7th IFAC Conference on Manufacturing Modelling, Management, and Control
International Federation of Automatic Control
June 19-21, 2013. Saint Petersburg, Russia

# An Engineering Prototype Workflow Management System

**Matthew Daniels*, Pezhman Ghadimi**, Ivor Lanning***,**
**Cathal Heavey****, Alan Ryan***** & Mark Southern********

*Enterprise Research Centre, University of Limerick, Limerick, Ireland*
*(e-mail: *Matthew.Daniels@ul.ie;**pezhman.ghadimi@ul.ie;***ivor.lanning@ul.ie;*
*****cathal.heavey@ul.ie;*****Alan.Ryan@ul.ie;******mark.southern@ul.ie)*

**Abstract:** Engineering workflow management is a key focus for European manufacturing companies, however, issues such as time required to gather data, develop systems and integrate into current manufacturing environments presents obstacles for adoption. This paper presents a high level prototype of an engineering workflow system developed in conjunction with a medical device company to address this gap. The prototype data was used to construct a high level artifact which illustrates how the implementation of Advanced Platform for Manufacturing Engineering and Product Lifecycle Management (7th Programme, "amePLM") engineering workflow management system can improve product design and development processes through increased productivity by capturing workflows which previously went unquantifiable.

*Keywords:* workflow, engineering, manufacturing, engineering workflow, WfMS, product lifecycle management, prototype

## 1. INTRODUCTION

Workflow is focussed on the automation of the way things are done in an organisation, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules (WfMC, 2008). Huang et al., (2003) defined workflow as an on-going process distributed among multi-participants that transfer information or tasks according to some previously defined rules or sequences. Workflow involves the interaction of humans and computer processes to generate and share information; its requirements need to reflect both the technical as well as social and organizational needs (Huang et al., 2003; Bolcer & Taylor, 1998). Workflow captures the systematic assignment and processing of activities in dynamic, distributed environments by enabling process scalability, availability and performance reliability (Watson & Holmes, 2009). Put simply, workflow is a description given to the completion and coordination of processes and procedures employed in some system to get things done.

Workflow Management System (WfMS) is a software system to support automatic and efficient execution of the business processes (Hollingsworth, 1995; Kim et al., 2000; WfMC, 2001). The system contains a set of tools and interfaces that provide support for the necessary services of workflow management, process definition, administrative and monitoring tasks, workflow client applications and other invoked applications (Georgadopoulos & Hornick, 1995; Hollingsworth, 1995).

During the last decade workflow management technology has become readily available (van der Aalst & Oberwei, 2000; van der Aalst & van Hee, 2002; Jablonski & Bussler, 1996; Leymann & Roller, 1999). Generic modelling and performance capabilities have been offered by IBM, COSA, Staffware, MQSeries in order to make business processes structured (Van der Aalst & Weijters, 2004). Besides pure workflow management systems, many other software systems have adopted workflow technology. Consider for example ERP (Enterprise Resource Planning) systems such as SAP, PeopleSoft, Baan and Oracle, CRM (Customer Relationship Management) software, SCM (Supply Chain Management) systems, B2B (Business to Business) applications, etc. which embed workflow technology. Despite its promise, many problems are encountered when applying workflow technology.

One of the problems is that these systems require a workflow design, i.e., a designer has to construct a detailed model accurately describing the routing of work. Modeling a workflow is far from trivial: It requires deep knowledge of the business process at hand (i.e., lengthy discussions with the workers and management are needed) and the workflow language being used (Wen et al., 2009). This brings the issues of excessive time needed to be spent due to the fact that an engineering workflow management system should be able to remove much of the administrative burden experienced in the current day to day management of product lifecycle by automating engineering related activities. Besides that, to our knowledge workflows of PLM are neglected in current practices mentioned above. Daniels et al., (2012) reported on the diverse range of organisations participating in amePLM from small medical devices manufacturing company to a large semiconductor manufacturer, illustrated that workflow during product lifecycle management (PLM) is fragmented, inadequately structured and composed of many disparate systems for all of the pilot cases. Therefore, it can be perceived that there is a need for a workflow system that can address these issues in the domain of PLM which is the main contribution of this paper. Advantages for users are that information can be kept, found, shared and used more efficiently. The prototype extends past gathered information, supports the creation and structuring of new information within a digital repository and enables project management and collaboration activities that support PLM projects during the full lifecycle. The main focus of this paper is covering the whole PLM in the engineering workflow system which is prototypically developed for now and will be expanded and fully developed in future.

