Tasks, Cognitive Agents, and KB-DSS
in
Workflow and Process Management

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Abstract

In recent years, Workflow Management is proposed as the panacea for problems that increased quality and efficiency requirements impose on organizations. A sound theory of Workflow Management and Workflow Management Systems, however, is lacking. In this article, we deal with modeling issues that developers of workflow methodologies face. We describe some of the modeling pitfalls that we encountered in the domain of planning and scheduling support, we demonstrate how these pitfalls are addressed by our approach to analyze and support planning and scheduling, and we explain why this approach is applicable for Workflow Management as well.

1.

Introduction: Current research on Workflow Management

Workflow management (WFM) is a broad concept that is approached from different perspectives. Clearly, all research on WFM somehow deals with regulating and aligning the flow of work in organizations. If aspects of this flow of work are incorporated in computer systems we are talking about WFM Systems. In this, however, several viewpoints can be taken.

Joosten (1996) and Joosten & Brinkkemper (1995) describe some areas of research that relate to WFM systems. *Technical* research looks at WFM system aspects. *Conceptual* research looks at the modeling of workflows. Research in *organizational and business sciences* studies the relation between workflow tools and organizational aspects. *Route-oriented* workflow approaches study the route of the workflow through the organization, whereas *task-oriented* approaches mainly focus on the activities themselves. Since WFM could be a new field of science, *methodological* research deals with the search for new methods. The latter research field is aided by research on workflow in *practice*.

Jablonski (1995) gives a similar classification. He describes a number of perspectives to approach activities, which are the small building blocks of a workflow. A *functional* perspective looks at the kind of work that is performed within an activity. The order of activities is described by a *behavioral* perspective. The *organizational* perspective describes the roles that perform the activities, e.g., manager, claims assessor, or client. The information that emanates from the activities is depicted by the *informational* perspective, and the *technological* perspective looks at the software components that are used by activities.

WFM systems enable new possibilities for the way that workflows can be managed. WFM systems often integrate the control of the workflow with automating the documents that participate in the workflow with techniques such as imaging and document information systems. The major advantage of this is the instantaneous and simultaneous availability of documents at multiple locations. To be able to use these advantages, however, implementation of a WFM system should be preceded by business process analysis and restructuring at deep levels in the organization. We

will explain later what we mean by "deep", because there lies the kernel of our contribution. Discussions about "do's and don'ts" in WFM systems are abundantly available. Articles concerned with theories of WFM systems, however, mainly originate from vendors of WFM systems, dealing with case studies and tool-oriented articles (Joosten & Brinkkemper, 1995). At a somewhat more conceptual level, The Workflow Management Coalition (WFMC) is mainly concerned with designing standards for WFM systems (Hollingsworth, 1994). Another example is Jablonski (1995), who describes a development methodology for WFM Systems.

Articles that deal with conceptual and methodological issues of workflows and WFM, however, are much less available, while these subjects are, in our opinion, essential to establish a firm theoretical basis of WFM. Some articles that present conceptual work on WFM are Ngu et al. (1996; task and transaction modeling), Joosten (1994; trigger modeling), Medina-Mora et al. (1992) and Winograd (1986) (ActionWorkflows and speech-acts), and Van der Aalst et al. (1995; using petri-nets to model workflows). We think and will argue, however, that existing approaches have a number of disadvantages.

In this contribution we have two main themes. The first is the assessment of the wrong level of description that is used in WFM and Workflow Management Systems. The second is the application of our planning and scheduling perspective (Scheduling Expertise Concept or SEC) that starts at the right level of description to WFM and WFMS. Therefore, in section 2 we start with the demarcation of WFM. Because we want to look at WFM from our perspective on planning, section 3 deals with WFM, logistics and planning. In section 4 we shortly explain the SEC-framework. An example of the application of this framework will be discussed in section 5. Because the level of description has immediate relevance for system implementation, we will turn to Knowledge Systems and Decision Support Systems and its relevance for WFM in section 6. Section 7 ends with conclusions and a research agenda for WFM and WFMS.

2. The demarcation of workflow management

Workflow management is about the analysis, the diagnosis, the control, and the manipulation of the flow of work in organizations. Joosten & Brinkkemper (1995, p.1) speak about the workflow paradigm in which WFM deals with the coordination of productive work in a business process. According to them this is characterized "a) by a focus on the interaction between actors rather than on activities themselves, b) by the number of different people and organizational units being involved, c) by boundary spanning both within and outside the organization and d) by the integration of procedures and tools". Although these statements are generally accepted, they are far from specific. There is too much left for interpretation. This is perhaps one of the reasons that there is so much disagreement in the field of WFM. Many researchers and practitioners claim to do the same thing, that is to say WFM, but they also like to call it business processing (re)designing, business (re)modeling, business process re-engineering or business process (re)structuring (Hammer & Champy, 1993; Davenport, 1993). Whatever name is used, is not relevant here, because we think that there are at least four things wrong with the "traditional" approaches to WFM. The first (a) is that one does not treat workflow processes at an adequate level of analysis or description. The second (b) is that one does not correctly deal with the human factor in business processes and task execution. That is to say that we think that humans (people) in workflow are not treated as complicated, but restricted information processing systems. The third issue (c) is that concerning software or computer support too much an engineering perspective is adopted in which efficiency is calculated with reference to ideal "human-ousted" circumstances. Organizational or business reality, however, is such that for the time being, for the better or the worse, one cannot do without humans. The fourth issue (d) deals with what we like to call the propensity to imitate in modeling. Very often designing or modeling an "ideal" workflow layout presupposes an objective reality that only has to be implemented in the organization. This, what one might call implicit positivist, world view hampers rather than enhances WFM. Designing and modeling are activities dealing with artifacts, interpretations and meanings and not with "hard" facts and the real nature of state of affairs. We will discuss the four

shortcomings in detail below. We will return to aspects of Joosten & Brinkkemper definitions in the next sections.

It is not our purpose, here, to resolve controversies in workflow research nor to settle a new definition for WFM. In this contribution we want to discuss and to demonstrate an approach with regard to the organization of workflow that we developed for a different but adjoining area. In the analysis of, diagnosis of and support for planning and scheduling problems in organizations, we developed and applied a conceptual framework in which some of the indicated shortcomings in modeling WFM have been dealt with. Some might argue that planning and scheduling are inseparably connected to WFM, but this is only partially true. We will show later on that WFM and planning have many things in common, but that if one wants to reduce the one to the other, WFM should be reduced to planning and not the other way around. In our illustration we will refer to the analysis of - and the software support for - the scheduling and planning cases that we came across (Jorna et al., 1996; Van Wezel et al., 1996).

