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Title: **Workflowmanagement in construction; Opportunities for the future**

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Abstract: *Process control is an essential base for the efficient and successful execution of construction projects. At the same time, construction processes are complex and difficult to control. A lot of processes are critical and an overview of all these processes is often not clear. In other industries workflow management has shown to be a successful tool in controlling standardized processes. Workflow management systems take care of the information logistics and give a process overview that enables better management and control of the process. The research described in this paper focuses on the possibilities of workflow management in dynamic, project oriented processes. More specific, the paper makes clear whether workflow management systems are usable and profitable in construction and to what extent.*

After studying the properties of specific processes in different construction projects the criteria for the selection of an automated workflow management system are listed. This teaches that classical workflow management systems were not suited for the development of a prototype, mainly because of the lack of flexibility. Case handling systems, a type of workflow management system, seemed more appropriate for the dynamic processes. Within a large Dutch construction company the prototype has been tested in practice.

The main conclusions of the research are that workflow management can be applicable and profitable in construction and that workflow management makes the processes more manageable and controllable. Information in the processes is gathered in one system that makes it easier to track down and information in the system is always up to date.

Keywords: *Workflow management, process control*

The need for process control in construction

Failure costs

It is well known that costs due to failures are high in the construction industry. Recent studies by Stichting Bouw Research in the Netherlands indicate that 6 á 7 % of the contract price can be allocated as expenses due to failures [12]. A lot of these failures are caused by an inadequate organization of the construction process, e.g. a weak coordination of processes and uncertainty about available information. As a result of this Stichting Bouw Research launched a research program “building better” (in Dutch: bouw beter) [12].

Also in other countries there is deep concern that the industry as a whole is under-achieving. In the United Kingdom the low profitability of the construction industry and the fact that the industry invests too little

in capital, research and development and training were motives to start the major project “Rethinking Construction” [7]. Too many of the industry's clients are dissatisfied with its overall performance.

Integrated processes

To improve this situation different approaches are possible. Stichting Bouw Research points to the need for process improvement. The program “rethinking construction” defined five key drivers of change which need to set the agenda for the construction industry at large [7]: committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda, and commitment to people.

The conclusion is that improvement of integrated processes has to be placed high on the research agenda. Not only these recent studies point to the need for well-supported management processes. In the past many authors addressed the need for mapping of processes, measurement of performance and continuous improvement to improve quality and eliminate waste.

Workflow management

An interesting point with respect to this subject is comparing the construction industry with other industries. In the past several concepts, from manufacturing, seemed to be applicable in the construction industry [5, 8, 9].

During the past decade Workflow Management (WFM) has become an important driver to improve and integrate processes in the service industry. Workflow management systems such as Staffware, IBM MQSeries Workflow, COSA, etc. offer generic modeling and enactment capabilities for structured business processes. By making graphical process definitions, i.e., models describing the life cycle of a typical case (workflow instance) in isolation, one can configure these systems to support business processes. Besides pure workflow management systems many other software systems have adopted workflow technology. Consider for example ERP (Enterprise Resource Planning) systems such as SAP, PeopleSoft, Baan, Oracle, as well as CRM (Customer Relationship Management) software and recently projectweb-software used within the Internet.

Workflow management systems have proven to be very successful in supporting well-defined, structured processes. Even though each project is unique, construction processes even on a detailed level are mostly the same. The process of construction in its essentials is repeated from project to project. According to [7] up to 80% of inputs into buildings are repeated. Much repair and maintenance work also uses a repeat process.

The conclusion is that it is of great value to investigate the benefits of application workflow management systems in construction.

The concept of workflow management

Introduction to workflow management

Workflow management systems are *case-driven*. This means that only business processes describing the handling of one *case* (workflow instance) in isolation are supported. Many cases can be handled in parallel. However, from the viewpoint of the workflow management system these cases are logically independent. To handle each case, the workflow management system uses the corresponding *workflow process definition*. The process definition describes the routing of the case by specifying the ordering of *activities*. Activities are the logical units of work and correspond to atomic pieces of work, i.e., each activity is executed by one worker (or another type of resource) and the result is either “commit work” or “abort and roll back”. Normally, to specify the ordering of activities is a graphical language such as Petri nets [1] used. These languages allow for sequential, conditional, and parallel routing of cases. Typically, an activity, which is enabled for a given case, may be executed by many workers and many workers may execute a given activity. To support the distribution of work, the concept of a *role* is used. A worker can have multiple roles, but an activity has only one role. If activity A has role R, then only workers with role R are allowed to execute activities of type A. Based on this information, the workflow management system works as follows: The corresponding workflow process definition is initiated for each new case, i.e., for each case (e.g., request for information, insurance claim, customs declaration, etc.) a new workflow instance is created. Based on the corresponding workflow process definition, the workflow

