Challenges and Solutions of Document and Workflow Management in a Manufacturing Enterprise: A Case Study

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Abstract

We present an Integrated Document and Workflow Management System (DMS/WMS) applied to the core business process "Customer-oriented Offer Processing" of a machine tool company. We emphasize the integrational aspect where the challenge is to integrate various types of electronic documents and formatted data, different existing and innovative application systems. Furthermore, it is necessary to flexibly integrate the business process-related activities into a homogenous workflow while considering the organizational structure. We introduce the concept of an Integrated DMS/WMS and a phase model to structure the numerous complex aspects of a running DMS/WMS. Only a completely integrated DMS/WMS allows an efficient control of business processes. In this paper, we address the problem of controlling the offer processing of our industrial partner company. We present the design of a DMS/WMS prototype which is able to solve the mentioned integrational problems. In addition, we report the performance of this prototype that is already largely implemented as a running system in the environment of our industry partner. We show several key features of this implementation.

1 Introduction

Documents represent the know-how of industrial corporations much more than formatted data, but to a large extent, document processing is still based on paper. In addition, many other drawbacks like long flow times, it is especially disadvantageous that information which is embedded in paper documents is partly or entirely lost after their active processing has terminated. Then the documents are usually stored in insufficient paper archives or transferred only partly to persistent on-line databases.

Industrial core business processes focus increasingly on documents as carriers of "high quality" information. DMS that are able to administer a lot of different types of documents with a uniform retrieval interface are the most important aides in this context. In spite of this fact, there still exists the danger of generating two separated worlds: electronic document processing and "classical" processing of formatted data such as pay slips or invoices. Therefore, the prevalent task for information engineers will be to look at electronic documents and formatted data in an integrated way.

Workflow Management Systems are often based on DMS implementations in order to manage entire business processes. In this sense, the challenge for successful information engineering is

- to integrate existing and innovative application systems in workflow implementations,
- to develop efficient techniques and methods to support the analysis and modeling of workflows,
- to design WMS as controlling tools in order to enrich the planning and control system layer of a corporation.

Usually papers about DMS/WMS are rather formal and tool-oriented or very general, where concrete examples for running applications are missing. The objective of this paper is to show how the above mentioned aspects can be realized for a industrial core business process of a manufacturing company. The result is a rather extensive DMS/WMS within an heterogeneous IT-architecture that especially takes into account new possibilities for integration. This DMS/WMS is the object of a research project that the Department of Information Systems I of the University Erlangen-Nuremberg (Prof. Dr. Dr. h.c. mult. P. Mertens) leads in cooperation with INA Waelzlager Schaeffler KG (a machine tool company in Herzogenaurach, Germany).
## 2 Integrated Document and Workflow Management

### 2.1 Basic idea and phase model

The essential tasks of a DMS are archiving, classifying, storing, searching, displaying, processing, and distributing electronic documents. These tasks of DMS have already been formulated in the past [Some84]. Since recently a proliferation of DMS products and application solutions has resulted in progress in information technology, above all in the optical memory sector, it is now possible to realize these tasks for many information objects.

WMS aim to model and analyze business processes. The basic idea is this: Information objects, e.g. order application forms, are passed through all stages of a certain business process and are enriched gradually, just like a physical product during the manufacturing process. In this sense, the WMS selects for each activity of the process a proper person who executes the activity and supports the processing by linking suitable application systems. The final product of a workflow again is an information object, e.g. the completed order application form. For the rest of the paper we assume to have a WMS based on a DMS. The coordination principle of this architecture corresponds to processes that heavily involve documents, e.g. complaint processing or order processing: Process folders that contain all relevant documents are handed through the process activities.

We use a Workflow Management phase model (figure 1) to structure the numerous complex aspects of a running WMS. These aspects must not be purely seen in sequence since overlaps and feedback exist. The phase model consists of two main phases:

1. **Process Description** (Analysis, Modeling, Definition, Configuration)
2. **Process Execution** (Planning, Initialization, Routing, Integration, Controlling, Archiving)

The former contains the modeling of the business process and the mapping of the model into a form where a WMS is able to translate and execute it. The process execution is referred to as a run-time WMS.