## 2. LITERATURE SURVEY

### *2.1 Engineering Workflow*

The term “Engineering Workflow” refers to the flow of work through those activities that create or use engineering data (Bijwaard et al., 2000). Engineering data contains technical files/reports on research materials, quality assessment, engineering test, evaluation and qualification test, parts and materials specifications, manufacturing, design, process controls, solder-ability data and other related engineering data on parts, components, materials and processes. In theory, the Engineering workflow starts with initial product specification, and ends with some product used by the customer (GIDEP, 2012).

Engineering workflow is not a linear process, starting with one well determined activity, and continuing serially through other well-determined activities, until it reaches a well-determined final activity. Instead, it is a complex process in which some activities run in series, and some run in parallel. This engineering data covers a wide span of topics crossing over many professional disciplines pertaining to commercial applications generated during research, development, testing, production, procurement, and logistical operations (GIDEP, 2012).

Engineering workflow activities are critically dependent on: coordination, this involves the use of communication and information exchange to reach mutual benefits among parties by working harmoniously. Cooperation, involving aspects of coordination but also incorporates resource sharing to support goal achievements. Commonly cooperation will exhibit a component of division of labour among all participants and therefore the aggregated value in the result of adding the individual parts. Finally, collaboration is an important aspect of engineering workflow and the most difficult to support. Collaboration in engineering workflow needs to support, the sharing of information, resources, and the responsibility to jointly plan, implement, and assess the set of activities required to achieve a common goal, thus jointly creating added value (Nof, 2009).

Engineering workflow exists to provide engineering data when and where necessary to produce and support the design and development of a product. Without engineering data, there would be no need for the engineering workflow. In this respect engineering data and engineering workflow are symbiotic. Yet for many manufacturing firms the workflows associated with engineering and PLM remain unstructured (Bijwaard et al., 2000). This is an important matter for manufacturers to have a structured and integrated PLM workflow. A manufacturing company that can’t make use of its past gathered information related to some similar product development projects in a reasonable time might incur a huge administrative and man-hour costs in order to retrieve all the important information needed for the new product development project through an unstructured engineering data and workflow. Apart from the issues involved in engineering workflow, an workflow management system needs a communication language that can be understood by all the entities of the system or other systems. This is addressed in next section.

### *2.2 Engineering Process Model*

The origins of workflow management systems are traced to the business domain, and have been designed to help users involved in a business process to carry out their tasks following certain business logic (Krishnakumar & Sheth, 1995). This means that the WfMS should have a process model representing the business logic. Business Process Management (BPM) is a technique focussed on defining the overall business process, and managing and tracking that process wherever it goes, often through multiple organisations, different computer systems, multiple locations, and even different enterprises (Fischer, 2012). Similarly this paper refers to the process models used to define engineering processes as Engineering Process Models (EPM’s).

The generally accepted standard for defining processes is Business Process Management Notation (BPMN) (Giaglis, 2001). BPMN was defined to achieve certain goals such as: providing a standardized graphical notation for modelling business processes, understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes. (Weilkiens et al., 2011; Workflow Patterns Initiative, 2011).

There is limited academic research to emphasize the advantages of developing an engineering workflow management system involved with daily activities of PLM in specific. This paper aims to narrow this gap by proposing a prototype engineering workflow management system. Requirements obtained from the amePLM industrial pilot case, SCS, are presented in Section 3. The prototype based on this pilot case is illustrated showing how projects are created and supported through activity related processes in Section 4. Section 5 concludes with the benefits and advantages of the proposed prototype along with future integration potential.

## 3. INDUSTRIAL PILOT CASE

The findings of the literature survey support the practical realities of engineering workflow for amePLM. To this end industrial partners produced detailed pilot case studies and sets of requirements on the observed deficits in their current PLM systems. The proposed engineering workflow focuses on activities and processes that address the industrial partner requirements for PLM. A detailed case study of SCS resulted in 13 requirements for the amePLM system. These requirements are listed in Table 1.

