

Chapter 9

Process-Aware Information Systems



Besides black art, there is only automation and mechanization.
Federico García Lorca (1898–1936)

In the previous chapters, we have learned how to use qualitative and quantitative analysis techniques in order to identify issues of existing business processes. We have also seen that many processes in practice have problems with flow-time efficiency. Various redesign heuristics emphasize the potential of using information systems to improve the performance of processes.

This chapter deals with information systems that support process automation. First, we will briefly explain what an automated business process is, after which we will focus on a specific kind of technology that is particularly suitable to achieve process automation, i.e., Process-Aware Information Systems (PAISs) and Business Process Management Systems (BPMSs). We will present the different variants of these systems and explain their features. Finally, we will discuss some of the advantages and challenges that are involved with introducing a BPMS in an organization.

9.1 Types of Process-Aware Information Systems

Process automation is a subject that may be approached from different angles. In a broad sense, it may refer to the intent to automate *any* conceivable part of routine work that is contained within a business process, from *simple* operations that are part of a *single* process activity up to the automated coordination of *entire*, complex processes.

Take, for example, the order-to-cash process that we modeled in Chapter 3. Automating such a process may imply that every time the seller receives a purchase order, this is automatically dispatched to the ERP systems of the warehouse and distribution department where the availability of the product is checked against the warehouse database. If the product is not in stock, the relevant suppliers are automatically contacted, e.g., via a Web service interface, to manufacture the

product. Otherwise, instructions are sent to a warehouse worker, e.g., using an electronic form, to manually retrieve the product from the warehouse. Subsequently, an order clerk from sales receives a notification that a new order needs to be confirmed, e.g., via email. That clerk would then log into the purchase order tracking system within sales, check the order electronically, and confirm it by pressing a button.

In this example the dispatching of the purchase order, the automated check of the product's availability, and the automated Web messages are all manifestations of process automation in its broadest sense: They automate a particular aspect of a process. In this context, we will refer to an *automated business process*, also known as *workflow*: a process that is automated in whole or in part by a software system, which passes information from one participant to another for action, according to the temporal and logical dependencies set in the underlying process model. Let us now consider systems that work with automated business processes. These systems are called *Process-Aware Information Systems* (PAISs).

9.1.1 Domain-Specific Process-Aware Information Systems

A specific kind of process automation, which interests us most in this book, exploits knowledge about how different process activities *relate* to one another. In other words, the type of information systems that we consider are *process-aware*. The overarching group of Process-Aware Information Systems (PAISs) can be subdivided into two major categories: domain-specific PAISs and domain-agnostic PAISs.

There is a plethora of domain-specific PAISs. Here, we briefly describe four prominent types, which are offered as commercial packages from various software vendors such as Microsoft,¹ Oracle,² Salesforce,³ and SAP.⁴ These include the following:

Enterprise Resource Planning (ERP) systems: These systems provide essential and generic business functionality, which is required across various industries. The core modules of ERP systems support business processes in accounting and controlling, human resource management, and production management. The two most important processes that most ERP systems fully cover are the procure-to-pay and the order-to-cash process.

Customer Relationship Management (CRM) systems: These systems support marketing and sales processes that directly interact with customers, both on an

¹<https://dynamics.microsoft.com/>.

²<https://www.oracle.com/applications/erp>.

³<https://www.salesforce.com>.

⁴<https://www.sap.com/products/erp.html>.

individual and on an aggregated level. On the individual level, CRM systems help to document the interaction with individual customers through various channels, including telephone, email, Internet portal, and personal encounters at brick-and-mortar branches. On the aggregated level, CRM systems support sales and marketing activities related to products, pricing, distribution, and campaigning. At the heart of a CRM system is an extensive database that provides information on existing and prospective customers. Many CRM systems integrate data mining techniques to help with customer segmentation. Important processes supported by CRM systems are campaign-to-leads and lead-to-order.

Supply Chain Management (SCM) systems: These systems focus on the support of logistics operations that integrate with suppliers and customers. On an operational level, SCM systems support the management of freight and transportation, inbound and outbound warehousing, storage and inventory, as well as corresponding planning and calculation processes. On a technical level, SCM systems support electronic data interchange with suppliers and customers, as well as various tracking technologies such as Radio-Frequency Identification (RFID) and barcode scanning. Key supply chain processes are order-to-delivery and return-to-refund.

Product Lifecycle Management (PLM) systems: PLM systems support the various processes of the lifecycle of a product from an engineering perspective. These include the conception and design phase in which the product is specified, designed, and validated. In the realisation phase, the manufacturing system is planned and actual products are built, assembled, and tested. In the service phase, products are sold and delivered, used, maintained, and eventually disposed of. Important processes supported by PLM systems are idea-to-launch and different types of order processes including built-to-order, engineered-to-order, or assembled-to-order.

Although less numerous, there are also several types of domain-agnostic PAISs, chiefly Issue Tracking systems, Document Management Systems (DMSs), and Business Process Management Systems (BPMSs). Issue Tracking Systems, such as JIRA⁵ and Pivotal Tracker,⁶ have their roots in the field of software development and IT service management. The central concept behind these systems is the notion of an issue, which can be, for example, a bug in a software system, a request to add a feature to a software system, or a request to grant privileges to a given contractor to be able to access an IT system. Each issue goes through different states, including opened, assigned to an employee, suspended, canceled, closed, re-opened, etc. An issue moves from one state to another according to a pre-defined lifecycle. Different tasks may be performed when an issue is in a given state, some of them manually, others automatically. In this way, an Issue Tracking System supports the resolution of an issue, and accordingly, issue trackers are commonly used to support issue-to-

⁵<https://www.atlassian.com/software/jira>.

⁶<https://www.pivotaltracker.com>.

resolution processes. Nowadays, Issue Tracking Systems are widely used to support issue-to-resolution processes even outside the fields of software development or IT services management.

In line with its name, a DMS supports the management of documents all the way from their creation to their archival or deletion. They provide functions to create, search, access and update documents, but they also provide functions to route a document across multiple stakeholders. Originally, the document routing capabilities of DMSs were rather limited, but over time they became more sophisticated to the point that modern DMSs can support relatively complex processes. Nowadays, many companies employ DMSs to execute employee-initiated processes, such as vacation request approvals and travel requisition approvals. Concretely, an employee starts an instance of a vacation request process by creating a vacation request from a pre-defined template. This template contains rules for routing the request from said employee to his supervisor. Once the supervisor approves, the request is forwarded to the human resources department, where the vacation is recorded and the corresponding rosters are updated.

DMSs have evolved over time to support not only documents, but almost any type of content, whether structured content such as vacation requests or travel requisitions, to unstructured content such as scanned documents, images, and audio recordings (e.g., recordings of telephone conversations with customers). As DMSs grew more sophisticated and their use became widespread in enterprises, they became known as Enterprise Content Management (ECM) systems. Major ECM systems include IBM FileNet,⁷ Microsoft SharePoint,⁸ and OpenText.⁹

Exercise 9.1 The PAISs mentioned above (ERP, CRM, SCM, PLM, ECM) form a specific category in the market for enterprise software. Enterprise software covers not only PAISs, but also database systems, middleware, office software, and analytical software, which are not directly process-aware. The market for enterprise software is huge. According to a Gartner Report from 2017, it is estimated with a sales volume of almost \$ 400 billion (more than € 340 billion). Conduct an Internet search to find the Top 5 vendors of (a) enterprise software in general and (b) ERP systems specifically.

9.1.2 Business Process Management Systems

A Business Process Management System (BPMS) is a system that supports the design, analysis, execution, and monitoring of business processes on the basis of explicit process models. As discussed in Chapter 1, BPMSs originate from an older

⁷<https://www.ibm.com/us-en/marketplace/filenet-content-manager>.