- **Analysis, Modeling**
  First the actual processes of the considered environment have to be registered. After an analysis of their weaknesses, the nominal concept is set up, i.e. a process model that contains all views which are necessary for a WMS.

- **Definition, Configuration**
  In the next step, the process model has to be transformed into a workflow model that is executable for the WMS. A major element to support this is the workflow script which can be defined with the help of a process description language. The script defines a network of process activities and is the basis for routing and integration. Further views of the process model (e.g. organizational structure, application systems to integrate) have to be configured depending on the WMS structure.

- **Planning, Initialization**
  Planning and initialization are the first steps during the workflow run-time phase. Workflow planning refers to laying out an activity network of a process as well as fixing the time and costs of single activities. The initialization usually coincides with the planning: e.g. a process folder is generated, pre-filled with documents and classified.

- **Routing, Integration**
  Based on the workflow model, the WMS executes a certain workflow, that means it routes the process folder through the activity network. For each activity, initial conditions, e.g. the availability of certain documents, are checked, and proper users are selected and supported by integrated application systems.

- **Controlling**
  Controlling functions of the WMS are e.g. rescheduling measures in case of critical violations of deadlines. Compact management information is extracted, processed and presented, e.g. in the form of workflow statistics or a monitoring system.

- **Archiving**
  After the workflow has been processed the "final product" process folder is classified and archived. In this step also activities like the modification of external information bases according to the workflow results or an automatic resubmission of the process folder take place.

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**Figure 1. WMS phase model**

<table>
<thead>
<tr>
<th>Process Description</th>
<th>Process Execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis, Modeling</td>
<td>Planning, Initialization</td>
</tr>
<tr>
<td>Definition, Configuration</td>
<td>Routing, Integration</td>
</tr>
<tr>
<td></td>
<td>Controlling</td>
</tr>
<tr>
<td></td>
<td>Archiving</td>
</tr>
</tbody>
</table>
2.2 Integration aspects

The following aspects of integration are related to the use of DMS/WMS:

- Integration of various document types
  If a DMS can deal with scanned documents as well as documents of other application systems (e.g. word processors, CAD applications), the design of a system with a uniform retrieval mechanism for numerous document types in the sense of a "unified view on documents" is accomplished. The DMS serves as an "organizational memory" [Spra95, p. 33; NeDi95, p. 78], meaning it is administering the document-related know-how of the corporation (reports, ideas, concepts, ...).

- Integration of data and document processing
  Interfaces between DMS and the processing of formatted data allow the merger of information types. For example, formatted data could be integrated in compound documents by a Form Management System as part of a DMS. Links between formatted master data and index data of a DMS make it possible e.g. to display a scanned supplier bill and the related data set.

- Process-oriented integration
  WMS seem to be useful as tools for process-oriented integration: Single activities can be flexibly assembled to a process with the aid of a workflow script. If a WMS has to be modified, the application systems that are especially designed to support a certain business function do not have to be changed. A large potential exists for WMS, in particular against the background of criticism of complex standard software packages which have a reputation of not being able to flexibly map business processes.

- Integration of the organizational structure
  For each activity of a workflow, the WMS has to select and notify users. This has been called the integration of information systems and organizational structure [Heil94]. The goal must be to have the most flexible choice of proper users according to the recent workflow status and additional criteria. The most popular concept is the choice of persons according to role-based mechanisms [Essw93]. Beyond that, there are more complex selection mechanisms, e.g. user profiles combined with rules for the choice of a certain profile [BuJa95].

- Integration of application systems
  Another challenge for a WMS is to enable convenient access to application systems that are involved in a workflow activity in the sense of an "intelligent front-end" [Mert92]. Since the results of an application system can be added to the process folder, it is possible to integrate formerly isolated application systems or programs that run on different platforms.

3 Case study: offer processing in a machine tool company

We study the customer-oriented offer processing of our industry partner INA. This process starts with a customer inquiry for a special product and terminates with a customized offer. We have developed a DMS/WMS prototype that fulfills the requirements mentioned in the introduction. As a guide for the following description, we use the Workflow Management phase model presented above.