Table 1. SCS Pilot Case Requirements

| | Requirement Definition |
|---|---|
| 1 | Quick set-up of project space to log an incoming client request. Not all requests become active projects therefore this should be an easy to produce simple area to start from. Project space should then be extendible depending on project go-ahead |
| 2 | Details such as dates, company, contacts involved, information received easily associable to this product with simple outline and even early post-mortem if endeavour is not made into an active project. Thus reasons for non-take up are documented. |
| 3 | Ability to log various project-functional files against this project space. Such files often in form of emails, text/word/pdf files, technical drawings (e.g. AutoCAD). |
| 4 | Ability to make associations within that space such as relating it to “materials” or “product aesthetics” – tagging. This associated/meta data can help ontologically link “materials” issues from project to project building knowledge in the area. Visible links of files supported by underlying semantic links required. |
| 5 | Research support space within the project space where various forms of internal research support files can be detailed. Examples could include, web-based research, internal minute meetings supporting go-ahead on activities. |
| 6 | Similar associations/tagging capability for research support related files within project space as there is for project-functional files. |
| 7 | Project space collaboration capability for external partners. Space can easily accommodate access, granted by SCS with ability to put a boundary on the visibility of various partners. |
| 8 | Ability of collaborators to drop-in information (ideally by standardised means such that it follows SCS’s records management and can be ontologically linked), related to problem investigation - proposed solutions, fathomed options. Also, for proposal implementation, sign-offs and agrees ways-of-working for next step (manufacture and assemble) |
| 9 | Capability to put timeline and workflows along lifecycle such that stages/milestones to delivery, dates, precedence constraints can all be entered by relevant parties and progress to date can be measured |
| 10 | Capability to define standard operating procedures (SOPs) at management/engineering director level, which will facilitate development and change. Documented decisions and process steps should be logged to the product lifecycle development based on SOPs which can support regulatory/audit requirements and reduce administration and information retrieval when establishing compliance with relevant bodies. |
| 11 | Development of alliance-type support space. Company information of alliance partners (potential collaboration partners) upload capability once permissions granted by SCS but with strict restrictions on such partners for SCS data protection. |
| 12 | Capability to link information via ontology for various companies so searches can be made e.g. across materials, machining methods, location, size etc. |
| 13 | Front end development flexibility should be substantial such that intensive set-up or coding is not a part of creating or modifying work/project spaces, therefore making amePLM easy to use and develop. |

The requirements have been addressed in the implementation of the logic in the engineering workflow prototype. Requirements addressed by the workflow are referenced again at the end of the engineering processes in the prototype description.

## 4. PROTOTYPE DESCRIPTION

The SCS case study is selected for the amePLM prototype on the basis that their workflow has a number of common and typical engineering activities for each of the other participants. In this regard targeted processes defined in the prototype are directly mapped against the SCS Unified Modelling Language (UML) diagram illustrated Fig. 1.

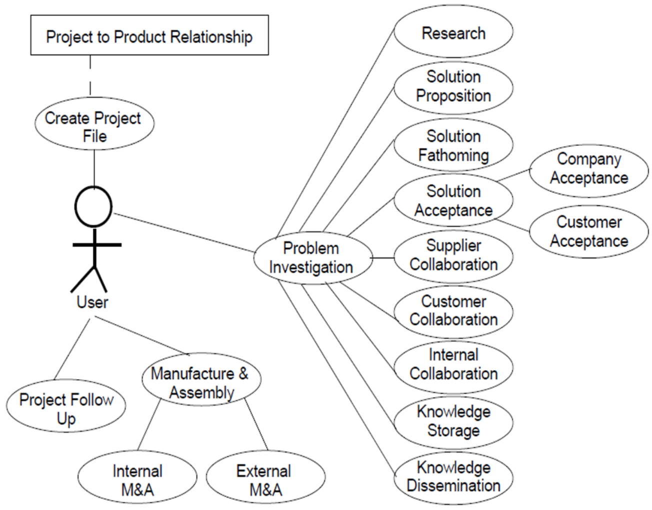


Fig. 1. SCS UML Diagram.