2.1.   *Level of analysis*

Some have regretted that WFM is missing a firm theoretical basis (Joosten & Brinkkemper, 1995). Let us grant this situation to be true, the follow-up question then is why is theory missing and in answering this question one might get a rough idea of how the situation can be changed. To put it briefly we think that the theoretical basis for WFM is missing, because one is looking at the wrong level of description. In Nagel's classical description of the structure of science (1961) he claims that a theory consists of a set of propositions in which law-like relationships are expressed which enable explanations to be given and predictions to be made. In the propositions entities and their properties are described at an adequate level of description. According to us, here lies the key issue. A theory of WFM is something like a theory of societies. And a theory of societies is not available as such. Until now the only theories we have are from sociology, psychology, economy and of course from physics, chemistry, biology, and so on. The adequate level of description in WFM is not the workflow itself but the constituting elements of

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workflow. If we look at a (slightly different) definition of workflow by Joosten & Brinkkemper (1995) they say that "A workflow is a system whose elements are activities, related to one another by a trigger relation and triggered by external events, which represents a business process starting with a commitment and ending with the termination of that commitment." Not much theory can be formulated at this level neither, but if one goes into the details of this definition one can find theories about activities in sociology and psychology, about conditions for triggering in sociology and economy and about commitments in law, economy and psychology. Although not completely satisfying according to many designers, this closer look is usually more valuable than dwelling on all kinds of commonsense thinking at a higher level of description.

Another point of discussion is much related to this longing for theories. In our opinion, one has to look at the right level of description. Investigating intentions of people at the level of group compositions is the same as looking for electrons at the level of microorganisms. Much discussion and analysis in WFM take the view that one should go from top to bottom. In contradistinction to this we would like to argue to go the other way round. One first has to look at and define or demarcate the lower end entities in workflow situations that in general consist of tasks and sub-tasks and intelligent actors whether or not cooperating in groups or units. This means a direction of analysis that goes from bottom to top. However, the same dangers that are threatening the top-down approach are also present here. That is to say that one might never reach the top level. Although we realize that this might be a shortcoming in this approach, we consider this to be less devastating than never reaching the bottom level. In some approaches towards WFM analysis we recognize the same tendencies. Although medium and high level structures are important, the basic thing is that workflow starts with the fact that one or two humans (as information processing systems) consider it to be worthwhile, profitable or are motivated otherwise by internal of external factors, to realize something. This "realizing" may include production, administration, marketing or servicing. Placing an economic shell over these activities turns things into what is called private, government or non-profit organizations, with all the concepts and subdivisions that are familiar in this field. This brings the discussion about theories about workflow down to theories

about humans as intelligent actors and tasks and task structuring. And there are many theories available that deal with these basic elements.

2.2.   The human factor

It is not the place, here, to discuss theories about humans as information processing systems and task(structuring) in large detail. We only discuss the gist of it to get a better grip on the basic elements in workflow. We start with human information processing and we continue with task structures. Its relevance is especially important when dealing with Knowledge-Based Decision Support Systems, as will be shown in section 6.

In stating that humans are information processing systems it is argued that human cognition consists of three connected but independently descriptive parts: a cognitive architecture, a system of representations, consisting of symbol structures, and a set of manipulations, computations, or operations on these symbol structures (Posner, 1989). Every intelligent human activity requires the cooperation of these aspects. If an employee in an insurance company judges the responsibility of a customer in a car accident, this person is manipulating (judgment) representations (client information) within its existing cognitive architecture to make a decision whether to pay or not. Take a welder in a steel factory who decides to use a higher temperature in welding two separate pieces of steel. In terms of cognitive activities, this person is manipulating (deciding) representations (steel welding and temperature) within his cognitive architecture. Relevant for workflow analysis is the mental load that each task requires from the human agent. Furthermore, it is important to know whether a (sub-)task remains within the limitations of the cognitive architecture. A task requiring heavy information retrieval from (human) long term memory within 5 seconds while at the same time the person is monitoring a production unit, is beyond the possibilities of the human cognitive architecture. If in a business process redesign project one carries on these kinds of combinations, the resulting workflow will be full of errors (Rasmussen, 1986; Norman, 1988). This is the real meaning of Herbert Simon (1976) remark that in business and administration processes one has to be aware that humans have bounded rationality.

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Alas, this lesson is forgotten repeatedly, even in today's practice of workflow design and BPR. Notice that this does not imply that humans are sometimes irrational. Because rationality also has to do with a means-ends ratio, it might often be the case that employees prefer their personal goals above the company's goals, especially when the company's goals require impossible cognitive resources. Although it is not always a favored consultancy position – who wants to be confronted with his limitations - it might be a rewarding point of view from the perspective of realistic WFM design.

Besides the (limited) properties of the human intelligent agent it is important to look at the kind of tasks that have to be accomplished in the organization. Several divisions and categorizations of task types have been proposed. We will only deal shortly with a division proposed by Clancey (1985) with a follow-up by Schreiber, Wielinga & Breuker (1993), a division in terms of required mental resources and a division related to planning itself (Card, Moran & Newell, 1983).

Clancey (1985), in discussing task support with AI, suggested a division in tasks which require what he called system analysis, system change and system synthesis. In some tasks analysis is the most important activity. Examples are diagnosis tasks, tracing of causes tasks and classification tasks. Other tasks mainly require adjustment or change, for example in monitoring or supervision tasks. The so-called synthetic tasks require the combination or integration of separated elements or sub-tasks. It is as if an artifact is created. Examples are planning and scheduling tasks and design and layout tasks. One might call the task to design a workflow a synthetic task, whereas the task to monitor the workflow is an adjustment task. Clancey proposed his partitioning to formulate generic tasks and because the characteristic of generic tasks is that they have things in common, routes to develop task support can be shorter. Such a taxonomy of tasks has benefits for the design of A.I.-systems. Especially the analytic tasks have been investigated thoroughly (Schreiber, Wielinga & Breuker, 1993), not however the synthetic and adjustment tasks.