3.1 Process description

3.1.1 Analysis, Modeling. In this section, we want to mention only some important aspects of analyzing and modeling in the context of DMS/WMS, since there is a prodigious number of publications in this field. Our analysis and modeling tool ODAN (Office Document Analysis) supports the development of a workflow process model [MoRa94], [RaMo95]. The basic element of the concept of ODAN is a document-based approach, where it is assumed that documents mirror the immaterial net value added during a business process. All documents that are important for the offer process have been analyzed and structured according to the HIPO (Hierarchy-Input-Process-Output) model. Additionally, documents contribute essentially to the synchronization of the activities of a process [Spra95, p. 29]. Very often activities are triggered by documents that lie on a desk and contain all necessary data to accomplish a task. A control flow in the true sense of the word does not exist [ReWe92, p. 74]. The result of a net value adding activity consists of information that is recorded on a document. This information can induce successive activities. Therefore, it is possible to describe workflows completely by documents. A study of the Xerox company states that 92% out of 2.300 lines which connect the 263 activities of a core business process are entirely determined by documents. Other control objects, e.g. time thresholds, have only a minor meaning [McSo91].
Table 1. Activities of the "Inquiry/Offer Process"

<table>
<thead>
<tr>
<th>Activity</th>
<th>Role</th>
<th>Subsequent Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Register Customer Inquiry</td>
<td>Field Service</td>
<td>2</td>
</tr>
<tr>
<td>2 Schedule Workflow</td>
<td>Process Manager</td>
<td>3</td>
</tr>
<tr>
<td>3 Quest for Already Available Solutions</td>
<td>Application Engineering</td>
<td>4</td>
</tr>
<tr>
<td>4 Create Requirement Catalogue</td>
<td>Application Engineering</td>
<td>5</td>
</tr>
<tr>
<td>5 Create Calculation Form</td>
<td>Application Engineering</td>
<td>6</td>
</tr>
<tr>
<td>6 Design Draft</td>
<td>Application Engineering</td>
<td>7 and 8</td>
</tr>
<tr>
<td>7 Technical Assessment</td>
<td>Application Engineering</td>
<td>9</td>
</tr>
<tr>
<td>8 Commercial Assessment</td>
<td>Marketing/Sales</td>
<td>9</td>
</tr>
<tr>
<td>9 Choose Decision-Maker</td>
<td>Process Manager</td>
<td>10 or 11</td>
</tr>
<tr>
<td>10 Decision by Division Manager</td>
<td>Division Manager</td>
<td>12 or 15</td>
</tr>
<tr>
<td>11 Decision by &quot;Electronic&quot; Special Bearing Committee</td>
<td>Special Bearing Committee</td>
<td>12 or 15</td>
</tr>
<tr>
<td>12 Create Rejection Document</td>
<td>Marketing/Sales</td>
<td>13</td>
</tr>
<tr>
<td>13 Dispatch Rejection Document</td>
<td>Marketing/Sales</td>
<td>14</td>
</tr>
<tr>
<td>14 Archive Workflow</td>
<td>Marketing/Sales</td>
<td>END</td>
</tr>
<tr>
<td>15 Initialize Offer Process</td>
<td>Marketing/Sales</td>
<td>16</td>
</tr>
<tr>
<td>16 Search for Standards</td>
<td>Application Engineering</td>
<td>17</td>
</tr>
<tr>
<td>17 Execute Calculations</td>
<td>Application Engineering</td>
<td>18</td>
</tr>
<tr>
<td>18 Create Design-FMEA</td>
<td>Application Engineering</td>
<td>19</td>
</tr>
<tr>
<td>19 Create Offer/Supply Design</td>
<td>Application Engineering</td>
<td>20</td>
</tr>
<tr>
<td>20 Adjust Design with Customer</td>
<td>Application Engineering</td>
<td>21</td>
</tr>
<tr>
<td>21 Note Design Adjustments</td>
<td>Application Engineering</td>
<td>22</td>
</tr>
<tr>
<td>22 Complete Calculation Form</td>
<td>Application Engineering</td>
<td>23</td>
</tr>
<tr>
<td>23 Make-or-Buy-Decision</td>
<td>Operation Scheduling</td>
<td>24</td>
</tr>
<tr>
<td>24 Choose Production Plant</td>
<td>Operation Scheduling</td>
<td>25 and 26</td>
</tr>
<tr>
<td>25 Create Calculation Form for Components</td>