The prototype processes have been developed with RMP (RunMyProcess) software (RunMyProcess, 2012). The software has a number of attributes that are suitable for developing the amePLM prototype. These include drag and drop flow chart/BPMN 2.0 compliant, cloud platform for, multi-tenant architecture, secure reliable channels, distributed access, front and back end integration capabilities and reporting capabilities on real-time dashboard with centralised administration capabilities.

The engineering prototype is initiated by a process to automate project registration and file creation. This engineering process can be mapped against the UML activity “Create Project File”. Newly created files become the project repository to enable the UML activities “Knowledge Storage” and “Knowledge Dissemination”. In this respect a repository has been created to automatically store and organise digital

information. Projects are defined in the prototype using processes to assign categories and status, in these processes the UML activities: Research, Solution Proposition, Solution Fathoming and Problem Investigation are addressed. Such implications will determine the continuation of a project and the route to how it has progressed. The prototype makes provision for flexible acceptance processes. To this end, consideration has been given to the UML activities labelled Company Acceptance, Customer Acceptance and Solution Acceptance. The final prototype process focusses on collaboration. The UML diagram labelled Supplier Collaboration, Customer Collaboration, Internal Collaboration and Project Follow Up are therefore addressed.
The user initiates the engineering workflow by opening the form to create a project file as illustrated in Fig. **2**. The form is configured with mandatory fields so the form will not update the engineering process unless the mandatory fields are satisfied.

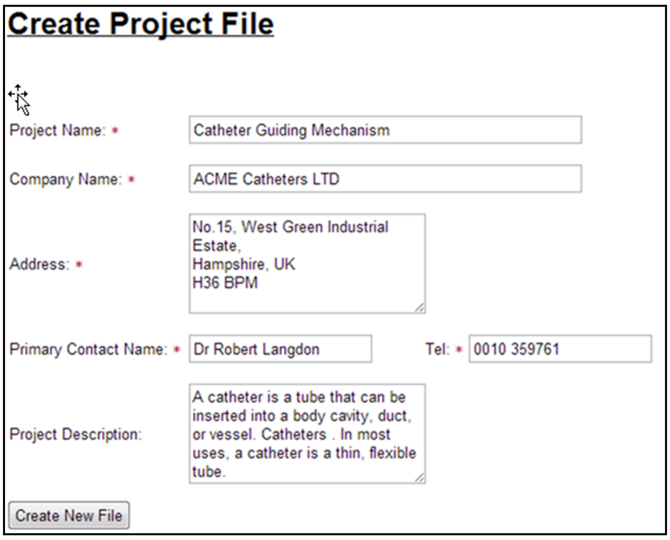


Fig. 2. Create Project File Screen.

Activities are triggered when the user completes the form. A pre-defined spread-sheet illustrated in Fig. **3** (middle) is updated with the information input via the Create Project File Screen, a file is created and an email is sent to a recipient to confirm that a new project has been registered and that a file has been created.

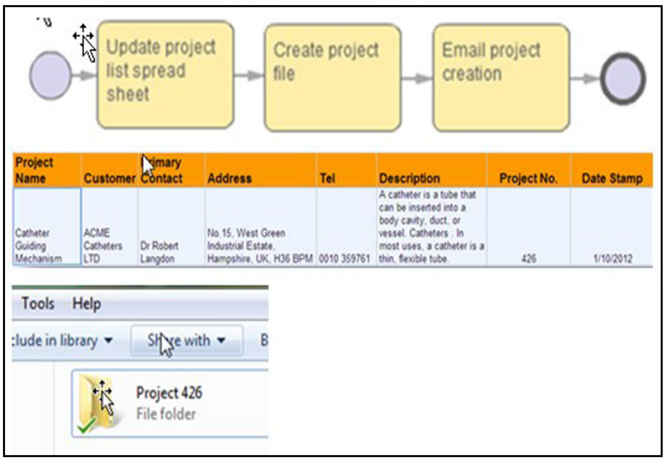


Fig. 3. Create Project EPM (top), Project Register (middle), New Project File (bottom).