⁸<https://products.office.com/en-us/sharepoint>.

⁹<https://www.opentext.com>.

type of PAIS known as *Workflow Management System (WfMS)*, which was focused on modeling and execution and did not very well support the other phases of the BPM lifecycle.

The purpose of a BPMS is to coordinate an automated business process in such a way that all work is done at the right time by the right resource. To explain how a BPMS accomplishes that, it is useful to see that a BPMS is in some way similar to a *Database Management System (DBMS)*. A DBMS is a standard, *off-the-shelf* software package offered by many vendors in many different flavors, such as Microsoft SQL Server,¹⁰ IBM DB2,¹¹ and Oracle Database Server.¹² With a DBMS it is possible to capture company-specific data in a structured way, without ever having to consider how the exact retrieval and storage of the involved data takes place. These tasks are taken care of by standard facilities of the system. Of course, at some point it is necessary to configure the DBMS, fill it with data, and it may also be necessary to periodically adapt the system and its content to actual demands.

In a similar manner, a BPMS is also a standard type of software system. Vendors offer different BPMSs with a varying set of features, covering different phases of the BPM lifecycle: from simple systems only catering for the design and automation of business processes, to more complex systems also involving process intelligence functionality (e.g., advanced monitoring and process mining), complex event processing (CEP), service-oriented architecture (SOA) functionality, and integration with third-party applications and social networks.

There are several ways to classify the available BPMSs. Figure 9.1 shows a classification based on two axes: one that captures the *degree of support* that the BPMS delivers, while the other that expresses how these systems differ from each other with respect to their *orientation on process or data*. We describe and illustrate four different types of systems: groupware systems, ad hoc workflow systems, production workflow systems, and case management systems. These systems can be positioned in the spectrum of BPMSs as shown in Figure 9.1.

Groupware systems: The two underlying principles of groupware systems are that the user is enabled to: (i) easily share documents and information and (ii) directly communicate with other users. The best known example of a groupware system is IBM Notes.¹³ Groupware systems are widely used and particularly popular for their high operational flexibility. On the downside, Groupware systems traditionally do not directly support business processes in a strict sense; however, several commercial groupware systems offer workflow extensions.

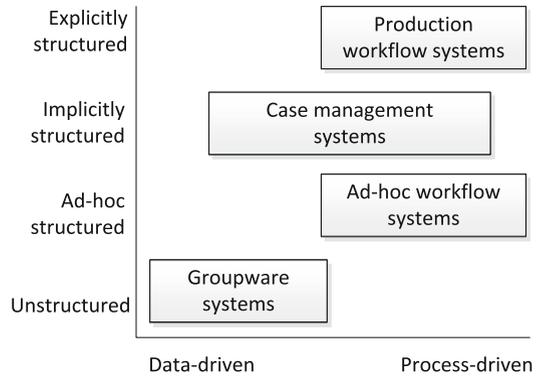
¹⁰<https://www.microsoft.com/sql-server>.

¹¹<https://www.ibm.com/analytics/us/en/db2>.

¹²<https://www.oracle.com/database>.

¹³<https://www.ibm.com/us-en/marketplace/enterprise-email>.

Fig. 9.1 The spectrum of BPMS types



Ad hoc workflow systems: Ad hoc workflow systems, like TIBCO's ActiveMatrix BusinessWorks¹⁴ or Comala Workflows,¹⁵ allow on-the-fly process definitions that can be created and modified. Even when there is already a process defined to deal with a specific case type, it is possible to adapt the process during the execution, for example by adding steps. On the technical level, these systems often maintain a private process definition for each case in order to offer this flexibility. This means that working on a case might even start from a completely empty process definition, which is extended as it becomes clearer what needs to happen and in what order. Alternatively, the ad hoc workflow system might work on the basis of a standard solution or template, which can be modified during execution. Interestingly, such a modified procedure may be used as the template for starting the processing of a new case. In general, there are two major requirements to successfully apply an ad hoc workflow system in an organization. The first requirement is that end users are aware of the processes in which they operate. This means that processes should be defined or modified only by people with a good overview of the process and the consequences of deviating from usual practice. The second requirement is that users have sophisticated tools at their disposal to model business processes and that they are capable of modeling. The combination of these requirements restricts the application of these systems at this point.

Production workflow systems: The most prominent type of BPMS is the production workflow system. Typical representatives are IBM's Business Process Manager,¹⁶ Bizagi Studio,¹⁷ and Camunda BPM.¹⁸ Much of what we described in the previous sections on workflow applies to this class of BPMSs. Work is

¹⁴<https://docs.tibco.com/products/tibco-activematrix-businessworks>.

¹⁵<https://www.comalatech.com/products/comalaworkflows>.

¹⁶<https://www.ibm.com/us-en/marketplace/business-process-manager>.

¹⁷<https://www.bizagi.com/en/products/bpm-suite/studio>.

¹⁸<https://camunda.com/bpm>.

routed strictly on the basis of explicitly defined process descriptions captured in process models. The management of operational data is typically handled by a complementary DBMS. In general, it is not allowed to deviate from a process logic if that has not been explicitly captured in the process model. Sometimes, the two types of *administrative* and *transaction processing* BPMSs are distinguished based on the degree of automation of the work that is coordinated. Administrative BPMSs are used in settings where a large portion of work is performed by people; transaction processing BPMSs support business processes that are almost fully automated.

Case management systems: The idea behind a case management system (or adaptive case management system (ACM)) is to support processes that are neither tightly nor completely specified. Rather, *implicit* process models are used, which capture a conventional flow from which a user can deviate—unless this is explicitly prohibited. A case management system is usually fully aware of the precise details of the data belonging to a case (including customer data, financial or medical data). On the basis of such awareness, the system is able to inform end users about the status and history of a case, as well as the most obvious steps to continue with. Contemporary examples are i-Sight’s Case Management Software,¹⁹ Case Management by PEGA,²⁰ and ISIS Papyrus.²¹ The latter also, if desired, supports a production workflow approach and in that sense is a hybrid BPMS.

There are other types of systems that often integrate characteristics and functionality of BPMSs. Document Management Systems primarily take care of the storage and retrieval of documents, like document scans and PDFs, but they often offer workflow automation features as well. An example is Adobe LiveCycle.²² *Process orchestration servers* focus on process automation but have a specific emphasis on automated processes that require the integration of multiple enterprise applications. An example is Oracle SOA Suite.²³

9.1.3 Architecture of a BPMS

How does a BPMS work and what are its components? Figure 9.2 shows the main components of a BPMS, namely the execution engine, the process modeling tool, the worklist handler, and the administration and monitoring tools.

¹⁹<https://i-sight.com>.

²⁰<https://www.pega.com/de/case-management>.

²¹<https://www.isis-papyrus.com>.

²²<http://www.adobe.com/products/livecycle.html>.

²³www.oracle.com/technetwork/middleware/soasuite.