<td>Operation Scheduling</td>
<td>30</td>
</tr>
<tr>
<td>26 Create Inquiry/Order Sketch</td>
<td>Application Engineering</td>
<td>27</td>
</tr>
<tr>
<td>27 Require Supplier Offers</td>
<td>Purchasing</td>
<td>28</td>
</tr>
<tr>
<td>28 Create Supplier Offer Survey</td>
<td>Purchasing</td>
<td>29</td>
</tr>
<tr>
<td>29 Choose Supplier</td>
<td>Purchasing</td>
<td>30</td>
</tr>
<tr>
<td>30 Determine Pre-Calculated Component Costs</td>
<td>Operation Scheduling</td>
<td>31</td>
</tr>
<tr>
<td>31 Create Calculation Form for Assembly Group</td>
<td>Operation Scheduling</td>
<td>32 and 35</td>
</tr>
<tr>
<td>32 Determine Offer Price</td>
<td>Marketing/Sales</td>
<td>33</td>
</tr>
<tr>
<td>33 Fix Offer Expiration Date</td>
<td>Marketing/Sales</td>
<td>34</td>
</tr>
<tr>
<td>34 Fix Delivery Date</td>
<td>Marketing/Sales</td>
<td>36</td>
</tr>
<tr>
<td>35 Fix Production Date</td>
<td>Operation Scheduling</td>
<td>36</td>
</tr>
<tr>
<td>36 Create Offer Document</td>
<td>Marketing/Sales</td>
<td>37</td>
</tr>
<tr>
<td>37 Dispatch Offer Documents</td>
<td>Marketing/Sales</td>
<td>38</td>
</tr>
<tr>
<td>38 Trace Offer (Renewed Submission)</td>
<td>Marketing/Sales</td>
<td>39</td>
</tr>
<tr>
<td>39 Archive Workflow</td>
<td>Marketing/Sales</td>
<td>END</td>
</tr>
</tbody>
</table>
Experience teaches that process steps executed by users have to be modeled more abstractly than those completely processed by application systems [CuKe92, p. 84]. The human agents' comprehension of process details (e.g. "How can I calculate a certain offer?") is more distinct than the comprehension of the process as a whole (e.g. "Which process steps have to be performed before the calculation step?"). In terms of workflow modeling this means that a relatively high level of abstraction has to be chosen corresponding to the final product of a process step (e.g. the document "Calculation Form for Components" within the process step "Create Calculation Form for Components"). In the workflow model, the state that has to be established is mentioned in a workflow order whereas the way to create this state remains hidden [Wede95, p. 3]. In addition, the approach used to solve a problem within a certain process step is pre-defined by the application systems in most cases.

As soon as the discussed level of abstraction is fixed, an explosion of complexity can be stopped. This way, the customer-oriented offer process of INA could be modeled with ODAN by 39 activities (figure 1), starting from activities like "Register Customer Inquiry", "Quest for Already Available Solutions", "Create Calculation Form", "Design Draft" and ending with "Dispatch Offer Documents" and "Archive Workflow" [MoRa94, p. 19-47].

### 3.2 Process execution

#### 3.2.1 Planning, Initialization.
In order to put our research subject in more concrete forms, we want to trace an example of a workflow. A customer of the mechanical engineering trade, e.g. a manufacturer of hydraulic pumps which are used in truck steering, asks for a special transmission bearing that is not an item of the INA standard production program.

First the customer inquiry is registered in an INA field service office with a Computer-Aided-Selling package. In addition to the type of business process and customer/product master data, the structured recording of the specified requirements of the product is particularly important for further treatment by the clerks. The data is transmitted overnight to the central host system. Next the workflow server initializes the corresponding inquiry workflows. An electronic document folder is created automatically. With the generation of the folder a workflow process is triggered. The workflow is then routed to the first official. Each user can see the workflow activities that correspond to his/her roles in a worklist, his or her "To-do-list".