engine calculates which activities to enable for that case. For each enabled activity, one work-item is put in the in-tray of each worker having the appropriate role. Workers can pick work-items from their in-tray. By selecting a work-item the worker can start executing the corresponding activity, etc. Note that, although a work-item can appear in the in-tray of many workers, only one worker will execute the corresponding activity. When a work-item is selected, the workflow management system launches the corresponding application(s) and monitors the result of executing the corresponding activity. Note that the worker only sees work-items in his/her in-tray and when selecting a work-item only the information relevant for executing the corresponding activity is shown.

Lack of flexibility

In this paper, we argue that the lack of flexibility in contemporary workflow management systems stems from the fact that routing is the only mechanism driving the case, i.e., work is moved from one in-tray to another based on pre-specified causal relations. This causes various problems, when the concept is used in the construction industry. The construction industry needs a more flexible WFM system, in which activities *can* be done instead of *have to be* done [6, 13]. The possibility of redoing or skipping activities is an important requirement of the system to be chosen. Case-handling systems meet these requirements.

Case-handling

The central concept for case handling is the *case* and not the activities or the routing from one in-tray to another [2]. The case is the 'product' which is manufactured and at all times workers should be aware of this context. To handle a case, *activities* need to be executed. Activities are logical units of work. Clearly activities are related and cases follow typical patterns [3]. A *process* is the 'recipe' for handling cases of a given type.

It is important that workers have insight in the whole case when they are executing activities. Therefore, all relevant data should be presented to the worker. Moreover, workers should be able to look at other data objects associated to the case they are working on (assuming proper authorization). *Forms* are used to present different views on the data objects associated to a given case. Activities can be linked to a form to present the data objects most relevant.

Actors are the workers executing activities and are grouped into *roles.* Roles are specific for processes, i.e., there can be multiple roles named 'manager' as long as they are linked to different processes. One actor can have multiple roles and roles may have multiple actors. Roles can be linked together through role graphs. A role graph specifies 'is_a' relations between roles. This way, one can specify that anybody with role 'manager' also has the role 'employee'.

Three roles need to be specified for each process and activity: the execute role, the redo role, and the skip role.

- The *execute role* is the role that is necessary to carry out the activity or to start a process.
- The *redo role* is necessary to undo activities, i.e., the case returns to the state before executing the activity. Note that it is only possible to undo an activity if all following activities are undone as well.
- The *skip role* is necessary to pass over activities. In order to skip over two consecutive activities, the worker needs to have the skip role for both activities.

The three types of roles associated to activities and processes provide a very powerful mechanism for modeling a wide range of exceptions, which is very important for a successful application in the construction industry. The redo ensures a very dynamic (as it is dependent on the role of the employee and the status of the case) and flexible form of a *loop*. The skip takes care of a range of exceptions that would otherwise have to be modeled in order to pass over activities.

For case handling the in-tray is replaced by a flexible *query mechanism*. This mechanism allows a worker to navigate through all active cases. The query "Select all cases for which there is an activity enabled which has an execute role R" can be used to emulate the traditional in-tray.