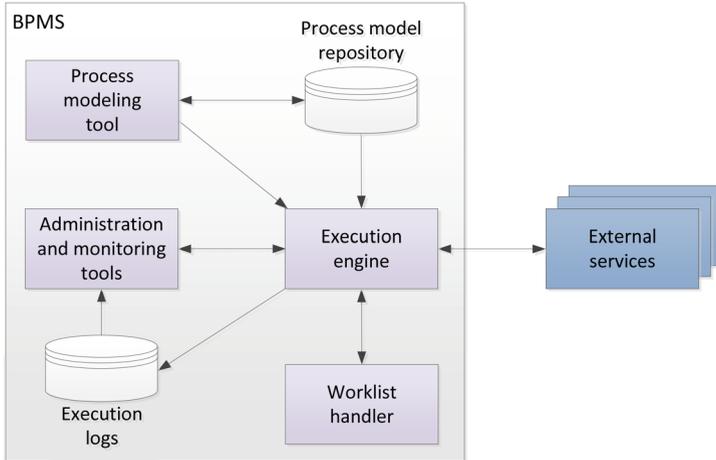


Fig. 9.2 The architecture of a BPMS

Execution Engine: Central to the BPMS is the *execution engine*. The engine provides different functionalities including: (i) the ability to create executable process instances (also called cases); (ii) the ability to distribute work to process participants in order to execute a business process from start to end; (iii) the ability to automatically retrieve and store data required for the execution of the process and to delegate automated activities to software applications across the organization. Altogether, the engine is continuously monitoring the progress of different cases and coordinating which activities to work on next by generating work items, i.e., instances of process activities that need to be taken care of for specific cases. Work items are then allocated to resources which are both qualified and authorized to work on them. The execution engine also interacts with the other components, as discussed next.

Process modeling tool: The *process modeling tool* component offers functionality such as (i) the ability for users to create and modify process models; (ii) the ability to annotate process models with additional data, such as data input and output, participants, business rules associated with activities, and performance measures associated with a process or an activity; and (iii) the ability to store, share and retrieve process models from a *process model repository*. A process model can be *deployed* to the engine in order to be executed. This can either be done directly from the modeling tool or from the repository. The engine uses the process model to determine the temporal and logical order in which the activities of a process have to be executed. On that basis, it determines which work items should be generated and to whom they should be allocated or which external

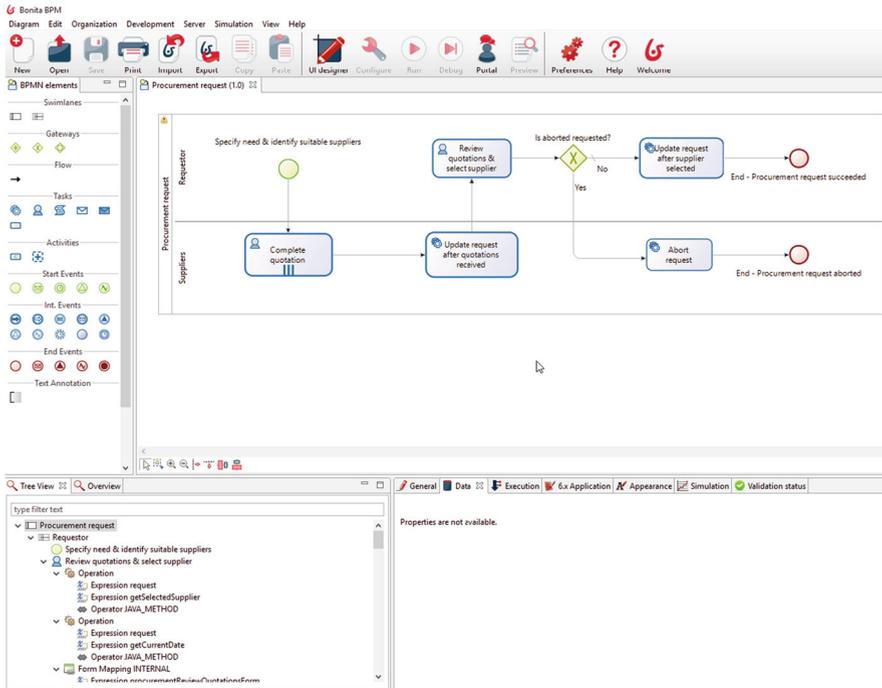


Fig. 9.3 The process modeling tool of Bonita BPM

services should be called. Figure 9.3 shows the process modeling tool of Bonita BPM.²⁴

Worklist handler: A *worklist handler* is the component of a BPMS through which process participants (i) are offered work items and (ii) commit to these. It is the execution engine that keeps track of which work items are due and makes them available through the worklist handlers of individual process participants. The standard worklist handler of a BPMS can best be imagined as an *inbox*, similar to that of an email client. Through an inbox, participants can see which work items are ready to be executed. The worklist handler might use electronic forms for an activity’s input and output data. When a work item of this activity is selected and started by the participant from the worklist, the corresponding electronic form is rendered on screen. This step is called *check-out*. Participants can then enter data into the form and signal completion to the engine. This step is called *check-in*. Afterwards, the engine determines the next work items that must be performed for the case in question. Often, participants can to some extent exert control over the work items in their worklist, e.g., with respect to the order in which they are displayed and the priority they assign to these work

²⁴<https://www.bonitasoft.com>.

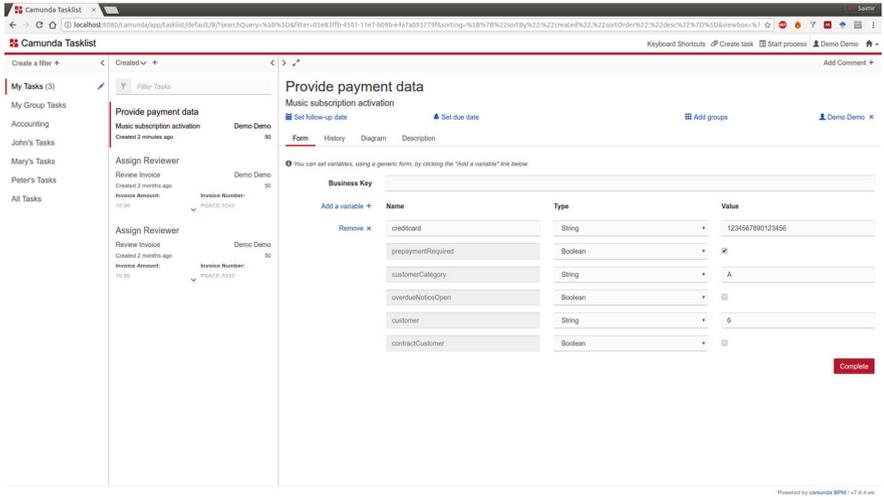


Fig. 9.4 The worklist handler of Camunda BPM

items. Also, a worklist handler will typically support a process participant in temporarily suspending work items or passing on control to someone else. What exact features are available depends on the BPMS in question and its specific configuration. It is fairly common to customize worklist handlers, for example according to corporate design, to foster its efficient usage and acceptance within an organization. Figure 9.4 shows the default worklist handler of Camunda BPM.

External services: It may be useful to involve external applications in the execution of a business process. In many business processes, there are activities which are performed fully automatically, such that the execution engine can simply call an external application, for example to assess the creditworthiness of a client. The external application has to expose a service interface with which the engine can interact. We refer to such applications as *external services*. The execution engine provides the invoked service with the necessary data it will need for performing the activity for a specific case. On completion of the request, the service will return the outcome to the engine and signal that the work item is completed. Sometimes too, a BPMS may need to transfer control over cases between different organizational units or organizations. One way of achieving this is by interacting with an external BPMS, which exposes a service interface for this purpose. For example, consider a global insurance company that has offices in three different time zones: Japan, the UK, and California. At the end of the working day in each of these time zones, all work items can be transferred to the execution engine in the next zone where the work day has just started. In this way, the execution of the business process never stops.