Fig. **3** (top) illustrates the Engineering Process Model (EPM) used to define the logic for the Create Project File requirement. Fig. **3** (bottom) is the created file stored in a preconfigured location. The spread sheet automatically creates a number that is assigned the project file along with a date stamp. The final activity in the process sends an email to one or many recipients to confirm that a project file has been created. This process addresses the use case requirements 1, 2, 3, 6, 7 & 13 listed in Table 1.
The following processes support projects during product lifecycle stages.
Defining the project is actuated on completion of the "Define Project" form illustrated in Fig. **4**. In this screen the user is asked to select the category for the project. The corresponding engineering process model in Fig. **4** illustrates three available categories. Using the drop down list, the category of a project is selected. From the use case information these categories include R&D, Repeat, and Modified.

- R&D category is when a new project is being investigated; this is likely to involve new suppliers, standards and manufacturing processes.
- Repeat category can be used for project that has the same attributes as a previous project; this type of project will have established suppliers, standards and process.
- Modified is a category used to define a project with many similar attributes as a previous project, yet require some R&D activities. In this type of project a product is modified to incorporate new features (new addition to the product family) and as such is given a new revision number.

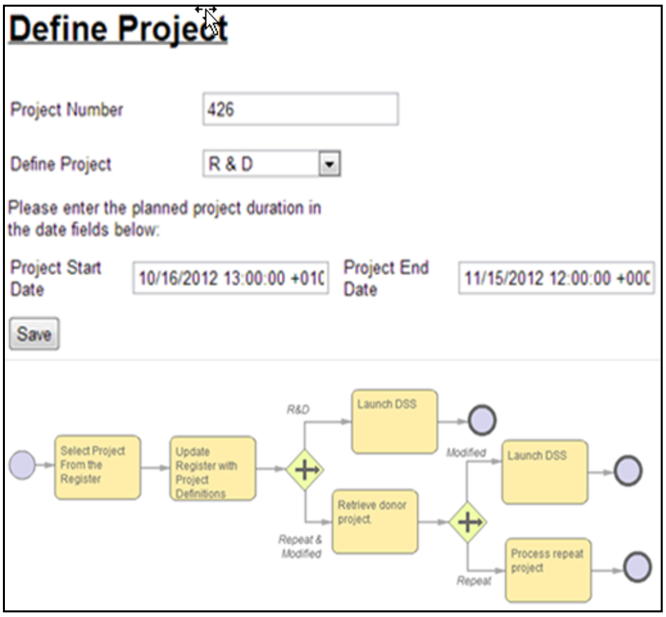


Fig. 4. Define Project Screen (top), Define Project EPM (bottom).

Finally start and end dates of the project are added. This is for the purpose of planning the scheduled use of resources. This process addresses the use case requirements 4, 5, 9, 10, 11 & 12 listed in Table 1.

Users can retrieve a project from the register and assign the status from a drop down list. The status of a project may also change depending on the workflow criteria. The screen is illustrated in Fig. **5**. This process is finalised when an email is sent confirming project status. This process addresses the use case requirement 1 listed in Table 1.

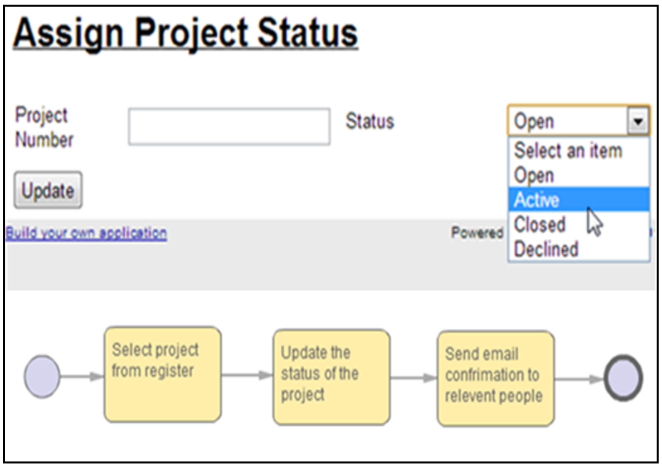


Fig. 5. Status Screen (top), Status EPM (bottom).