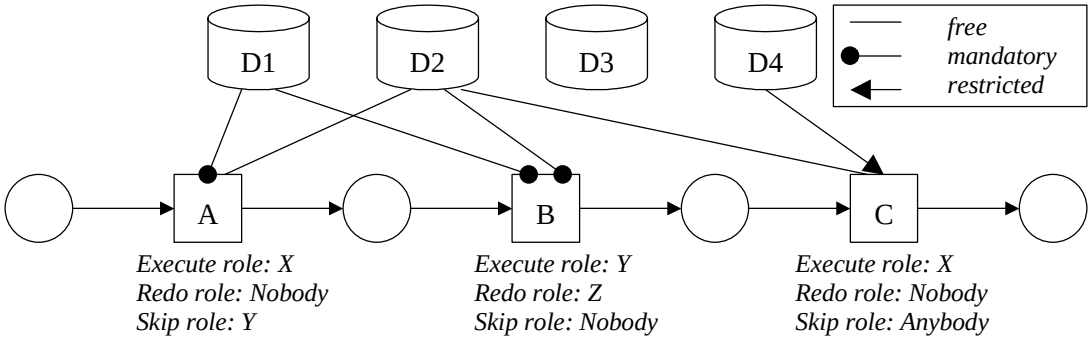

Figure 1: an example illustrating some of the case-handling concepts

Figure 1 illustrates some of the case-handling concepts graphically. Note that each activity has three roles associated to it. For example, activity A may be executed by a worker having role X. However, it can also be skipped by a worker having role Y. Assuming that there is no worker having role Nobody, this activity cannot be redone. Similarly, activity B cannot be skipped but can be redone by a worker having role Z. Figure 1 also shows the free, mandatory, and restricted data objects associated to each activity. Activity A requires data element D1 to be set because D1 is mandatory for the completion of A. Activity B has two mandatory data objects (D1 and D2). D4 is restricted to C. Note that because of the explicit modeling of data objects, activities are no longer "black boxes" and their interrelationships become clear. Moreover, it is possible to remove explicit causal relationships and it is possible to execute several activities in one activity. Consider for example the scenario where a worker enters both D1 and D2 when executing activity A. After completing A all mandatory data elements for B are present which indicates that B is not required. Using this information B is skipped and C is the next activity to be executed.

Using case-handling in construction

Characteristics of processes in construction, related to automation

Construction processes are mostly project-oriented. Characteristics of projects are their complexity and their uniqueness. The goal of a project is usually agreed on during its start-up. Although a project result does not have to be completely new, a project itself contains many new elements or a new combination of these elements. Examples are the involved parties, the situation of the project, and the techniques used. An efficient process is in construction important. Projects usually last for several years. Therefore, controlling and managing projects are at the same time necessary and difficult.

These project characteristics complicate the translation of construction processes into workflow management descriptions [10]. Besides the above-mentioned new elements, a project usually follows a new process. A workflow management description has to be able to offer flexibility to meet differences between several projects or parts of the project.

On the other hand, a construction project has to contain a certain level of standardization. To build a completely new workflow management model for each project that will be executed costs a lot of time and money. Besides, workers within a construction company have to know how to build such a model. Not only knowledge of modeling processes is necessary, but also having an overview of the project is needed at all times.

Automation is useful for processes with the following characteristics:

- a large interest for the total project result in terms of time, costs, and quality,
- an occurrence in more projects, and
- a lot of moments of handing over information in the process.

Case-study

During a case study at a large Dutch contractor a process model is set up for two construction processes that meet the criteria mentioned, the processes of preparing HVAC installations and the processes of preparing semi-prefab concrete floor elements [4]. The process model is used to estimate the feasibility of translating construction processes into a workflow management system. This process model not only describes all steps in the processes but also describes the possible routings through the processes by defining AND-/OR- splits and joins. Figure 2 gives an idea of the complexity of the whole model.

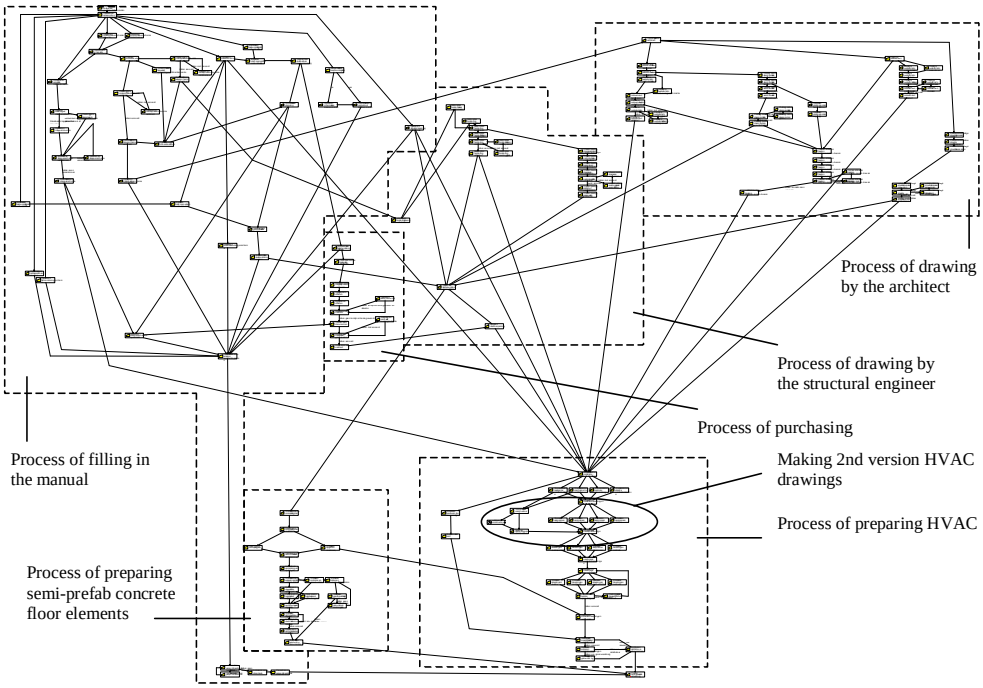

Figure 2: process model

The process model in figure 2 learns that the needed flexibility can be modelled and that the construction processes can be defined at a certain level of detail that the processes can be standardized without being too generally.