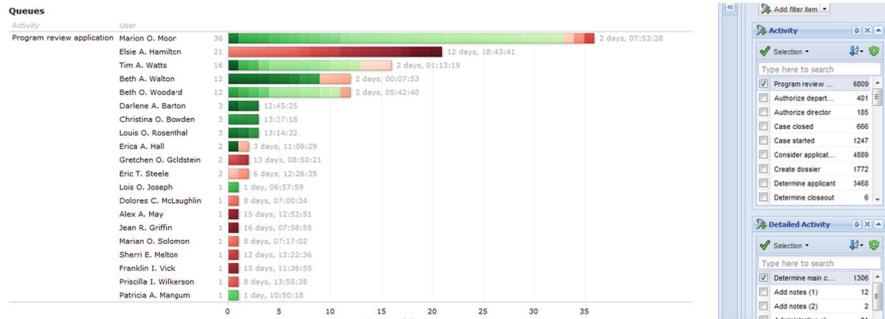


Fig. 9.5 The monitoring tool of Perceptive

Administration and monitoring tools: Administration and monitoring tools are the tools necessary for the administration of all operational matters of a BPMS. Consider the actual availability of specific participants as an example. If someone is unavailable to work because of illness or a vacation, the BPMS has to be made aware of this fact in order to avoid allocating work items to that person. Administration tools are also required to deal with exceptional situations, for example to remove outdated work items from the system. Administration tools are also equipped with process monitoring functionality. One can use these tools to monitor the performance of the running business processes, in particular with respect to the progress of individual cases. These tools can aggregate data from different cases, such as average cycle times of cases or the fraction of cases that are delivered too late. The BPMS records the execution of a process model step-by-step. The execution-related events recorded in this way are stored and can be exported in the form of *execution logs* from which performance dashboards are generated. An example of a dashboard generated by Perceptive²⁵ is shown in Figure 9.5. The topic of performance dashboards will be discussed in Chapter 11.

Exercise 9.2 The monitoring of user queues provides good transparency of the current workload of the different process participants. However, any sort of chart should be carefully reflected upon before decisions are made. Before interpreting the chart in Figure 9.5, try to answer the following questions.

1. Which important information is not visible in the chart?
2. Does the chart allow you to conclude who are good and bad employees?

The generic BPMS architecture described above is the evolution of a reference model for WfMSs, which was proposed by the Workflow Management Coalition (WfMC) in the 1990s. The box “WfMC Reference Model” expands on this model.

To illustrate how a BPMS works, recall BuildIT’s business process for renting equipment from Chapter 1. Let us suppose it is supported by a BPMS. The execution

²⁵<https://www.hyland.com/en/perceptive>.

engine can track that for orders #1,220 and #1,230 *site engineers* have already filled out the equipment rental requests. On the basis of a process model of the renting equipment process, the execution engine can detect that for both of these cases the proper piece of equipment must be determined. This needs to be done by any of the clerks at the depot. Therefore, the BPMS passes on the request to all worklist handlers of all clerks for further processing. For order #1,240, on the other hand, the equipment rental request is not available yet. So, the BPMS engine will not pass on a similar request for this order yet. Instead, it will await the completion of this work item.

Exercise 9.3 In which state is the process after all the actions of the rental process of BuildIT have been performed as described above? Which work items can you identify that are under control of the BPMS? Make sure to identify both the case and the activity for each work item.

WFMC REFERENCE MODEL

The Workflow Management Coalition (WfMC) is a standardization organization, founded in 1993, in which BPMS vendors, users, and researchers have a seat. The purpose of the WfMC is to achieve generally accepted standards for terminology and interfaces for the components of a BPMS [68].

The WfMC has produced the so-called *WfMC reference model*, which has become well-established in the world of process automation. The idea behind this reference model is that any supplier of a BPMS can explain the functioning of its specific system on its basis. The original reference model included six components, which resemble the components of the BPMS architecture in Figure 9.2. They are: workflow engine, process modeling tools, administration and monitoring tools, worklist handler, external applications and external BPMSs.

In the reference model, the interactions between its components take place through so-called *interfaces*, which are numbered from 1 to 5. Three of these interfaces can be directly recognized in the BPMS architecture that is discussed in this chapter: *Interface 1* concerns the interaction between the engine and process modeling tools, *Interface 2* concerns the interaction between the engine and the worklist handler, *Interface 5* concerns the interaction between the engine and the administration and monitoring tools. The other interfaces of the WfMC reference model have become obsolete since the introduction of Web services.

Exercise 9.4 Consider the following questions about a BPMS:

- Can you imagine that a BPMS can work on the basis of a business process model without any information on the types of resources that are available to work on the tasks? What problems would the BPMS run into when executing this process?

- In what situation will the execution engine generate multiple work items after the completion of a single work item?
- Can you provide examples of external services that may be useful to be invoked in a loan application process?
- If it is important that a BPMS hands out work items to available resources, can you imagine information on resources that is useful to be captured by an administration tool (apart from whether they are ill or on vacation)?

9.1.4 The Case of ACNS

Building on the explanation of the BPMS architecture in the previous section it is now possible to sketch an example of an operational BPMS. We use a simplified view on a process in which claims are assessed within the ACNS company (*A Claim is No Shame*). The first activity in this process is an assessment of the claim, which is done by a *senior acceptor* or a *regular acceptor*. Regular acceptors are responsible for assessments when the amount of the claim is below € 1,000; more valuable claims are assessed by senior acceptors. In case of a negative assessment, it is the responsibility of the account manager to convey the bad news to the customer. In case of a positive assessment, an electronic invoice is to be generated by a clerk of the financial department, who needs to dispatch it to the client. After these activities, the process is completed. Figure 9.6 shows this process.

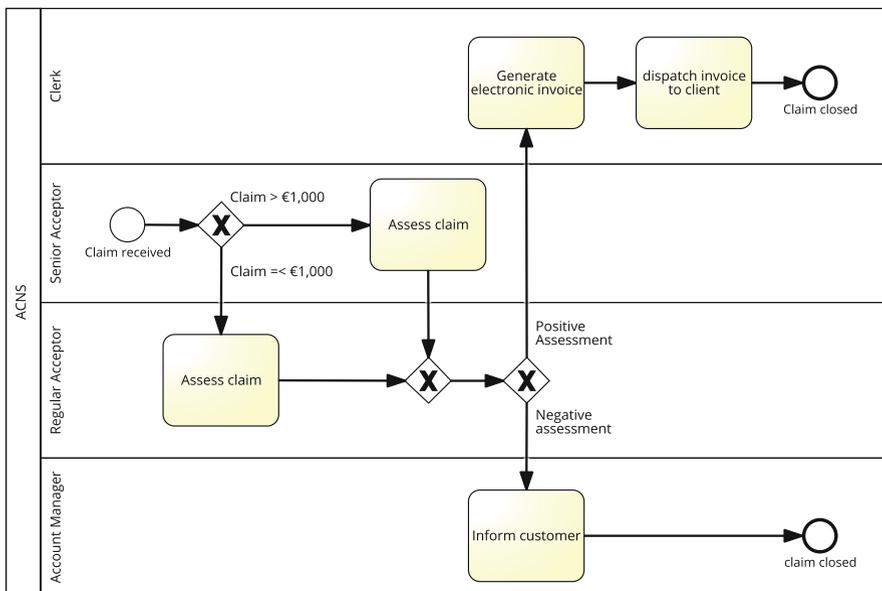


Fig. 9.6 Model of the claims handling process at ANCS

The above description shows that there are two dimensions that must be covered with the process modeling tool of the BPMS: (1) the procedure that specifies the various activities and (2) the various participants who are involved in carrying out the activities. The former part is recorded in a process model; the second is captured in what is often referred to as a *resource classification*. In addition, the relations between these two specifications must be defined, i.e., who is able and qualified to perform what activity. Often, these relations are also specified as part of the process model. These relationships may be dependent on all kinds of business rules. For example, the distinction between the authorization levels of the senior and ordinary acceptor in assessing claims is an example of a dynamic rule, i.e., it is determined by the current value of a variable.