Clancey's approach does not take into account the fact that many tasks have to be executed by humans. His generic task taxonomy is only related to what has to be done. However, it is also possible to look at tasks in a generic perspective from the

viewpoint of users. Rasmussen (1986) in analyzing vigilance tasks in nuclear plants, and later Norman (1988) in discussing the design of devices, proposed a task taxonomy in which characteristic aspects as the involvement of and the load on motor, perceptual, and reflexive resources determine a task taxonomy. A highly loaded motor task is easier to perform than a medium loaded perceptual task and in the same sense a medium loaded reflexive task is easier to perform than a highly loaded perceptual task. The determination is in terms of amount of errors, tiredness, or time to accomplish the task.

One can look at generic tasks in general, but one can also look at a particular kind of task, for example the planning task. A closer look shows that this task can be interpreted in two ways. From a psychological point of view, planning is a mental activity besides problem solving and perceptual and locomotive skills (Card, Moran & Newell, 1983). People establish an order or arrangement on how to solve problems beforehand. This might include sub-tasks such as counting, ranking, grouping or selecting. The degree of planning depends on the complexity of the problem and the kind of task. Mental arithmetic hardly requires planning, whereas for example a game of chess requires much planning. In this view, planning is part of a larger task. Planning, however, can also be a task itself. Important sub-tasks of planning, then, are for example clerical work, counting, negotiating, and problem solving (Mietus, 1994). Clearly, planning as a task (like other tasks such as chess or mental arithmetic) incorporates planning as a mental activity. The most apparent distinctive determinant between the planning task and the mental activity is the question of who or what will execute the plan. Somebody who mentally creates a plan will use this plan himself to perform the larger task. Contrarily, the outcome of a planning task is often used by others in their own task context.

In taking into account the human limited capacities and one or several task taxonomy's the orientation in the analysis of workflow and workflow management will dramatically change. In our opinion this is not a favorite position at the moment. However, we think that such a perspective is inevitable if one talks about the design and development of intelligent decision support systems and knowledge based systems. We will show that in a later section.

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2.3.   *The engineering perspective*

Although there always has been a tendency in management science to imitate mechanical and other kinds of engineering, the orientation towards these kinds of labor and work structuring is growing in recent WFM and BPR discussions in general, with an emphasis on the notion of "efficiency". Simon (1976) discusses three, in time consecutive, interpretations of the notion of efficiency. In the first interpretation efficiency is the ratio between input and output and the definition is as follows: "Efficiency in the sense of the ratio between input and output, effort and results, expenditure and income, cost and the resulting pleasure, is a relative recent term. In this specific sense it became current in engineering only during the latter half of the nineteenth century and in business and in economics only since the beginning of the twentieth." (p.180) The second interpretation says that it is the ratio between actual performance and standard performance. It is assumed that standard performance can be measured, which is obviously the case with actual performance. This interpretation means a shift from factual for input and output towards factual for actual performance and some kind of norm for standard performance. The problem with this interpretation is that the so-called preciseness is intrinsically vague. The third interpretation of efficiency is even more vague. It is said to be the ratio between what is accomplished and what might be accomplished. In this interpretation the danger of wishful thinking that is implicit in the term "might", most of the times, leads to a never ending story of redesigning, remodeling and reprocessing. Because it is well known that humans are quite flexible and adaptive, the determination of a new so called ideal situation is mostly done without considering the inherent limitations of human information processing and human intelligent architecture. The point is that not only efficiency, but also other aspects of organizational design are formulated in this ideal perspective. In this sense and with this interpretation of efficiency and a similar treatment of other aspects such as "communication" or "just in time delivery", the engineering perspective often leads to a less than "normal" performance. Unless one wants to agree with the remark that many (and perhaps) all processes in organizations are better of without humans. One may grant jokers the truth that the world might be much better of without human beings, but for the time being this is wishful thinking.

What we mean is that although there is nothing inherently wrong with the engineering perspective, one should be careful with the transfer of properties and mechanisms of entities at one physical level to be applicable to entities at another level. Combining steel (welding), to pick up our example, is not the same as combining people (increasing their cohesion). There are at least three differences. First, physical entities differ from conceptual or functional entities in the sense that different things can be done with them. Second, the kind of activities that can be used for physical entities can not obviously be transferred to conceptual entities. One only has to look at "welding" or "steering", to see the implication that literal meaning is different from metaphorical meaning. Third, concerning entities and activities, quantification and measurement procedures in the case of physical entities are fixed and determinate, whereas they often are ambiguous in the case of conceptual entities. Although we think that semiotic approaches offer solutions here, we will not pursue this line of thought in this article (Jorna & van Wezel, 1996).

2.4.   Representing the "objective organizational reality"

The critique we have on modeling approaches in management science also applies to WFM and BPR. Although there is a close relationship with the critique on the engineering perspective in WFM, this critique on modeling goes deeper. In our opinion one of the basic mis-interpretations of modeling in management science, whether it has to do with information technology, WFM, or other kinds of organizational design, is that modeling is supposed to be the same as imitating or depicting. It is assumed that in modeling, or in more general words in representing or representation, one has to deal with two domains of which the one has (to have) strong similarities with the other. As one could say: the one imitates is similar, or even equal to, the other. There are two problems with this approach to modeling. The first is that it is unclear what the starting (the to be modeled) domain should be. The other is whether, even if such a domain exists, similarities are supposed to be the cause of the modeling activity (Jorna, 1990). It can be argued that a similarity between, for example A and a, is a result and not the cause of the model or representation (Goodman, 1981). In both cases the core of the problem is that

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modeling principally, but unjustly, is conceived of as, to put it in logical terms, a two-place predicate. We would like to argue that modeling is a one-place predicate in which a model creates a so-called world or domain, without any reference to an objective or otherwise grounding reality. What designers and developers of workflow systems do is that they create, of course to their best knowledge, domains. This means that one is not copying or imitating, but that one is working with interpretation, meaning and versions. This implies a three-fold shift compared to what many designers are used to do in modeling. First one has to realize that one is dealing with structures that are most of the times formulated in terms of (quasi-formal) expressions, that is to say sign structures. The second is that a designer has to realize that the meaning or interpretation of a suggested model, which is a sort of categorization, may be different for different users or employees in a company. Third that in case of discussions a designer does not have recourse to a privileged domain that only he knows. Such a domain simply does not exist. The newest and latest designs for the flow of work in organizations are as much pieces of art as are Picasso's paintings or as the newest car models of Renault. Everyone knows that creating these different designs requires much more craftsmanship and skills than inspiration.