If e.g. the second activity of the offer process workflow "Schedule Workflow" is selected, the execution has to be typified, for the inquiry type "New Design" the due date 68 (measured in corporate diary days) for the offer has to be fixed. Additionally, it is possible to add special customer requests that have an influence on the activity schedule. E.g. the customer wants to have a design test report in the form of a FMEA- (Failure Mode and Effects Analysis)
When all activities are scheduled, the process manager receives information about the scheduled total flow time and the planned activity-based costs of the workflow. If the planning seems to be reasonable to him or her, he or she releases the process. Subsequently, the process folder is routed via the role assignments to the first group of employees in the technical department.

3.2.2 Routing, Integration. To illustrate routing and integration aspects, we take a look at the major workflow activity "Quest for Already Available Solutions". This activity is particularly used to transfer available solutions and products in a qualified manner to recent tasks in order to avoid the repetition of similar technical and commercial activities.

When a clerk of the "Application Engineering Department" has selected a certain workflow in his or her To-do-list, a window to process the activity pops up (figure 3). The window consists of two sections: the process folder at the lower part of the window and the action list in the upper part. In the beginning, the content of the process folder only consists of the electronic form that holds the most important inquiry specifications. Each activity is subdivided into several actions. The action list in this case is linked with an automatic call for relevant application programs: the know-how database TADDY, the electronic product catalogue INA-EPK and the technical information system TIS.

3.2.2.1 Know-how database TADDY. The most important application system of the activity "Quest for Already Available Solutions" is the know-how database TADDY (Technical Application Documentation and Decision System). In TADDY the search for completely available solutions with the corresponding know-how (technical environment, special features) is featured.

After the action "Know-how Database Retrieval" (figure 3, third action of the action list) is selected, a query mask for TADDY documents is displayed. It supplies extended query options for application engineers, e.g. for application fields like propulsion technique. In our example, where the customer looks for a special transmission bearing, the user of the application engineering department "climbs hand over hand" from the general field "street vehicles" via the specifications "trucks, buses" and "steering" to "servo-assisted steering" supported by a menu sequence. Alternatively, the engineer can perform a query via descriptors, e.g. customer id's, etc. After the application system has been executed, the quest result, i.e. available solutions of INA for the special application, is shown. Since a special INA-solution can not be described in a single document, we have to deal with TADDY-document folders. If the technician thinks the new offer can be based on the available solution, he or she adds the TADDY-document folder with a "drag and drop function" in the process folder.

Within the DMS, a TADDY folder is one of the numerous document types. Since TADDY is able to make know-how accessible from available offers and developments in the sense of an "organizational memory", it exceeds simple document archives.
3.2.2.2 Electronic product catalogue INA-EPK.

In this state of the process the INA-EPK (figure 4), which is the second action of the action list (figure 3), is used to search for standard products that might become part of a special bearing solution. If the action "Retrieval of Standard Products" is selected, the INA-EPK query mask appears - analogous to the TADDY query mask.

As soon as the DMS has found a standard bearing with all desired characteristics, the design engineer is able to start the INA-EPK by double-clicking it in the DMS application list. The core of the INA-EPK is the program WorldView, a hypertext-tool for documents of the DTP system Interleaf. Thus, it is able to quickly transform the text-based product catalogues of INA (created with Interleaf) into an electronic form. Within the INA-EPK the engineer has many possibilities to navigate, e.g. full text queries and hypertext links to different products, technical tables and so on. If he or she considers a certain INA-EPK document to be useful, he or she is able to insert the actual document in the process folder of the WMS.