Once these process and resource specifications are defined, the execution engine of a BPMS would generally be able to support the process. Now let us assume that almost simultaneously two claims come in:

1. A car damage of € 12,500, as claimed by Mr. Bouman.
2. A car damage of € 500, as claimed by Mrs. Fillers.

Ms. Senora has been with ACNS for a long time and, for the past years, works as a *senior acceptor*. This month, *Mr. Regulo* has started his training and works as a *regular acceptor*. At the start of his contract, the system administrator has used the administration tool of the BPMS to add *Mr. Regulo* to the pool of available acceptors.

Based on the process model, the resource classification, and operational data on the availability of the various employees, the enactment service of the BPMS now takes care of forwarding both newly received claims to the worklist handlers of *Ms. Senora*. After all, she may assess both claims based on her qualifications. *Mr. Regulo*, in his turn, will only see in his worklist handler the damage claim of *Mrs. Fillers*.

On noting the work item in his worklist, *Mr. Regulo* starts to work on it immediately. He selects the damage claim of *Mrs. Fillers* to handle. In response to that action, the execution engine ensures that the corresponding work item *disappears* from the worklist of *Ms. Senora*. The reason is that this piece of work needs to be carried out only once. *Ms. Senora* herself is at this point still working on the handling of an earlier case, but shortly thereafter selects the claim of *Mr. Bouman* through her worklist handler to deal with.

In response to the selection of work items by both *Mr. Regulo* and *Mrs. Senora*, the execution engine will ensure that both will see the electronic claim file on their screen of the respective customers. The execution engine does so by using the appropriate parameters in invoking the DMS of ACNS at the workstations of the acceptors. The DMS also displays the scanned version of the claims, which were originally sent in on paper. In addition, the BPMS takes care of displaying to both the acceptors an electronic form that they can use to record their assessment, also through the invocation of a service.

Mr. Regulo decides to reject the claim. The worklist handler notices this, because it monitors the specific field on the electronic form that receives a negative

value. Based on the logic captured in the process model, the execution engine can determine that the case must be handed over to the account manager of Ms. Fillers and sends a work item to that participant, requesting to inform the client on the negative assessment.

Ms. Senora arrives at a positive assessment of the claim under her watch and decides to approve it. The execution engine ensures that a service is invoked to determine the new monthly premium for Mr. Bouman, taking into account his no-claim history which is registered in a claim database. The retrieval of the information from this database is also realized through a service. Once this calculation is completed, a work item for the various available financial employees is created to pay the damage. The work item appears in the worklist of each of these financial officers, until one of them selects it for processing. After the payment has been carried out, the process is complete.

As can be seen in the ANCS example, all components of the BPMS architecture play a role in coordinating the work, specifically to ensure that the appropriate work items are created and carried out by the involved participants.

Exercise 9.5 Consider the following developments and indicate which components of the BPMS architecture are affected when they are addressed

1. A new decision support system is developed to support acceptors in making their assessment of claims.
2. Ms. Senora retires.
3. A new distinction between claims becomes relevant: regular acceptors are now also qualified to deal with claims above € 1,000 as long as they worked on previous claims by the same client.
4. Claims that are issued on cars which are over 10 years old need to be continuously monitored by management.

9.2 Advantages of Introducing a BPMS

In this section we reflect on why it would be attractive for organizations to use a BPMS. There are four broad categories of advantages that we will discuss here: workload reduction, flexible system integration, execution transparency, and rule enforcement.

9.2.1 Workload Reduction

A BPMS automates part of the work that is done by people in settings where such a system is not in place. First of all, it will take care of *transporting work* itself. In a paper-based organization, work is usually transported by internal postal services, often delaying processing for one work day at each handoff, or by the participants

themselves at the expense of their working time. All such delays are completely eradicated when a BPMS can be used to dispatch work items electronically. In some situations, the BPMS can take care of the entire process by invoking fully automated applications. In such cases, we speak of *Straight-Through-Processing* (STP). Particularly in the financial services, many business processes that used to involve human operations are now in STP mode and coordinated by BPMSs. Also in other domains—think for instance of electronic visa—at least a portion of the cases can be handled in a completely automatic fashion.

The second type of work that is being taken over by the BPMS concerns *coordination*. The BPMS uses the process model for determining which activities need to be performed and in what order. So, every time the BPMS uses this knowledge to route a work item it potentially saves someone the time to even think about what should be done next. Another form of coordination time saved is the signaling of completed work. In a paper-based organization, work will be lying around for quite some time in case of work handoffs. What often happens is that someone takes over work, suspends it for some reason, after which the work package gets stuck in another pile of work. The BPMS will at all times be able to signal the status of all work items and it can take actions to ensure that progress is being made.

The final type of workload reduction by using a BPMS is the *gathering of all relevant information* to carry out a particular task. In a situation without a BPMS, it is the employee who needs to do this collection. Finding the right file in particular—it is never there where you would expect it—can be a time-consuming affair. Note that this type of advantage rests on the assumption that along with the introduction of the BPMS the effort is taken to digitalize the stream of documents in an organization. The implementation of a DMS is actually what is often observed alongside a BPMS implementation. Certain vendors, such as IBM and ISIS Papyrus, offer integrated suites of BPMS and DMS functionality. Other BPMS vendors often have strategic cooperations with companies that offer a DMS, such that it is relatively easy to integrate their joint systems.

9.2.2 Flexible System Integration

Originally, the most popular argument to start with a BPMS was the increased flexibility that organizations achieve with this technology. To explain this best, a short reflection on the history of computer applications is due. There is an interesting trend, as identified by Van der Aalst and Van Hee [176], that generic functionality is split off from applications at some point.

Roughly throughout the 1965–1975 period, computer applications were run directly on the operating systems (OS) of a computer. Each application would take care of its own data management and would be using proprietary techniques to do this efficiently. As a result, it turned out to be difficult to share data among applications and to maintain consistency. Clearly, programmers of different applications would be involved with developing similar routines to solve similar

problems. From 1975 onwards, DBMSs as a new type of standard software emerged that took on the generic task of managing data efficiently. As a result, data could be shared rather easily and programmers of new applications would not need to worry anymore about ways to store, query, or retrieve data. Some 10 years later, around 1985, User Interface Management Systems (UIMS) were introduced to provide a very generic interface component to many applications. Through the provision of facilities like drop-down boxes or radio buttons in accessible libraries, each computer programmer would be able to make use of these. By 1995, the first commercial BPMS enters the marketplace. Like DBMSs and UIMSs in their focus area, BPMSs would provide generic support for the area of business process logic.

The introduction of a BPMS is a logical sequel to the separation of generic functionality of what were once monolithic computer programs. Still in the 1990s, it was estimated that 40% of all the lines of code running on the mainframe computers of banks would have to do with business process logic, not with the calculations or data processing themselves. The typical kind of information processing in the context relates to the identification of activities, their order of execution, or the participants responsible for carrying them out. For example, it would be specified that after a mortgage offering was completed, this needed to be signaled to the manager of the department, triggering a signal on her monitor.

The obvious advantage related to this development is that it has become much easier with a BPMS to manage business process logic on its own. This is due to the fact that it is much more convenient to update the description of a business process without having to inspect the application code. Also, the inverse of this scenario would become easier, i.e., modifying an application while not touching on the order of how things on the business process level would need to unfold. BPMSs, in short, would enable organizations to become more flexible in managing and updating their business processes as well as their applications.

BPMSs also provide the means to “glue” together separate systems. Large service organizations typically deploy myriads of IT systems, which more or less all exist independently of each other. Often, such a situation is referred to as *island automation*. A BPMS may be introduced in such a situation as a means of integrating such systems. It will ensure that all the separate systems will play their due role in the business processes they support.