2.5. Towards another perspective

The criticism we formulated concerning WFM does not imply that we want to abandon this and similar approaches. Those who think that have misread us. We looked at WFM and WFMS from the perspective of users and tasks. This brings about a different level of analysis and description. It is not, as usual, from top to bottom down, but instead from bottom to top. Besides, we argue to take into account the limitations of the cognitive architecture and mental representations of the users as the principal entities in organizations. This is something that is easily overlooked in the search for efficiency, perfection and optimal solutions. We argue that there are no optimal solutions and that efficiency can only be relative. Therefore one should be cautious in interpreting redesigning or streamlining in the sense of striving for perfection. A better interpretation is to say that redesigning and streamlining start

from the elimination of unintentional mistakes and shortcomings of earlier designs. This never ending process, however, can better begin from the bottom than from the top.

It is always stated that criticism is easy, whereas formulating alternatives is the hard part in discussions and therefore is left out. Because we do not want to be guilty of this accusation, we discuss an alternative by comparing WFM to planning. We approach planning within the SEC-framework, in which many of the before mentioned shortcomings have disappeared. However, before we will go into the details of this framework, we will show that there are many similarities in WFM, planning and logistics.

3. Workflow management, logistics and planning

In the definition of workflow management by Joosten & Brinkkemper (1995) it is stated, among others, that "a workflow is a system whose elements are activities, related to one another by a trigger relation, ...". Other parts of the definition have to do with the requirements for triggering and the legal/economic wording of the organizational processes. The problem with this definition is that it might also be applicable to the issue of logistics or planning in an organization. The differences depend upon the definition one wants to give of logistics or planning. Because we claim that our approach towards planning and scheduling can be applied to WFM in general, we first want to compare workflow with logistics and planning.

Logistics has to do with the routing, coordination, adjustment, or arrangement of all kinds of elementary operations in an organization (Bertrand et al., 1990). The term "logistics' traditionally was applied to production plants, factories and transportation systems. The essential characteristics relate to distances in space and the routing of parts, entities or elements through an organization. In the past it mainly had a physical, hard-boiled meaning. Nowadays "logistics" is also used in the analysis of administrative organizations, such as the handling of claims in insurance companies, and service organizations, e.g., the routing of patients through large hospitals. In these kinds of organizations physical distance and physical routing are interpreted in conceptual and functional terms. And because this also

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involves tasks and activities done by employees and workers, the differences in practice between workflow and logistics have become very small.

A similar perspective can be taken with respect to planning. Key terms in discussions about planning are resources, constraints, coordination, and attuning. There are many definitions of planning (Mietus, 1994; Jorna, et. al, 1996) of which some have to do with the limitations of resources, others with the control of operations in order to reach a goal and again others with guiding principles that have to be implemented in low level organizational operations. We defined planning (and scheduling) *"as the attuning of instances of different object types, thereby upholding constraints and goals"* (Van Wezel, et al., 1996; Jorna et al., 1996).

The reason that we include scheduling in the definition of planning is that, according to us, the differences between the two do not pertain to the abstract activity of some kind of "attuning", but to the level of measurement of the (properties of the) object types. In planning the level of measurement is, at most, the ordinal level, whereas in scheduling the level of measurement has to be interval level, at least, and, preferably, the ratio level. Although we are aware of the fact that there are many customs and language conventions around in planning and scheduling environments, we would argue that if one speaks about planning, mostly from a long term perspective, and scheduling, mostly from a short term perspective, the discussion is not about the attuning activity itself. Instead it is mostly about time in terms of longer/shorter/earlier/later (ordinal level) in the case of planning and about time in terms of between 8.00-10.00 PM or, for example, 60 units in 60 minutes (interval or ratio level) in the case of scheduling. One should be aware of the fact that real calculations can only be done at the interval or ratio level of (time) measurement.

The central elements in all kinds of discussions about planning and scheduling are the factor time and the restrictions or limitations in the so-called resources. In investigating more than 40 planning and scheduling cases (Bakker, 1995), it was found that time - in one or another sense - was always involved in planning. Restrictions of resources were found in the fact that not only time itself was limited or structured, but that at least one set of (properties of) instantiations of object types was also always limited. There were a limited number of employees, lorries,

machines, and so on, or their properties indicated limitations, for example, only 20 tons freight in the case of lorries or only qualified staff in the case of night shifts. We will come back to this in section about the SEC-framework.

Although different in tradition and terminology there are similarities between logistics, planning, and WFM related to three aspects. First, if one looks at the entities or elements that are dealt with in workflow, logistics, or planning, it is always about activities (tasks), employees (persons), workplaces or units (locations), and all kinds of equipment (machines, lorries, etc.). The differences consist in the fact that in workflow and logistics time is implicitly present, whereas it is explicitly defined (at some level of measurement) in the case of planning. However, in workflow and logistics the implicitness is only relative, because always some (fixed or flexible) time horizon has to be determined. In the earlier days of logistics the emphasis may have been on distances and routing, but in present day discussions this element has become of minor importance. There are some exceptions, of course. In regional and country planning the central element is the attuning of space(s) and no one would think of it as workflow or logistics.

Second, looking at workflow, logistics and planning from the perspective of what is really being done in these activities, that is to say what is the action involved, it is all about integration, harmonizing, synchronizing, accommodating, adjusting, coordination, and control. Although the differences between these concepts may be large if it boils down to operations, from a high level perspective they all have to do with fitting and attuning (as a matter of fact: with organizing) and, connected to that, with evaluating whether the outcomes are realized. After that sometimes regulating, refitting or reattuning is required.

Third, from our view on outcomes and results, logistics, planning, and WFM have another important thing in common. The past years on improving workflow, logistics, and planning demonstrated the failure of the search for one and only one optimal solution. In all three areas a lot of effort has been put into the quest for the (one) final (optimal) outcome. The point, however, is that there is no optimal planning, workflow layout or logistic structure. Always the perspective of the user(s) influences the outcome. What may be optimal for a designer may be only third best for a user. Another big problem with "optimal" is that it requires

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evaluation mechanisms by the user to a degree that is reasonably beyond his cognitive capacities. Many people in organizations - even developers - often only have a rough idea of the "ultimate" outcome of the workflow or the planning. Finally, it can be argued that at the same time the so called real world is dynamic, which means that even what might be optimal for the model, has already changed in reality. Instead of looking for optimal or ideal, one should try to design workflow (or planning) in such a way that there are degrees of freedom in the design which a user or an organization can apply to adjust the structure at that moment.