The pilot case illustrates that peripheral acceptance is required when a solution is derived from R&D activities. Given the diverse nature of projects the workflow should enable a flexible policy with regards to the acceptance procedure. Where acceptances are required an automated document is generated and contains the criteria for review. For example, it was illustrated in the pilot case that the output from a decision support system may contain pertinent information with regards to defining a specification. Using this example the workflow directs acceptance documents to the relevant authorities for approval. Filters are configured to ensure that any commercially sensitive information is restricted to the appropriate authority. In the applied use case these authorities are responsible for company acceptance and customer acceptance. To this end the customer may not see information that is commercially sensitive. The EPM is illustrated in Fig. **5**. This process addresses the use case requirements 7, 8 & 11 listed in Table 1.
The use case illustrates considerable emphasis on collaboration. The objective for collaborative efforts is to reach a consensus or a merging of ideas and tasks to support the project. One of the frustrations noted in the pilot case is the length of time to get quality responses from various collaborators or potential collaborators. The workflow assigns metrics to the quality of the collaboration effort. Simple capturing information regarding who is responsible for a task and when is their task is complete can be used as inputs for monitoring such collaboration efforts. Once monitored the system will flag delays and bottlenecks in the collaboration process and provides useful background information for future projects. Implementation of Customer/Client Relationship Management (CRM) tools into the engineering workflow system is utilised to manage the company's interactions with collaborators. This process addresses the use case requirements 2, 8 & 11 listed in Table 1.

## 5. CONCLUSION & FUTURE INTEGRATION

Ensuring accurate and tangible data allows companies to manage projects/resources in a measured proactive approach; a successfully integrated engineering workflow management system represents a cornerstone to such an approach. The prototype suggested in this paper illustrates how this data may be gathered.
The prototype is at a high and conceptual level yet it clearly illustrates that engineering workflow management has the ability to remove much of the administrative burden experienced in the current day to day management of product lifecycle by automating engineering related activities. From the example pilot case study, project files are currently created manually and stored in a filing cabinet. In practice this process fails because files are removed, information is lost, inaccurate and unstructured. The prototype system provides a tool to organise and structure digital information with a discipline to ensure that detail is captured correctly and efficiently. Information is then stored in a central location and can be acted upon using simple visual user interfaces by authorised people. In this regard there is a clear reduction in the general process efforts.
Advantages for users are that information can be kept, found, shared and used more efficiently. The prototype extends past gathered information, supports the creation and structuring of new information within a digital repository and enables project management and collaboration activities that support PLM projects during the full lifecycle. To this end, future integration of other systems is given consideration. Take for example defining a project; this enables the allocation of relevant resources. In the case of a repeat project, donor projects can be retrieved and reused automatically. R&D activities can be directed to a decision support system, thus ensuring an efficient retrieval and use of engineering data. Another support mechanism is the process to assign status. This is not only a useful management tool but a mechanism to highlight changes in the system. For example, the status of a project can change automatically depending on an outcome in the workflow such as when a final task is complete and the project closes or active when an activity in the process has not yet completed. Acceptance processes support the project by enabling a flexible mechanism to engage internal and external competencies when required. In the pilot case example authorisations are required from supply chain companies to confirm medical conformity standards and specifications. The final project support in the prototype is a process for collaboration.
One of the biggest frustrations in the use case example is the efforts required for controlling the interactions with collaborative organisations. By recording who is responsible and when a response is required enables metrics to be assigned to the quality of the collaboration effort, this is combined with the integration of CRM to record and structure the collaborative dialogue between clients and customers. The process to create, structure and control, engineering project using the proposed system enables the monitoring and measuring of efforts from the early stages of the product lifecycle, thus creating an opportunity to better manage the efficiency and productivity or workflow. Visual

tools are available in the application software to create dashboards tailored specifically to user needs.

The prototype was developed on cloud based software; this satisfies criteria obtained in the use case requirements and also reduces the financial impact associated with desktop applications due to hardware and maintenance costs. Integration of other systems is achievable with published application programming interfaces. This has been illustrated with the use of web based spreadsheets, email and remote storage.

Future work will build on the prototype by targeting additional engineering processes from the amePLM industrial partners and the integration of supporting applications into an engineering platform.