A word of caution is due here. The BPMS itself will offer no direct solution to the problem of redundant storage of information across many different IT systems. In fact, a BPMS will in general have no knowledge of the actual data that end users will manipulate using the various IT systems. If the BPMS is to operate as an integrator between all the existing systems, this will require a thorough information analysis to map which data is used and available.

9.2.3 Execution Transparency

An advantage that is often overlooked is that a BPMS can operate as a treasure trove with respect to the way that business processes are really executed. Sure enough, to have a BPMS operate at all, it must keep track of which work items are. This can only be determined by actively monitoring which work items have been completed by which resources and at what time new cases enter the process. Yet, for a BPMS to function properly, it is not necessary to keep all that data available once the associated cases are completed. The management overseeing such a process, however, may have an entirely different perspective on this issue. There are two types of information that may be useful to generate business insights from BPMS data:

1. *Operational information*, which relates to recent, running cases, and
2. *Historic information*, which relates to completed cases.

Operational information is relevant for the management of individual cases, participants, or specific parts of a business process. A characteristic example is the following. From analyses of various governmental agencies involved with granting permits in the Netherlands it has become clear that determining the exact status of a permit application was one of the most time-consuming activities for the civil servants involved. Through the use of most commercially available BPMSs, retrieving that status is a futility. Such a status may be, for example, that the request of Mr. Benders to extend his house with an extra garden wing has been received, matched with the development plans for the area he is living in, and that further processing is now dependent on the receipt of the advice of an external expert. Another use of operational information would relate to the length of a queue in terms of work items. For example, there are 29 applications for building permits that await the advice of an external expert. From these examples it becomes clear that initiatives to improve customer service, in particular with respect to answering questions about their orders, often relies on the use of a BPMS.

Historic information, in contrast to operational information, is often of interest on a particular level of aggregation, for example covering more cases over an extended period of time. This kind of information is of the utmost importance to determine the performance of a particular process or its conformance to particular rules. With respect to the former, you may think of average cycle times, the number of completed cases over a particular period, and the utilization of resources. The latter category could cover issues like the kind of exceptions that have been generated or the number of cases that violated a particular deadline.

It makes sense to consider the kind of insights that need to be retrieved from a BPMS before it is actually implemented in an organization. Technical issues play a role here, like the period of time that the logs of a BPMS need to be kept and, therefore, how much storage space should be devoted for that. Consider that it becomes problematic if historic information is important on the aggregate level of years if there is only space to save the events of at most a month. There are also

conceptual issues. If it is important to monitor a certain milestone within a process, it is essential that it is represented in the model that is used for the execution of the related business process. To use the previous example: If it is important to be able to recognize the stage in which a case has to wait for the advice of an external expert, then that milestone must be part of the process model. In this way, process automation provides the foundation for process intelligence (see Chapter 11).

9.2.4 Rule Enforcement

Except for the obvious advantage that a business process could be executed more efficiently by using a BPMS, such a system will also ensure that the process is carried out in precisely the way that it has been designed. When rules are explicitly enforced, this can be considered as a quality benefit: one does what one promises. In many settings, employees will have considerable freedom to carry out a business process in the way it looks best to them (or most convenient). This individual assessment does not necessarily coincide with the best possible way a business process is executed from the overall perspective of an organization. In this respect, a BPMS can be a means to safeguard that business processes are executed in a pre-defined way, without any concessions.

As an illustration, consider the *separation of duties* control that is well known in the financial services domain. It means that the registration and inspection of a financial transaction will need to be carried out by different individuals. This type of logic is both quite easily implemented and enforced in a BPMS. The BPMS registers which individuals have carried out which work items and can take this information into account when allocating new work items. Note that a BPMS is, in general, sufficiently sophisticated so that employees can alternatively fulfill the registering and inspecting role for different cases.

The capacity of a BPMS to enforce rules is currently of much interest to organizations. Around the year 2000, governmental organizations used BPMSs purely for reasons of enforcement, such that they could prove that they comply with the law. Nowadays, financial and other professional service organizations have become similarly enamored by BPMSs. An important development is the rise of various governance frameworks, which started in 2002 with the *Sarbanes-Oxley Act* as a reaction to misconduct in Enron and Worldcom. The law places a high responsibility with company executives to install management controls and to check their proper execution. Obviously, this is where BPMSs can play an important role.

Exercise 9.6 To which categories would you classify the following incentives to introduce a BPMS in an organization?

- An auditing agency has found out that the written procedures and actual execution of business processes are not aligned. The management of that organization wishes to enforce the written procedures and decides to introduce a BPMS.

- The clients of a company complain that they can only get very shallow updates on the progress of the orders they make. The IT manager of that organization looks into the use of a BPMS to capture and provide status information on all these orders.
- An insurance organization finds out that there is an urgent need to quickly adjust their claims processing to the offerings that its competitors bring to the market. Using a BPMS is considered to address this demand.

9.3 Challenges of Introducing a BPMS

Despite the many advantages, there are some notable obstacles to the introduction of a BPMS in an organization. We distinguish between technical and organizational challenges.

9.3.1 Technical Challenges

What should be one of the strengths of a BPMS is also one of its pitfalls. A BPMS is capable of integrating different types of information systems to support a business process. The challenge is that many applications have not been developed with this coordinated use in mind. The mainframe applications that can still be found within banks and insurance companies today are notorious in this regard. In the most favorable case, such systems are technically documented but it often happens that there is no one of the original development team available anymore who knows exactly how these are structured. In such cases, it is very hard to determine how a BPMS can trigger such systems to make them support the execution of a particular work item, to exchange information between the BPMS and such a system (e.g., case data), and how to determine when an employee has used such a system to complete a particular work item.

A technique that has been used to make interaction at all possible with such legacy systems is *screen scraping*. The interaction between a BPMS and the mainframe application then takes place on the level of the user interface: The key strokes that an end user should make are emulated by the BPMS and the signals sent to the display are tracked to establish the progress of carrying out an activity. It will come as no surprise that such low-level integration solutions bring in its train much rigidity to the overall solution and will, in fact, undermine the flexibility advantages that are normally associated with using a BPMS. Recent systems that provide so-called *Robotic Process Automation* promise a more flexible integration. The following box explains how it works.

ROBOTIC PROCESS AUTOMATION

Robotic Process Automation (RPA) [15] refers to a novel class of software tools that automate tasks, or entire business processes, which are heavily based on clerical work. This includes highly-repetitive tasks or chains of tasks, such as copying data from one screen to another, that are quite time-consuming and error-prone, and can thus benefit from automation. RPA tools are configured by observing what human workers enter in different screens of existing systems, such as a claims management system or a legacy mainframe. For example, an RPA tool can be configured to automate the following human behavior: when a customer fills out a Web form to inquire about the status of an order, an employee copies the order number from this form, uses this number to search for the order status in an ERP system, copies the status from there and pastes it into a reply email. RPA tools can identify, extract, and analyze relevant information from user interfaces that are implemented in a variety of technologies, from Web-based forms and Java applications through to legacy command-prompt interfaces, where screen-scraping is required. As such, RPA constitutes a powerful and versatile technology. RPA can relieve human workers from tedious work on standard cases and it is often set up by organizations to achieve better process scalability and cost savings. However, configuring an RPA tool requires knowledge of the systems in place at an organization, and technical skills to train and test the software robots that will mimic human behavior.

A specific problem that occurs with respect to the integration of existing applications with BPMSs is the lack of process awareness of traditional systems. In a process-aware system, separate cases will be handled separately. In other words, such a system works on a case-by-case basis. In many traditional systems, however, *batch processing* is the dominant paradigm. This means that a particular task is executed for a large set of cases, which does not always align with the philosophy of a BPMS. Note how the “Case-based work” heuristic mentioned in Chapter 8 explicitly targets this situation.