Although we argued that there are many similarities between WFM, logistics and planning, we also have to point to certain seemingly differential characteristics of WFM, logistics and planning. One big difference between most manufacturing situations on the one hand and most workflow situations on the other hand, is the place of the original trigger. In manufacturing, customers order an end product with a due date. The activities that must be performed to create that product are determined backward. Hence, this is a pull system. Contrarily, in most data processing organizations, the trigger is a document that must be processed. The end product is not always defined beforehand because the path depends upon the content of the document and therefore is determined by the activities themselves. This is a push system. In push systems, the magnitude of work that the current collection of documents or orders will bring can not be calculated as accurate as with pull systems. Of course, some manufacturing situations are push directed and some workflow situations are pull directed, but our message is that both require different control mechanisms, and that we should be conscious of the fact that most logistic concepts assume a pull system.

Besides this point of difference WFM usually deals with the management of transformation of pieces of information by humans. The emphasis is not on the content of the transformation process but on the whole of tasks that must be organized. Hence, it can be fruitful from a management point of view, to abstract from the content of the transformation process. Then, concepts of production management can be assessed with respect to appliance in data processing organizations. Platier & Brand (1996) and Brand & Platier (1996) describe how concepts from production management can be applied to WFM, e.g., master

production schedule, allocation of capacity, delivery performance, and workload control. They conclude that existing WFM-systems do not posses the functionality that is required to manage the workflow with these parameters. We endorse this approach with some reservations. First, the level of analysis, the human factor, the engineering perspective, and the propensity to imitate in modeling, that were discussed in section 2, are still not accounted for. Second, logistic concepts are developed for transformation of products by machines. Although we can view information processing as product transformation and humans as machines, they are not the same. Third, production management frameworks have not always been applied successfully. These frameworks are meant to be generically applicable in all situations, but the lowest level, i.e., scheduling and sequencing of activities, is repeatedly neglected in production management frameworks. We will show that the Scheduling Expertise Concept (SEC) is able to overcome such deficiencies in the scheduling domain (Van Wezel et al., 1996; Jorna et al., 1996) and with the danger of exposing ourselves to the hazards of applying an approach to a domain it is not initially meant for, we will describe how we think the SEC can remove some of the inadequacies of current approaches to WFM.

Our conclusion is that WFM and planning share so many characteristics with respect to entities concerned and actions that are involved, that it is justifiable to look whether a framework that has been developed to overcome the earlier mentioned shortcomings in planning approaches can be used for WFM and WFM systems. The explanation of the SEC-framework and the example we show are supposed to be convincing. Thereafter we will turn to software support, because the orientation towards tasks and users have implications for the design and implementation of this support.

4. The SEC-framework

In this section, we claim that WFM Systems must contain functionality to assign, in corporation with a human planner, activities to individuals and time periods, and that this is a non-trivial task that requires more attention than it currently attains. We propose the Scheduling Expertise Concept (SEC) to analyze, design, and

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support the task of human schedulers. It addresses the deficiencies that are discussed in the previous sections with respect to scheduling and planning.

The main principle of the SEC is the use of a bottom-up approach, i.e., the first level of analysis is the human planner and his task. Therefore, human factors can be incorporated explicitly in the design of control structures and computer support. The main problem to apply this to the WFM-domain is the absence of such a planner. Therefore, the orientation shifts from descriptive to prescriptive. However, our presumption is that, to a certain level, knowledge about scheduling and planning is generic, and that the results from previous analyses can help in designing the scheduling task for WFM to a certain extent. Application in practice, however, must fill in the details of Workflow Scheduling.

Several scientific fields address planning and scheduling issues. Table 1 provides an overview of some of these fields.

Planning as …	Addressed by
Mental activity	Cognitive science
Task	Organization theory, psychology
Attunement of scarce resources	Economics
Arrangement of space	Spatial sciences
Control of production	Production management
Combinatorical problem	Econometrics; AI-scheduling
Determining sequence of activities	AI-planning
Problem in practice	Decision Support Systems theory

Table 1. Scientific areas that deal with planning

In our view, an approach to planning and planning support should be able to incorporate results from the available scientific fields. In addition, planning not only appears in many forms in science. In practice, the diversity is even larger. Planning appears in industry, in service organizations, in space missions, and even in our personal life, e.g., making a shopping list for tomorrow. We could easily get lost in tracking the differences in these fields. Contrarily, the SEC tries to map the similarities in order to search for general planning and scheduling knowledge. We claim that planning of the workflow has enough similarities with the other fields of planning to consider applying the generic knowledge about planning and scheduling.

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The SEC contains a framework with various models to depict the task of the scheduler. The basis for all models is the object-model. This model depicts the objects or entities that are scheduled. By using the abstract notion of objects, several planning and scheduling situations can be described with the same modeling language, i.e., the generic structure of the models creates the possibility to model different types of planning and scheduling, such as production planning, personnel planning, transportation planning, etc. This forms a basis for extracting generic knowledge about planning and scheduling.

In the case of WFM, the schedule consists of scheduled activities. Each scheduled activity is the assignment of an activity and a performer to a time period (Figure 1).
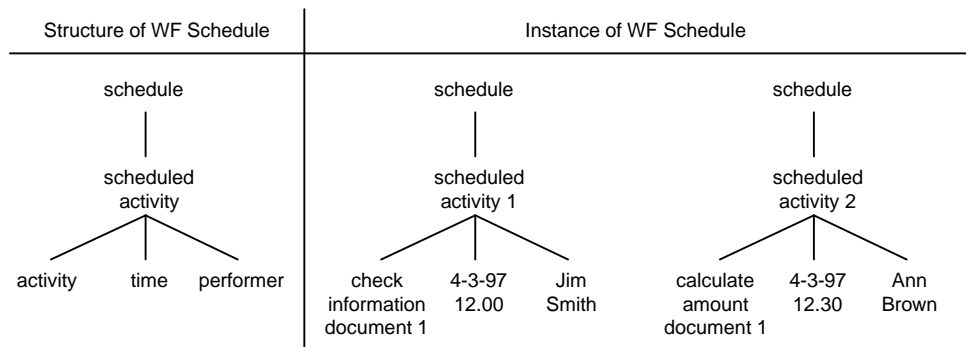

Figure 1. Object model of a Workflow schedule

All other models in the framework directly or indirectly refer to object models. First, constraints specify illegal assignments. For example, the minimum time between the two activities in Figure 1 might be 45 minutes. Then, the depicted schedule would be illegal. Other constraints deal with precedence requirements of activities and required cooperation of actors. Second, goals specify preferred combinations, e.g., to minimize the throughput time or maximize the use of capacity.