Experiences: the case-handling prototype

We decided to continue the research by developing a prototype using the process model as a base. This prototype can give better insight in the possibilities ("proof-of-the-concept") and enables the discussion of the possibilities and feasibility of case handling in construction.

FLOWer, the case handling system of Pallas Athena, has been used to build the prototype [11]. We did not specifically choose for FLOWer; the main focus of this research is the principles of case handling and not one specific system. In FLOWer the roles and activities in the processes concerned are defined (figures 3). The four roles defined in the prototype are 'Nobody', 'Assistant-director', 'Project-manager', and 'Work planner'. The hierarchy of the roles determines the responsibilities in the process. Each activity from the process model has to be translated into electronic forms that the user will see in the case handling system. The process model describes all the activities that have to be done while FLOWer describes the transfer of work. Therefore one form can cover more activities in the process model. Loops in the process model are translated in FLOWer by assessing the redo-activity to one of the roles. For each activity this information can be defined in the forms shown in figures 4 and 5.

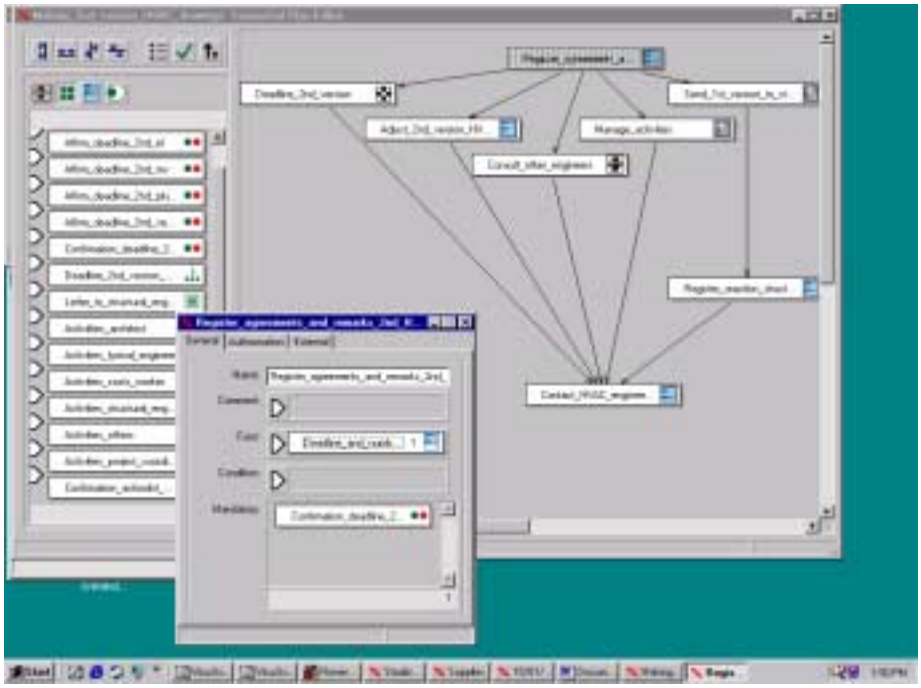

Figure 3: defining activities

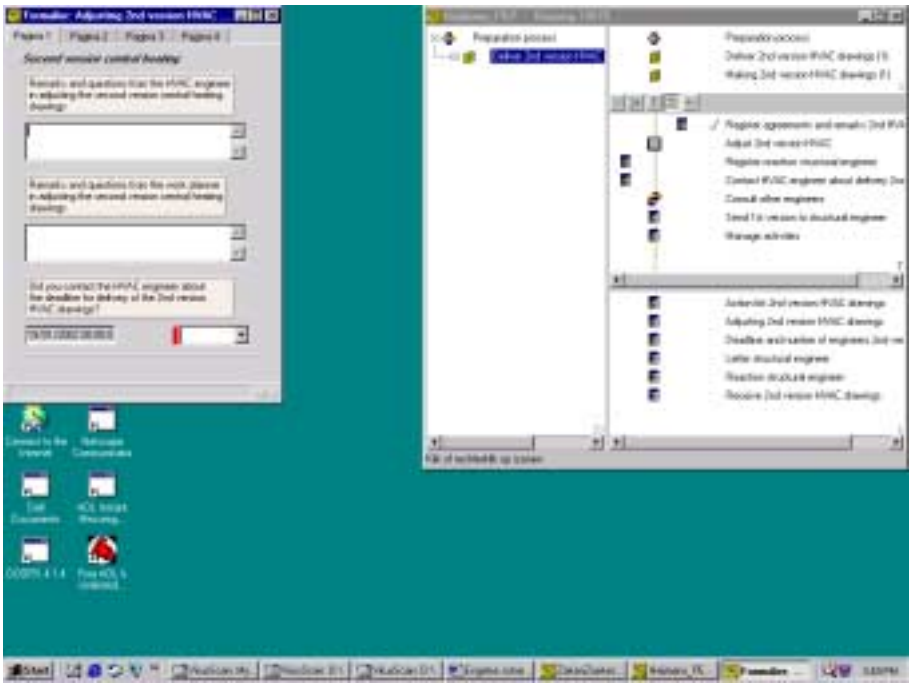

Figure 4: screenshot of the prototype showing an overview of the status of the case (right) and a form (left)

A user can start a new case or open an existing case in FLOWer Case Query. Figure 4 shows an example of a user form (left) concerning the making of the second version of the HVAC drawings. The right side of the screen provides an overview of the project. The user sees the activities that are already executed or skipped. These activities are displayed on the right side of the status line. Activities on the left side of this

