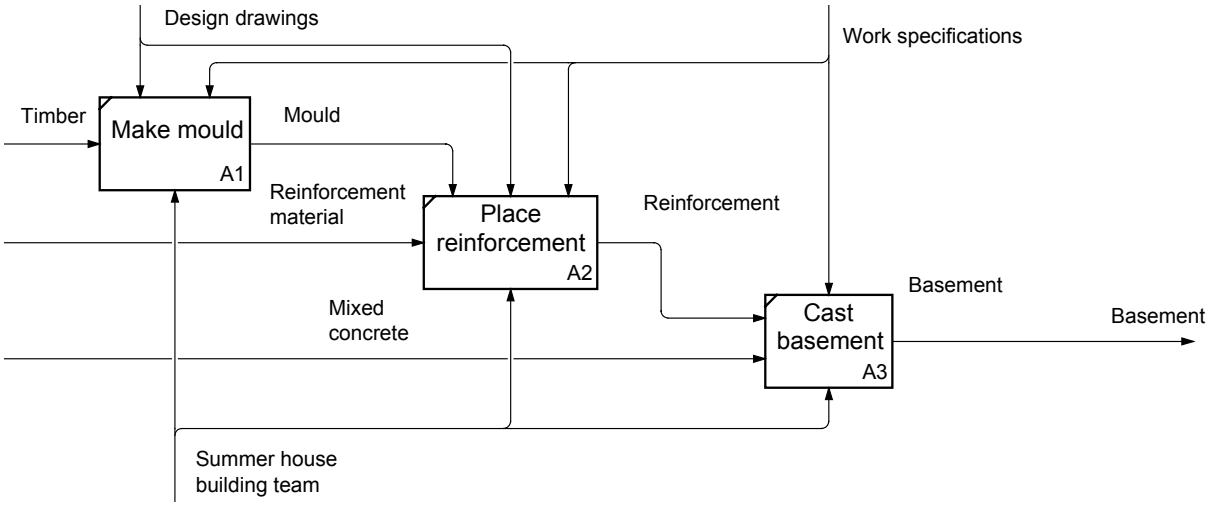

Figure 4. The example process described using IDEF0.

Conceptual model of the IDEF0 is shown is Figure 3. It shall be noted that each activity and ICOM has a label but these have been left out for clarity. The ICOMs are interpreted as flows between activities. An example of an IDEF0 model is shown in Figure 4. The input to activity 1 and 4 is timber. Reinforcement material is used in activities 2 and 5, mixed concrete will be used in activities 3 and 6. The controls for these activities are design drawings and work specification. Performers for the activities are clearly shown.

2.3. Simple flow method

The general contractor JM Byggnads AB in Sweden developed a flow chart method to describe their business process in an EU project called CONDOR [CONDOR 1999]. The reasons for using this kind of simplified process model chart were that the flow chart format is easier to understand at first sight, and that people, project managers, etc., are more used to read schedule flow charts, to which this type of chart has a certain similarity.
This flow chart method was tailored to suit JM Byggnads AB company's needs using the software tool Visio 4.0 from Vision Corporation. Hoffner [Hoffner 1997] has used this model to describe the process of the company. One may add that Hoffner additionally developed an IDEF0 model based on the flow chart. The conceptual model of the method is shown in Figure 5. A flow can be an input or output for an activity. The flow can be decomposed.

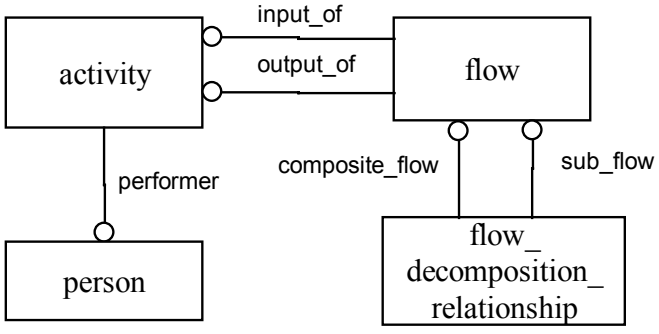

Figure 5. The conceptual model of simple flow method.

An example of the model is shown in Figure 6. The leftmost part of the figure shows the persons, i.e. performers, of the activities. Thus all the activities performed by the same person will be placed on the same row which makes visual inspection of the model easy. The arrows show the flows between the activities.

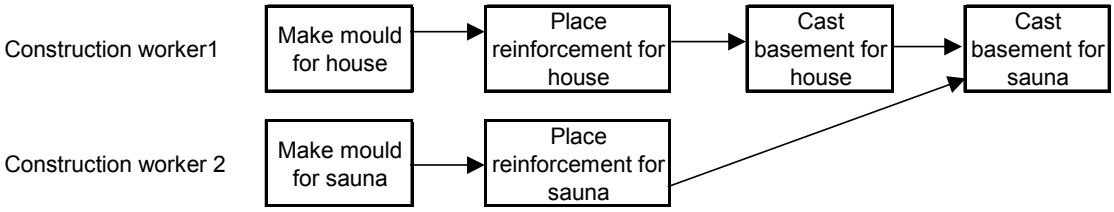

Figure 6. Summer house example using the simple flow method.

2.4. Summary of existing modelling methods

The scheduling method seems useful for describing the processes from the task point of view, and they are suitable for describing a sequence of tasks. The inputs, outputs, and controls are not modelled as such but they are treated as resources that are the necessary items for the activity to be performed. Thus, it may be difficult to distinguish what the output consists of, and what the task actually does with the resources.