Third, task models describe the way in which the task is carried out, i.e., the way the object instances are linked by the human scheduler. There is a separation in task decomposition and task strategy. The task decomposition describes the way the

scheduling task decomposes into sub-task, sub-sub-tasks etc. Examples of sub-tasks are counting, clerical work, negotiating, and arranging. The task strategy describes the order in which the various sub-tasks are performed. Table 2 provides some generic task strategy characteristics.

Task strategy characteristic	Meaning	Consequences for WFM
Periodical/continuous	When scheduling is performed periodically, the scheduler waits for a specific time to start, for example each Monday morning. Continuous scheduling is performed whenever a new impulse arrives.	If a fast response to incoming triggers is required, or if the result of an activity can reveal information that has serious implications for the rest of the schedule, scheduling should be performed continuously.
Pattern/exception	Scheduling with patterns means that a predetermined schedule pattern exists, for example a rotating personnel schedule in industry. In scheduling by exception, the schedule is made without a predetermined frame.	Events with a high rate of predictability or reoccurrence should be admitted in a frame or pattern. For example, incoming documents that have a fixed processing route can be scheduled in its entirety at once. This diminishes complexity by using the available characteristics of the underlying domain.
Empty/existing schedule	The scheduler can use the existing schedule and add something, or he can start with an empty schedule.	If it takes a lot of effort to reassign activities in the schedule, e.g., reallocation of documents, then the existing schedule should be maintained. Starting from scratch, however, can benefit the efficiency of the schedule because the search for a good solution is not impaired by existing assignments.
Batch/one by one	In one by one scheduling, each object is scheduled without considering the other objects that have not been scheduled	Scheduling in batches is more complex because of the increased number of alternatives that can be

yet. Batch scheduling does take into account all objects that have to be scheduled, e.g., it looks if an assignment does not preclude a valid schedule.	reviewed, but for the same reason the schedule can be made more efficient.

Table 2. Generic task strategy characteristics

In general, computer support for scheduling consists of a number of separable functionalities. The system must be able to retrieve the necessary data from the user or from other systems, create schedules, check constraints, assess goals, and provide insight in the schedule at different levels. From the perspective of the user, however, manipulation is the most important aspect. The system must provide insight into the workings of the algorithms, i.e., the generation functionality should not be a black box. In addition, the system should allow manual scheduling, what-if analysis, backtracking of decisions, manipulation of constraints and goals, and different views on the schedule for different persons that are involved in the planning process.

Advances in several of the mentioned scientific areas provide input to give content to these functionalities. Generic knowledge based decision support theory and cognitive science are used to create systems that cohere to human users (Prietula et al., 1994; Smith et al., 1996). Organization theory shows how planners can cooperate, production planning frameworks show how to manage the different planning levels, and results from econometrics, AI-planning, and AI-scheduling can be used to design algorithms that generate schedules.

The use of computer support means that the task performance will change. Planners that make plans manually are often glad to have a plan finished. Changing the plan afterwards will take considerable efforts and hence the planner has not enough time to search for alternative solutions. The computer will cause the planning task to be performed faster. Therefore the planner will, in most cases, be able to spend more time to search for alternative solutions. Hence, cognitive attention changes from generation to manipulation, as was found by Mietus (1994). To take full advantage of computer support, such new possibilities should be identified beforehand and considered in a new task design. An example is the shift

from periodical, one by one scheduling that starts with an empty schedule to continuous, batch-wise planning on the existing schedule. This can result in better schedules but requires considerably more information processing. Computer support enables this shift in task strategy. The task design should be bottom-up and take into account cognitive limitations, to avoid the pitfalls we identified in Section 2. Therefore, the first attention in task design is not optimality from the perspective of design or outcome but from the perspective of correspondence to (cognitive) characteristics of the human planner.

Until now, WFM system development has mainly focussed on standardized interfaces with existing systems and integrating communications, information, and data flows (Schäl, 1996). Current WFM systems do not satisfy the aforementioned requirements, not for basic logistic functions (Platier & Brand, 1996), and certainly not for detailed and user-oriented scheduling support. Clearly, if the logistic paradigm and the SEC are to be used for WFM and Workflow Scheduling, the focus of WFM should incorporate a more sophisticated control-oriented approach. This will be discussed in Section 6. First, however, we will demonstrate the SEC with an example.

5.An example

As an example of the SEC, we describe the redesign of the planning at a Dutch manufacturer of limestone. This factory produces both bricks and elements. The bricks have standardized sizes, but the elements, that are mostly used to connect the wall to the roof and hence have slanting edges, are different for each building. The process is roughly as follows. First, the building contractor must send the drawings of the building to the manufacturer. There, the drawing department makes detailed drawings of the bricks and elements that are needed. These drawings are sent back to the building contractor for comments or confirmation. Second, the bricks and raw elements are produced in the production department. Third, the raw elements proceed to the sawing department. This department saws the elements to the form that is specified on the drawings of the drawing department. Fourth, the expedition department handles the transport of the bricks and elements to the building site.

In this situation, there was little or no planning. The manufacturer promised a six-week delivery period, and orders were always accepted without a capacity check. The expedition department checked the list with forthcoming deliveries every day. The orders that were due in a few days were sent to the sawing department. This department then picked up the drawings from the drawing department, and they would tell the production department how much bricks and elements of what size they would need.

The first problem here was the lack of coordination between the separate departments. We see a pull system for the planning, since the expedition department pulls the production at the sawing department. The sawing department then checks if the drawings are ready. The sawing sequence is important due to sequence dependent setup-times, but the pull-system makes that this can not be taken into account adequately. In addition, the unpredictability at the drawing department is high because the drawings sometimes take several versions before the building contractors agree, and the lack of communication about due dates between the expedition department and the drawing department makes that the drawing department does not know how to prioritize the current workload. Therefore, drawings were frequently not available when needed, resulting in missing the due date. A second problem is the lack of insight in the future workload. After analysis we found that, each week, the due dates of as much as thirty percent of the orders move to the next week because the building contractors have delays. Therefore, order acceptance should use techniques to determine the workload in a more advanced way than just adding up the current outstanding orders.