line cannot be done because previous activities need to be finished first. Activities on the line can be carried out. The form shown at the left side of the screen corresponds to the activity that is highlighted on the status line. A user can only see forms that (s)he is allowed to execute. Data fields marked by a rectangle in front of the field are mandatory.

A special kind of form is the Standard Letter Action. This form can generate documents with information filled in earlier in the project. Figure 5 shows the example of generating a letter to the structural engineer in Microsoft Word.

The prototype (also available on: http://ga1405.tm.tue.nl/Flower) supports mainly the information handling of the process. By using the prototype the user has a better overview on the process, especially on the available and completed documents. Retrieving information can be done more rapidly and easier. The overview can also be used to show the critical path in the project. A better overview of the process will lead to benefits in quality and time.

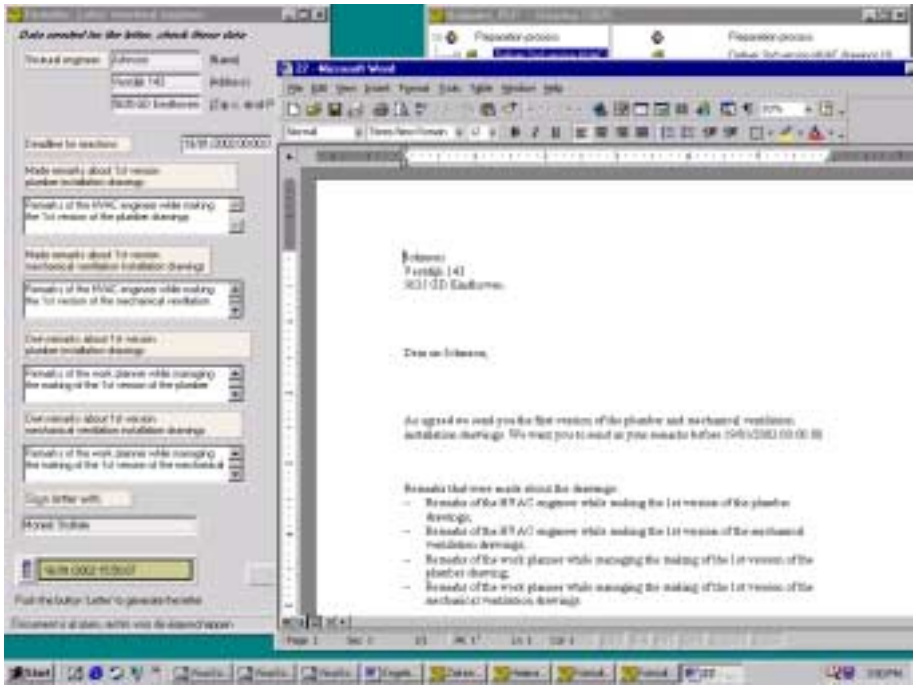

Figure 5: generating a letter in MS-Word

Conclusions

The research described in this paper shows that the construction industry, which is an industry with a high amount of failure costs, can be improved by using a specific form of workflow management, namely case handling. Workflow management makes the processes more controllable.

However, using this kind of system means a big change in the current way of working within the construction industry. Developing this concept is a great opportunity for the construction industry. Therefore, case handling has to be placed on the research agenda to further investigate the possibilities. For instance, the real amount of failure cost reduction and the specific impact on processes and people within the construction industry need to be investigated in more detail.

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