Fortunately, in the area of system integration much progress has been made in the past decade. Many old systems are being phased out and new, open systems with clearly defined interfaces take their places. Technologies that are referred to as *Middleware* and *Enterprise Application Integration* tools are now available that strongly facilitate the communication and management of data in distributed applications. Microsoft’s BizTalk Server²⁶ and IBM’s WebSphere²⁷ are well-known software suites that can be used in this respect. There are open source technologies available as well. The success of *Web services* is another driver behind improved,

²⁶<https://www.microsoft.com/en-us/cloud-platform/biztalk>.

²⁷<https://www.ibm.com/developerworks/downloads/ws/was>.

coordinated use of different types of information systems, including BPMSs. A Web service is a piece of functionality, for example the identification of the best possible price for a particular good within a range of providers, which can be invoked over the Internet. Most BPMSs provide good support for integrating specific Web services in executable business processes. This kind of set-up would fit within a popular software architecture paradigm that is commonly referred to as *Service-Oriented Architecture*.

With respect to technical integration capabilities it is fair to say that recent developments are favorable for the use of BPMSs and that technical challenges, at least with respect to this aspect, are likely to further decrease over the next years.

9.3.2 Organizational Challenges

The introduction of an operational BPMS has an impact on extensive parts of an organization. This implies that the introduction of a BPMS can be challenging from an organizational perspective. The interests of different stakeholders have to be balanced, since they usually have diverging performance objectives and vie for the same resources. Getting an insight into how existing processes unfold is an enormous challenge in itself, sometimes taking months of work. Here, not only political motives may play a role—not everyone will be happy to give away how work is done, especially if not much work is done at all—but psychological ones as well: People tend to focus on describing the worst possible exceptions when asked to describe what their role is in a process. One scholar has referred to this tendency as the reason “why modelers wreck workflow innovation”.

A factor that adds to this complexity is that organizations are dynamic entities. It is fairly usual that during the introduction of a BPMS, which may span a couple of months, organizational rules change, departments are scrapped or combined, participants get other responsibilities, and new products are introduced or taken off the market. These are all examples of events that may be important to consider when the aim is to make a BPMS function properly in an organizational setting. In practice, this accounts for the insight that the gradual introduction of a BPMS is usually more successful than a “big bang” strategy, in which a BPMS from 1 day to the other is expected to replace the way operations were managed.

The perspective of the users on the introduction of a BPMS should be considered carefully. Most process participants will first need to experience *hands-on* what it is to use a BPMS before they can really appreciate what that means for their job. There may also be concerns and fears. First, there might be a “Big brother is watching you” sentiment. Indeed, a BPMS will record all the events that are involved with executing a process, including who carried out what piece of work and at what time. It makes no use—and from a change management perspective, it could actually be self-defeating—to ignore this concern. Rather it is up to organizations to clarify how this information will be used and that there are positive effects that can be expected of the usage of this information as well.

Another fear that is common with end users of BPMSs is that their work will take on a mechanistic trait, almost as if they are working as a chain gang. This fear is in part genuine. It is true that the BPMS will take care of the allocation and routing of work. What can be argued, though, is that these are not the most exciting or valuable parts of the work that needs to be done (which is precisely the reason that they could be automated in the first place). If you would consider the situation where employees need to spend large parts of their time on finding the right information to do the job properly, the BPMS can be an attractive mechanism to give that time back to the employees. Another line of reasoning is that it highly depends on the configuration of the BPMS whether the mechanization effect will actually occur. Compare, for example, the situation where a BPMS pushes a single work item at a time to an employee to be carried out versus a range of work items such that someone could choose according to his or her own preferences. These options, which result from a configuration decision, can make a huge difference in the perception of the value of the BPMS.

To sum up, the introduction of a BPMS is particularly complex, precisely because it supports entire business processes. It is for a good reason that research into IT projects identifies “strong management commitment” as a major factor that explains implementation success. The introduction of a BPMS is, perhaps even more so than for other types of technologies, not for the faint of heart. The box on “Change Management” points to principles that any project to introduce a BPMS should consider.

CHANGE MANAGEMENT

Introducing a BPMS is often part of larger transformation initiatives, which tend to be far from easy. Some studies have suggested that two out of three transformation initiatives fail. The reason for failure is often poor management: poor planning, monitoring, and control, lack of resources and know-how, and incompatible corporate policies and practices [55]. Change management is the collective term for approaches that deal with change, from the perspective of both an organization and the individual, to make it succeed. Here, we briefly summarize some of the principles that have been identified as being conducive to successful change.

Factors of influence: A popular view on the factors that influence the success of a change management is the following: what truly matters is the **D**uration of the initiative, the **I**ntegrity of the project team, the **C**ommitment of the top management on the one hand and the affected employees on the other, and the **E**ffort that is demanded of employees on top of their usual work. This is referred to as **DICE**. Its maxim is: The shorter the project is, the more capable the project team, the higher

(continued)

the commitment of management and employees, and the lower the excess demand on employees, the bigger the chance on success [165].

Early victory: A phenomenon that has been observed in many process redesign projects is that victory had been declared too soon. After two or three years into the project, the team gets dissolved and the organization is trusted to continue with the fresh new way of working or the technology that had been implemented. But then, within two more years, the seemingly useful changes that had been introduced slowly disappear—even to the extent that sometimes no trace of the original change can be found back. What is killing the momentum is *premature victory celebration*. By contrast, successful efforts focus on short-term wins or small projects to use these as stepping stones for even bigger projects over time [81].

The nature of resistance: One of the most confounding aspects for managers is that skilled and smart employees, highly committed to the organization, and genuinely supporting a change, actually *do nothing* to make that change successful. The reason is that many people are unwittingly applying productive energy toward a hidden *competing commitment*. For example, a professional may have experienced that each time she completes a difficult assignment she ends up being assigned with an even more difficult one. This type of experience may make her less willing, perhaps even unconsciously, to embrace yet another new initiative. The key here is to take the time to truly understand people's behavior and analyze the assumptions they hold [74].

Programmatic change fallacy: Arguably the greatest mistake is to expect that change can only be brought about by company-wide change programs driven by corporate staff teams. This is also called the *fallacy of programmatic change*. A key element in a successful change program is that it spreads to all departments without too much pushing from the top. This means that there must be room for individual units to adopt a modified version of the envisioned change. Only after change has taken root in this way, the formal structure of the organization should change to institutionalize the applied changes [19].

Exercise 9.7 Consider the following issues that come up when introducing a BPMS in a hospital to support preoperative care, i.e., the preparation and management of a patient prior to surgery. Classify them as technical or organizational issues.

1. On hearing about the plans to introduce a BPMS, the surgeons flatly reject to cooperate on this endeavor. Their claim is that each patient is an individual person that cannot be trusted to the care of a one-size-fits-all system.
2. The anesthetists in the hospital use a decision support system that monitors the proper dosage of anesthetics to patients. The system is developed as a stand-

alone system that is difficult to synchronize with the BPMS, which has to feed the decision support system with patient data.

3. The nurses are provided with mobile devices, which they can use to access their worklist handlers. However, they find it difficult to follow up on the automatic notifications, which are signaled to them as gentle vibrations of the device.

9.4 Recap

In this chapter we discussed Process-Aware Information Systems (PAISs) with a specific focus on Business Process Management Systems (BPMSs). We described the architecture of a BPMS and its main components: the *execution engine*, the *process modeling tool* and the *process model repository*, the *administration and monitoring tools* and the *execution logs*, as well as the *external services* that can be invoked.