To overcome these problems, we advised to appoint a central planner, who should accept orders, and assign periods to the departments in which they should do their work. In this way, each department has its own due dates without the need to communicate with the other departments. The departments can plan their work freely as long as they satisfy the assigned due dates. To a certain extent, we can reason about some of the task characteristics of the new planning tasks. First, the central planner should work continuously because of high rate of postponement of orders. Second, he should work with the existing schedule, because disruptions are passed on to the individual departments. Third, the central planner can work with a

pattern with standard period durations for the respective departments, e.g., three weeks for the drawing department, one week for the production department, one week for the sawing department, and one week for the expedition department. In this way, the sawing department can create a schedule in advance, since they know what orders must be produced in what period, and hence take into account the sequence of sawing.

Each of the departments can now have their own planning strategy, which has several advantages. First, the drawing department can prioritize communication efforts with building contractors because they know the due dates of the drawings. Second, the production department and sawing department know in advance which product must be made so they can batch-wise take into account sequence dependent setup-times. Third, the expedition department does not have to check with building contractors when deliveries must be made, and they do not need to negotiate with the other departments about due dates, which are now tasks of the central planner.

Each of the planning tasks should be supported differently. The support of the central planner will focus on manipulation and overview over the current order portfolio. The drawing department needs a system that provides information about the status of each order, the production and sawing departments need systems with algorithms that create efficient schedules, and the expedition department needs a system that is specialized for route planning.

In our designs, we accounted for the differences between the planning requirements of the departments, without loosing track of the overall picture. The central planning determines boundaries for the individual department plannings, but does not fill them in. That is the task of the people at those departments themselves. Therefore, we could account for (cognitive) limitations in the design of the support, instead of designing one centralized planning for the complete organization and prescribing a detailed planning to the departments.

This section dealt with an example of our approach to planning design and planning support in a manufacturing environment. We claim, however, that these same ideas can also be used in the field of WFM. In the next section, we discuss some consequences of our ideas for WFM and WFM systems with an emphasis on the requirement of knowledge based systems.

6.Information Systems, KB-DSS and Workflow management support

Basically there are three kinds of support in relation to WFM, that is to say a distinction can be made between support for WFM-(automation) design, support for WFM (in practice) and support within WF (workflow). First, support for WFM-design means that in the development of (integrated) WFM-systems the designer of such systems is aided by a decision support system. This high level support presupposes that validated knowledge is available about the best way to implement the structure and content of a WFM-system in an organization. As far as we know this kind of "expertise" is lacking and because we think that in many situations it can not be determined what an optimal implementation for the most efficient flow of work is, implementing these kinds of systems will principally be impossible. The only sophisticated applications one might get are supporting tools in the same way as graphic designers use CAD/CAM-software and similar tools.

Second, support for WFM, also called WFM-automation, means that in managing the workflow a (decision) support system is available. The (WFM)-manager uses this system to monitor, control and adjust the flow of work in the organization. Because we already argued to interpret WFM to a larger extent as an example of planning, the same refinement of supporting tools can be applied that we developed for individual planning and scheduling cases. From the lower end of support to the higher end this includes support in terms of classical MIS-tools to all kinds of DSS-tools. Classical support comprises of databases and database management systems, spreadsheets and (statistical) calculation software. In the case of planning support systems we suggested an editor, a controller, an evaluator and an interactor (Huisman et al., 1994). This can easily be translated into support for WFM. The WFM-editor explicitly visualizes all kinds of flows of products, services, transactions or documents through the organization and normally integrates database management systems and spreadsheets. High-end editors can easily reach even to the level of simulation tools. The WFM-controller investigates whether explicitly formulated constraints are violated. The violations are indicated, but no

repair or solution is suggested. One level above is the WFM-evaluator judging what outcomes of the - again explicitly formulated - goal functions in terms of minimization or maximization have been realized. Again the manager has to decide what kind of adjustment is necessary, that is to say no solution is provided by the system. The highest level of support consists of the WFM-interactor. This kind of support requires the implementation, presumably in knowledge bases and inference mechanisms, of rules that dictate the adequate flow of work. This again might lead to discussions about optimal and ultimate solutions. This is not what we mean. In the case of the controller, the evaluator and the interactor the tools do not work from the perspective of the best, but from the perspective of the least worst (Barth, 1993). This has the advantage that one can empirically validate possibilities and impossibilities. Discussions are about what can not be done and not about what is the best to do.

Third, support within WF (workflow) is about dedicated software support for individual tasks in the organization. Again, this may include the whole spectrum of support, from databases to knowledge based decision support systems. Take, for example, the department for the registration of complaints about repair services, which is part of the overall flow of work in a large electronic equipment company. The department's software support system may be developed without taking into account other processes in the organization. As a matter of fact this kind of support by information systems is normal in today's organizations. It might be the case that the data from the registration department is visible for the management, it normally is not integrated into a general perspective on the organization, let alone that it is part of an integrated workflow management system.

When we look at all kinds of software support in organizations, only support within WF is present and standard. One finds databases, spreadsheets, statistical software, and product automation software in organizations. One also finds, more and more frequently the last 10 years, decision support systems and expert or knowledge systems. However, most of these systems are only available for individual or group (or department) oriented task support. One does not find support for WFM-design and support for WMF is just starting to emerge. Although we built applications for planning and scheduling based on our SEC-model, we did not

implement this kind of support for WFM. We think, however, that it can be done, but we also think that from a helicopter view on software development there are complicating tendencies. We will try to mention them briefly.

At the moment there are two movements in computer systems development that, although at first sight opposing, will lead to different perspectives on support for the future. On the one hand there is a tendency to create bigger and more encompassing computer systems, whereas on the other hand there is a demand for small highly intelligent systems that are really adapted to individual users. These developments might also cause radical consequences for WFM and its support. In the first place both developments require that much time and much expertise have to be invested in thorough analyses of task domains and the individual task performance of human users. In the second place with the need for more comprising and more intelligent systems in an ever faster changing environment, the complexity, desultoriness, and dynamics of systems increase. Nowadays, computer systems do not exist five years unaltered anymore, they are continually adapted. In the third place advanced computer support changes the (old) task strategies and procedures. In the fourth place, because of the emergence of new hardware and software, the classical ideas about organizational structures will change, that is to say that the unity of task, time and place, that is also the basis of WFM, will disappear. We will discuss the four points in detail below.