The IDEF0 method has a practical difficulty that concerns the distinction between control and input. Consider, for instance, the architectural design process where the architect makes the conceptual designs after which the detailed designs are elaborated. The usage of conceptual designs may be used as an input for the detailed designs in case where the same drawings, for instance in CAD files, are further developed. In case where the conceptual designs are used only as references, they could be used as control. This occurs often when the computer system or program is changed for the detailed design. Another difficulty concerns the fact that the IDEF0 models tend to be interpreted as a sequence of activities. A sequence of, for instance, activity A and B form a finish-to-start relationship even though it is not part of the IDEF0 methodology or concept.

The simple flow method may be useful for certain purposes such as pointing out the activities that belong to certain performers in an organisation. Graphically the activities are grouped for each person, for instance, construction worker 2 is responsible for two activities as was shown in Figure 6. It is difficult to distinguish the inputs and outputs of the activity, i.e., what they consist of because the arrow does not have any label or name. The process model merely shows the sequence of activities and answers the question of what one should do next.

3. PROPOSED GENERIC METHOD AND PROTOTYPE

The scope of generic process modelling method GEPM is

- to provide a generic modelling method for construction process modelling
- to enable future software development

The modelling criteria for the method are

- activity and task should be separated
- sufficient modelling power should be obtained
- internal database storage could be used to generate views for different purposes and methods
- analogy with product data modelling should be observed
- neutral data exchange should be possible

An essential distinction should be made between an activity in the IDEF0, or the IDEF0v, and a task in the scheduling software. The activities in the IDEF0 method tend to be more general whereas the tasks in the scheduling are specified activities with duration, time, resources, etc. Thus, it would be useful to distinguish general activities and tasks. The reference models vs. specific models have been suggested by Hannus [Hannus et al. 1995].

A prototype application idea is shown in Figure 7. The prototype platform for the GEPM browser is Lotus Notes, which can be used to create a full GEPM model. On the other hand, one may use MS Project for scheduling, BPWin for IDEF0 diagrams, and Visio for simple flow diagrams. These have been programmed with OLE linking except for the IDEF0 model, which can be retrieved to the GEPM browser using the IDL (interface definition language) format. In practice one may work in each view using appropriate applications, and retrieve data back to GEPM browser database with the presumption that some data must be converted in one way or another. This enables a consistent model throughout the process. The dependency table is generated in the GEPM browser and exists only in conjunction with tasks. The reason why these views have been chosen is that they have been extensively used in building industry.

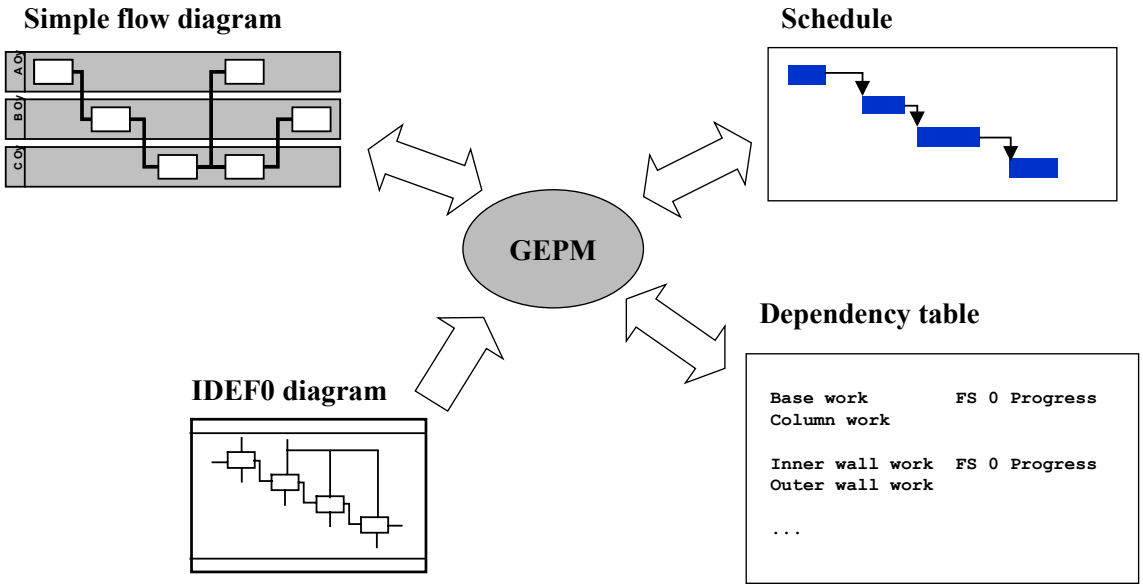

Figure 7. Views for different purposes chosen in this paper.

4. CONCLUSIONS AND FUTURE WORK

For analysing and describing a process it may be useful to use more than one process modelling method as has been suggested by some authors. Many methods are developed for specific purposes and, thus, lack some important aspects that are needed in describing other kind of process or more complex processes. One difficulty in process modelling seems that a generic process model is difficult to describe. In other words, the developed process models are more or less one-off solutions and, thus, a generic model does not describe the process in sufficient detail.

The distinction between a general activity and a task is essential. It may, thus, be possible to develop standardised process libraries. Process modelling methods need be developed together with modelling tools. Many models tend to become complex and are difficult to manage with undeveloped modelling tools. It may be proposed that a modelling method and tools may use, for instance, filtering for the presentation of the process model from different

points of view. A generic method may be filtered to meet the functional, behavioural, organisational and informational points of view.

One important aspect is the industry experience. A comprehensive and generic process modelling method should be adaptable to various conditions.

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