There are many reasons for considering process automation using a PAIS. First, it provides workload reduction in terms of coordination: work is assigned to process participants or software services as soon as it is available. Second, it offers integration flexibility. Processes can be changed with significantly less effort as compared to legacy systems, provided they are explicitly represented via process models. Third, the execution in a BPMS generates valuable data on how processes are executed, including performance-relevant data. Finally, BPMSs improve the quality of process execution as they directly enforce rules, such as separation of duties.

Introducing BPMSs poses various challenges. Technical challenges arise from the fact that many applications that have to be integrated are typically not designed as open systems with transparent interfaces. Beyond that, organizational challenges are rooted in the fact that BPMSs directly interfere with how people do their job. This fact calls for sensitive change management.

9.5 Solutions to Exercises

Solution 9.1 There are market research reports with different estimates available. For the period of 2016, they often mention Microsoft, Oracle, IBM, SAP, and EMC among the Top 5 enterprise software vendors. The Top 5 ERP vendors often include SAP, Oracle, Microsoft, Infor, and Epicor in the list.

Solution 9.2

1. There are various pieces of information that are not visible in the chart. It is not clear with what allocation strategy work items are assigned to process participants. It is also not clear whether the different participants work full-time or only part-time. It also does not tell in how far the participants have comparable

skills and expertise. Finally, it is not clear whether the activity Program review application is fully homogenous and standardized or whether there are important variations in the characteristics of the applications.

2. Without knowing the details about the matters discussed, it is difficult to interpret the chart in a way that is fair for the process participants. Note in this context that it is often the competent employees that are overloaded, because they help less-skilled colleagues when they do not know the right way to proceed.

Solution 9.3 There are three current work items:

1. Case #1,220: Determine Proper Piece of Equipment
2. Case #1,230: Determine Proper Piece of Equipment
3. Case #1,240: Complete Equipment Rental Request

Solution 9.4

- The execution engine would be unable to allocate work items to resources on the basis of a process model alone, when it would only cover control-flow information.
- One common situation would be that the process model in question specifies that after a certain activity there is a parallel split, enabling the execution of various follow-up activities.
- Other examples of services that can be useful to be invoked: calculation services (e.g., to determine a mortgage rate or to estimate the total cost of a service), information storage and retrieval services (e.g., to register the outcome of a completed work item or to look up client information), scheduling services (e.g., to plan work that is to be done in follow-up or to estimate a delivery date), communication services (e.g., to get in touch with the client or a business partner).
- Most notably, it would be important to specify on which working days particular resources are available and during which hours, e.g., Ms. Senora only works on Mondays and Fridays and then only from 9 a.m. to 4 p.m. In this way, it becomes possible for the execution engine to allocate work items in an efficient manner.

Solution 9.5

1. It should become possible that the new decision support system can be invoked as an external service.
2. If Ms. Senora retires, this must be recorded with the administration tool.
3. The new rule to allocate work items to resources must be captured in an updated process model.
4. The monitoring service must be implemented in a monitoring tool.

Solution 9.6

- Quality
- Transparency
- Flexibility

Solution 9.7

1. Organizational issue: BPMSs can be highly tailored to take patient-specific data into account.
2. Technical issue: The integration of the decision support system may require additional, customized software development.
3. Organizational/technical: The nurses may on the one hand get accustomed to using the BPMS in general and worklist handlers specifically. On the other hand, it may not be a good technical solution to use vibration signals—an alternative would be, for example, to use sound signals.

9.6 Further Exercises

Exercise 9.8 Draw the architecture of one specific commercial or open-source BPMS and identify all its components.

Exercise 9.9 Explain the similarities and differences between production and ad hoc workflow systems. Include in your explanation a reflection on the type of support they provide on the one hand and their orientation in the spectrum of data versus process on the other.

Exercise 9.10 Classify the following objectives of the various organizations described that use a BPMS and use the categories of advantages that were explained in Section 9.2.

- A legal company wishes to track all the participants it has involved in its formalized process for the preparation of litigation cases.
- A governmental agency wishes to reduce the penalties it must pay for late payments of invoices.
- A bank wishes to demonstrate to its external auditor that it strictly enforces the principle that each large loan is approved by two separate clerks.

Exercise 9.11 In a 2009 posting on LinkedIn, the director of Walgreens, an online pharmacy, asks what the common pitfalls are when implementing a workflow management system. A consultant at Microsoft answers as follows:

It's really all about people buying in to the system. The general tendency of people is that they don't like change, even if they say they do. Even if their current processes are very inefficient, they know how it works. So, when you introduce something that changes their world (with a workflow mgt system), they'll be very apprehensive. Also, the more the system changes how they do their job, the more resistance you'll get. Then it becomes an issue of how you gathered your business requirements. Chances are that due to misunderstandings the requirements will be different than expectations of how things should get done.

Explain whether you think this explanation relates to a technical or an organizational challenge.

9.7 Further Readings

Van der Aalst and van Hee's classic book [176] offers an introduction to workflow management technology as of the early 2000s. The evolution from workflow management systems to BPMSs that took place during the 2000s is discussed at length by Weske [193]. As stated in this chapter, the WfMC reference model was instrumental in shaping the architectures of workflow management systems and later that of BPMSs. Details on the WfMC reference model can be found on the website of the Workflow Management Coalition,²⁸ while Hollingsworth [69] gives a summary of the development and directions of this reference model.

A frequent critique of BPMSs is that they follow a Fordist paradigm, meaning that the BPMS forces process participants to act in a certain direction, i.e., exactly in the way it is captured in a process model. In the context of processes where unanticipated exceptions are common and where there is no predictable way to perform the process, a BPMS often ends up obstructing the work of process participants rather than supporting them. Approaches to support non-standardized or unpredictable processes are described by Reichert et al. [130]. One of those approaches is case handling. An introduction to this topic is given by Van der Aalst et al. [179], while a more comprehensive treatment of the subject is provided by Swenson [172].

A recent longitudinal study involving ten organizations has shed light into the success of BPMS deployments and their business impact [138]. Half of the organizations in this study abandoned their BPMS deployment efforts due to a variety of organizational reasons, chiefly related to change management. This finding highlights the importance of change management when introducing a BPMS in an organization as discussed in the "Change Management" box in Section 9.3.2 (see page 363). On the other hand, those organizations in the study that managed to deploy a BPMS benefited from substantial process improvements.

BPMSs are mainly focused on the automation of business processes within a given organization (*intra-organizational processes*). Many processes, however, span across organizational boundaries. For example, an order-to-cash process typically involves a purchasing company, a supplying company, and a logistics company. There might also be sub-contractors involved (e.g., a customs broker) as well as insurers and export credit agencies. Traditionally, the coordination of all these parties is done via message exchanges. Dispute resolution is a recurrent problem in these processes, for example when a party claims that goods have not been delivered or when a party does not accept an invoice issued by another party. These problems are particularly acute when there is a lack of trust between the parties. Blockchain is an emerging technology that can be used to coordinate *inter-organizational processes* involving untrusted parties. A blockchain provides a way to record that something has happened in a way that ensures that once something has

²⁸<http://wfmc.org/reference-model.html>.

been recorded, it cannot be deleted. Modern blockchains also provide mechanisms to ensure that a given routine (called a *small contract*) is executed every time a given type of transaction is recorded. Instead of exchanging messages, parties involved in an inter-organizational process can execute transactions on a blockchain. This alternative approach ensures that important business rules are always followed (e.g., an accepted delivery is followed by a payment).

Opportunities of applying blockchain technology for BPM are discussed in [113]. Research in this field has demonstrated the feasibility of executing business processes on top of blockchains by taking process models as a starting point [53, 191]. At the time of the writing of this book, BPMS vendors and other PAIS vendors have started to incorporate blockchain-based capabilities into their products. An open-source BPMS running entirely on blockchain has been recently released, namely Caterpillar [95].²⁹

²⁹<http://git.io/caterpillar>.