We have already been very explicit about the relevance of cognitive and integrated task analysis and the interaction of humans as information processing systems with computers. Because we are not talking about standardized, bureaucratic and hierarchical task execution anymore, careful and detailed task performance and task interaction analyses have to give information about the various ways people route and process elements through an organization. Task decomposition, fixed and various task strategies and flexible task procedures are part of this kind of WFM support. WFM-automation will be flexible, adaptive, descriptive, and task-user-oriented, or it will not be. In our opinion this requires the use of ergonomics, psychonomics, knowledge management and knowledge and decision support systems from a cognitive psychological point of view. A perspective, we think, that is hardly favored in today's WFM.

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Another point relates to the increasing complexity, or as some would call it chaos, in present and future organizations. Organizational boundaries are shifting, with consequences such as that what once was internal has now become external and that what once was external is now related to the internal workflow without becoming a legal part of the company. Outsourcing and (future) insourcing have an immediate effect on a company's internal workflow with consequences for the information systems. No one knows how to deal with these issues at the moment, although various organizations are looking for concepts to get a grip on the developments. The present connections in, on and with Internet only give a volatile view on the future intra- and inter-organizational possibilities.

A very important, but often neglected aspect of the introduction of software support for (groups of) tasks in organizations concerns the change in the task execution after some time. Until now no adequate methodology in software and cognitive engineering is available to deal with this, in general, normal human behavior. One can only dream about the effects it will have on workflow and workflow management.

Finally, perhaps the most important effect on workflow management will come from the coming developments in the ongoing information society. The 19th and 20th century showed an increasing loss in what might be called the unity of tasks. Tasks are sub-divided, restructured, sub-sub-divided and again restructured. The division of labor, with which we are all familiar, has gone so far that some people even claim that the so-called natural unity of a task has disappeared. Without the intention of going back to the old skilled workers, workflow management can partly be seen as an answer to too much dispersion in tasks. At the moment we are experiencing something even more drastic, that is to say the loss of the unity of time and the unity of place in organizations. Cooperation between humans and especially between humans and computers will be at different times, someone doing task A on time t and someone else doing related task B at time t+3, because the computer will store the intermediate results and display them if requested for. It will also be at different places, for example, a cooperation of people at different places and times, e.g., in Japan and England, however working on the same task. The physical reality, the old way of organizing structures, will be replaced by a functional or

representational reality, or as some might call it: a virtual reality. Clearly present day WFM has no idea at all how to deal with this dispersion in time and place. However, the same holds for management science, (cognitive) psychology, and computer science in general. Part of the answer has to come from more advanced and integrated knowledge and semantic (understanding) database systems on the one hand and on the other hand from the behavioral sciences indicating how our habits and customs have to change and can be changed. One thing seems to be sure, because of represented and interpreted (man-made) realities, WFM and WFM-automation will have to deal with semiotic, that is to say with sign and sign interpreting, issues.

In our opinion it is unclear in what direction the future of WFM and WFM-systems will go. The increasing organizational complexity, the vagueness of work and task boundaries, and the loss in unity of time and place will have differential effects. It will definitely not go without software and hardware support, although not developed within the classical perspective. Software support with knowledge systems and knowledge-based decision support systems will start with the analysis of users, user performance, and task structures. We think that software development in WFM-support and within WFM itself may benefit from this shift in perspective.

7. Conclusions

In the foregoing it was our intention to show that WFM is partly on the wrong track. We criticized WFM from a planning perspective that we developed in the last five years. We made the assumption that WFM is about organizing the flow of work or tasks done by humans in organizations. This organizing basically is about the attunement or accommodation of different kinds of object-types. We consider this activity to be some kind of planning. For that reason we argued that our SEC-perspective on planning can be applied to WFM and WFM-related issues. We illustrated this briefly in explaining the SEC-framework and in showing an example of what we did with this framework. Research and software development within this orientation is in progress (Heesen, 1996; van Wezel, 1997). This SEC-framework may be wrong, but in convincing us one also has found replacements for three

developments we see in present day software support and organizational structuring: the human intelligence factor, the issue of interpretation, and knowledge management.

The human intelligence factor will be decisive in many organizations of the near future. Low level intelligent tasks already are replaced by computers and the same is happening at the moment with the lower level of the medium intelligent tasks. This process will continue, requiring an attitude from users in which they ceaselessly have to adapt to changing tasks that ask for adjusted intelligence. Organizations that neglect this factor will have to look for more intelligence in the form of computers, which at their turn require interaction with (more) intelligent humans. In our opinion there is no other road. The reverse of this development is an ever-increasing awareness of the limitations of human cognition and our cognitive architecture. In our opinion, a research agenda in which these topics are missing will be unfortunate for WFM.

The issue of interpretation may be conceived of as a strange element within so-called hard scientific engineering. We think this is wrong. WFM and all its possible software support consist of man-made artifacts. As a matter of fact, artifacts often are very hard and enduring, but they are always the result of a certain view on things, they are ways of world making. To be more precise they are not only world making, they are also world viewing. For example, software support in the sense of WFM-automation is the result of a (validated) interpretation process by developers resulting in man-made structures mostly consisting of signs in the form of tables, diagrams, texts, pictures, and figures which require interpretation by users. This interpretation process is a never-ending story. This may be a bad thing for the old mechanical engineers. It, however, offers many changes for cognitive, organizational, software, and even semiotic engineers, especially those who realize that our organizational reality and therefore the WFM-reality is basically man-made.

As Nonaka & Takeuchi (1995) argued, rightly or wrongly, the future of organizations will depend upon their attitude towards knowledge management. We think they have three important points in relation to WFM. In the first place the increasing globalization, also of WFM, will require huge adaptive skills and attitudes of organizational members. In the second place the strength of future

organizations will more and more depend upon their ability to, what Nonaka and Takeuchi called, externalize tacit knowledge. By definition tacit knowledge resides in the minds of organizational members. Therefore, one has to start with humans as information processing systems as the primal bearers of knowledge. In the third place the implementation of ever more powerful and intelligent computers will challenge the flexibility and high-level task perspective of humans. How to adjust to new tasks if the underlying structure is unclear? This requires the internalization of explicit knowledge provided by other members of the organization. In our opinion present day WFM has no answer to either of these three developments. However, we think that there are abundant possibilities. We only showed our approach.

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