3.2.2.3 Technical Information System TIS.

The technical information system TIS (figure 3, first action of the action list) is the third application system to be used within the activity "Quest for Already Available Solutions". This host application, based on the product master database of INA, performs detailed quests for standard and special bearings. Usually TIS is operated by several quite cumbersome CICS-transactions. Therefore, we developed a user-friendly front-end that is called when the corresponding action is selected. In this process state, TIS is mainly used to search for details of single parts for a special bearing solution. It is again possible to integrate the retrieval result in the process folder, now as a plain text document. TIS is an example for the WMS as a user-friendly front-end for existing applications, even for the...
3.2.2.4 Termination of activities. The goals of TADDY, INA-EPK and TIS partly overlap. This is a result of the "organically grown" IT-infrastructure of INA. In this case, the WMS offers the possibility to integrate old host-based applications as well as innovative new applications in the process. The design engineer has now two possibilities to route the workflow. If he or she selects "Terminate Activity" (see figure 3, button "Aktivität beenden" (German)) the folder is routed according to the workflow script. In order to guarantee flexibility, it is also possible to route the workflow manually. If "Manual Control" (see figure 3, button "Manuelle Steuerung" (German)) is selected, the WMS presents a list of all possible activities and the application technician can choose the activity that has to be executed next.

Each of the other planned workflow activities (at best 39) is performed in a similar manner whereas all the major activities are supported by application systems. The process is completed with the activities "Dispatch Offer Documents" and "Archive Workflow".

3.2.3 Controlling. The recording of workflow performance data is necessary for comparing planned and actually achieved data and for report functions based on those comparisons. Run-time deadline warnings used for management information are examples of these report functions. The WMS should support this feature in order not to burden the user with too many administrative tasks. In our WMS this demand is taken into account, since the user can confirm the actual processing time calculated by the system before he or she terminates a certain workflow step and routes the process folder.

Thus the WMS manages both total flow time and execution time of single workflow activities. The difference between flow time and processing time corresponds directly with lag time and waiting period, since the electronic transport time can be neglected. This information is the foundation for continuous improvement of workflow processing and control with respect to flow time, service level, capacity utilization, and activity-based costs. We use two examples to illustrate this goal.

On one hand the WMS can supply early warning information during run-time. If a customer inquiry is behind schedule and therefore has the status "critical", it is marked in the To-do-list. On the other hand controlling data that the WMS provides contribute to the corporate-wide report system. In this sense, it is possible to compare different divisions (e.g. propulsion technique, textile machine tools) with respect to the average first order revenue and the corresponding average activity-based offer costs, which originate in the aggregated activity-based cost data of the WMS. Divisions with expensive and/or hardly successful offers can be extracted easily. This again triggers the improvement of the contribution margin of the weakly-performing divisions by a more efficient and effective offer process.

4 Conclusion

The main part of our DMS/WMS application is already implemented as running system at INA. First results indicate that the cycle time for the offer processing might be reduced by at least 45 %. Another benefit is the potential for a reduction of paper costs (about 90.000 DM per year). In addition, short term customer's wishes can be considered more flexibly. All current offer processes are permanently transparent in terms of knowing the state. Advanced, formerly isolated working application programs have been integrated and the access to historical know-how has been improved. The committee which decides whether or not to offer a special product could be replaced by an electronic meeting. The controlling functions are not yet a feature of the running system.

The adaptivity of DMS/WMS will be a future task of information engineering in this sector. As opposed to administration processes, core business processes in the machine tool industries have a complex and heterogeneous structure of its activities. Quickly developing and dissolving organizational structures, e.g. project teams, need to be integrated. In addition, unpredictable ad-hoc-workflows occur with a high probability due to the necessity of discussing technical details with the customer.

In summary, the DMS/WMS has to be able to adapt to its evolving environment in a most beneficial way. In this sense, one could speak of a learning WMS. The basic idea for a learning WMS is to start with a coarse structure of the process or with the entity of the occurring ad-hoc workflows and record the workflow runs and their performance. The next step is to launch a continuous learning process based on the recorded information. We take into consideration mechanisms like Case-Based Reasoning or similar experience-based artificial intelligence techniques in order to transfer successful historical workflows, e.g. activity orders, user and document selection, to current processes. Simultaneously, a continuous, interactive adaptation of the process structure should take place.

In addition, we will work on the possibilities of the DMS/WMS to support "Organizational Learning", where the DMS/WMS could be used to create comprehension of the business process as a whole for the single organizational member who is part of the process.

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6 References