REFERENCES

amePLM (2011). *amePLM*. Retrieved from advanced Platform for manufacturing engineering and Product Lifecycle Management: http://www.ameplm.eu/

Bijwaard, D., Spee, J., and Boer, P. (2000). Engineering Workflow: The Process in Product Data Technology. *9th symposium on Product Data Technology Europe,* 215-222.

Bolcer, G., and Taylor, R. (1998). Advanced workflow management technologies. Software Process: improvement and practice. Retrieved 06 05, 2012, from Institute for Software Research: http://www.isr.uci.edu/~taylor/documents/1998-AdvancedWorkflow.pdf

Fischer, L. (2012). *Introduction to BPM and Workflow*. Retrieved from http://store.futstrat.com.

Georgadopoulos, D., and Hornick, M. (1995). An Overview of Workflow Management: From Process Modeling to Workflow Automation. *Distributed and Parallel Databases,* 3, 119-153.

Giaglis, G. M. (2001). A taxonomy of business process modeling and information systems modeling techniques. *International Journal of Flexible Manufacturing Systems*, 13(2), 209-228.

GIDEP. (2012). Retrieved 06 2012, from Government - industry data exchange program: http://www.gidep.org/data/engineer/engineer.htm.

Hollingsworth, D. (1995). *The Workflow Reference Model.* Workflow Management Coalition, Hampshire.

Huang, C.J., Trappey, A.J., and Yao, Y.H. (2003). Design and develop WfMC-based modularized network collaborative design system. *Journal of Chinese Institute of Industrial Engineers*, 20(4), 422-434.

Jablonski, S., and Bussler, C. (1996). *Workflow Management: Modeling Concepts, Architecture, and Implementation.* International Thomson Computer Press, London.

Kim, Y.K. (2000). WW-Flow: Web-based workflow management with runtime encapsulation. *IEEE Internet Computin*, 55-64.

Krishnakumar, N., and Sheth, A. (1995). Managing heterogeneous multi-system tasks to support enterprise-wide operations. *Distributed and Parallel Databases*, 3(2), 155–186.

Lanning, I., Daniels, M., Heavey, C., and Southern, M. (2012). *D2.1: Requirements Specification and Pilot case Description.* University of Limerick deliverable document for European 7th framework amePLM work pachake 2 project.

Leymann, F., and Roller, D. (1999). *Production Workflow: Concepts and Techniques.* Prentice-Hall, New Jersey.

Nof, S.Y. (2009). *Springer Handbook of Automation.* Springer Berlin Heidelberg, Berlin.

RunMyProcess. (2012). *RunMyProcess*. Retrieved from RunMyProcess: http://www.runmyprocess.com/

van der Aalst, W.D., and Oberwei, A. (Eds.). (2000). *Business Process Management: Models, Techniques, and Empirical Studies, Lecture Notes in Computer Science* (Vol. 1806). Springer-Verlag, Berlin.

van der Aalst, W., and van Hee, K. (2002). *Workflow Management: Models, Methods, and Sys-tems.* MIT press, Cambridge.

Van der Aalst, W., and Weijters, A. (2004). Process mining: a research agenda. *Computers in Industry,* 53(3), 231-244.

Watson, F., and Holmes, K. (2009). Business Process Automation. In Nof, S.Y. (Ed.), *Springer Handbook of Automation* , 1598-1611. Springer, Berlin.

Weilkiens, T., Weiss, C., and Grass, A. (2011). Modeling Business Processes Using BPMN. In *OCEB Certification Guide: Business Process Management-Fundamental Level* , 77–121, Morgan Kaufmann.

Wen, L., Wang, J., van der Aalst, W. M., Huang, B., & Sun, J. (2009). A novel approach for process mining based on event types. *Journal of Intelligent Information Systems*, 32(2), 163-190.

WfMC. (2001). Workflow Handbook 2001. (L. Fischer, Ed.) Florida, United States of America: Future Strategies.

WfMC. (2008). *Workflow and Internet, Catalyst for Radical Change, A WfMC White Pater,*. Retrieved 05 20, 2012, from WfMC: http://www.wfmc.org

Workflow Patterns Initiative. (2011). *Vendors Corner*. Retrieved from Workflow Patterns: http://www.workflowpatterns.com/vendors