Fundamentals of Business Process Management

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To Inga and Maia—Marlon
To Chiara and Lorenzo—Marcello
To Stefanie—Jan
To Maddy, Timon and Mayu—Hajo

Foreword

Business processes represent a core asset of corporations. They have direct impact on the attractiveness of products and services as perceived by the market. They determine tasks, jobs and responsibilities and by this, shape the work of every employee. Processes integrate systems, data, and resources within and across organizations and any failure can bring corporate life to a standstill. Processes determine the potential of an organization to adapt to new circumstances and to comply with a fast growing number of legislative requirements. Processes influence the revenue potential as much as they shape the cost profile of an organization.

However, unlike other corporate assets such as products, services, workforce, brand, physical or monetary assets, the significance of business processes had not been appreciated for a long period. Despite the fact that processes are the lifeblood of an organization, they did not develop the status of a primary citizen in boardroom discussions and managerial decision-making processes.

Only the growing demands for globalization, integration, standardization, innovation, agility and operational efficiency, and the related challenge of finding further variables in the corporate ecosystem that can be optimized, have finally increased the appetite for reflecting on and ultimately improving business processes.

In response, over the last two decades a comprehensive set of tools, techniques, methods and entire methodologies has been developed providing support for all stages of the business process lifecycle. Relevant contributions have been made by diverse disciplines such as Industrial Engineering, Operations Management, Quality Management, Human Capital Management, corporate governance, conceptual modeling, workflow management and system engineering.

Business Process Management (BPM) is the discipline that now faces the difficult, but rewarding task of consolidating and integrating the plethora of these approaches.

This book is the first and most up-to-date contribution that faces and masters this challenge. It succinctly captures the current status of BPM and brings meaningful order and consistency into approaches that often have been developed, discussed and deployed in isolation.

"Fundamentals of Business Process Management" derives its merits from its firm foundation in the latest applied BPM research. Relying on scientifically sound practices means capitalizing on evidence rather than depending on confidence. This clearly differentiates this much needed publication from many of its predecessors. In particular, it gives BPM the credibility that a still young and growing discipline requires.

The book itself is also a compelling showcase for the importance of a new class of processes, i.e. long living, internationally distributed, complex and flexible business processes. In this case, it is the process of jointly writing a book involving four authors in four different countries. The team has addressed this challenge brilliantly and the outcome is an impressive compilation of the individual strengths of each author grounded in a shared understanding of the essential BPM fundamentals and a common passion for the topic.

I have no doubts that this book will shape the toolset, and hopefully even more the mindset, of the current and future generations of BPM professionals. This publication has the potential to become a significant catalyst for future BPM success by establishing a common sense for the fundamentals of BPM upon which it can be further developed and tailored to individual circumstances. The book provides the needed consistency and rigor within and across the diverse and fast growing community of professionals and researchers committed to and passionate about the merits of the process-based organization.

Finally, and maybe most of all, the book is an outstanding reference for all students who are keen to learn more about and want to embrace the fascination of BPM. This long missing BPM textbook addresses a severe shortcoming within the BPM community, i.e. the lack of resources to facilitate the introduction of BPM subjects into tertiary and corporate education. Making BPM more accessible to future decision makers ensures that processes will play the role they deserve.

Brisbane, Australia Michael Rosemann

Preface

First, master the fundamentals.
Larry Bird (1957–)

Business Process Management (BPM) is a special field for more than one reason. First of all, BPM is a crossroad of multiple, quite different viewpoints. Business managers are attracted to BPM because of its demonstrated ability to deliver improvements in organizational performance, regulatory compliance and service quality. Industrial engineers see BPM as an opportunity to apply well-trodden manufacturing optimization techniques in the context of organizations that deliver services rather than physical products. Finally, Information Technology (IT) specialists appreciate the fact that BPM provides them with a shared language to communicate with business stakeholders. Furthermore, business process automation technology allows IT specialists to implement and monitor IT systems in a way that is aligned with the vision that business stakeholders have of the organization. In other words, BPM is a boundary-spanning field that serves as a melting pot for otherwise separate communities. For those who have experienced how business managers, industrial engineers and IT professionals often seem to live in different worlds, this shared field of interest is a remarkable opportunity to achieve a joint understanding of the inner workings of a business.

A second special characteristic of BPM is that it is both actively practiced and actively researched. In other words, it is a field where there are both proven and established practices as well as open challenges. Businesses around the world are carrying out BPM initiatives with the aim to, for example, outperform their competitors or meet the demands of regulatory authorities. Academics in fields like computer science, management science, sociology, and engineering are working on the development of methods and techniques to support such initiatives. It is appropriate to see BPM as a "theory in practice" field. On the one hand, practical demands inspire the development of new methods and technologies. On the other hand, the application of these methods and technologies in practice feeds back to the drawing boards in universities and research centers.

After teaching BPM to thousands of students and professionals over the past decade, we strongly feel the lack of a textbook to give a structure to our courses and to allow our audience to study for themselves beyond classwork and homework

assignments. This situation is not due to a lack of excellent books on BPM—in fact there is a good number of them—but rather due to the cross-disciplinary and continuously evolving nature of BPM.

There are excellent treatments of BPM from a business management perspective, most notably Harmon's *Business Process Change* and Sharp and McDermott's *Workflow Modeling*. Both of these books provide useful conceptual frameworks and practical advice and should definitely lie in the bookshelves (or better in the hands) of BPM practitioners. However, one needs an introductory background and preferably years of experience in order to truly appreciate the advice given in these books. Also, these books give little attention to technology aspects such as business process management systems and process intelligence tools.

On the other side of the spectrum, other books adopt a computer science perspective to BPM, such as Van der Aalst and Van Hee's *Workflow Management* and Weske's *Business Process Management*, both focused on process modeling, analysis and automation for computer scientists. At a more specialized level, one can find a range of books focusing on process modeling using specific languages—for example Silver's *BPMN Method and Style*.

Against this background, we decided it was time to put together our combined teaching experience in BPM in order to deliver a textbook that:

- Embraces BPM as a cross-disciplinary field, striking a balance between business management and IT aspects.
- Covers the entire BPM lifecycle, all the way from identifying processes to analyzing, redesigning, implementing and monitoring these processes.
- Follows a step-by-step approach punctuated by numerous examples, in order to make the content accessible to students who have little or no BPM background.
- Contains numerous classroom-tested exercises, both inside each chapter and at the end of the chapters, so that students can test their skills incrementally and instructors have material for classwork, homework and projects.
- Relies on a mature and standardized process modeling language, namely BPMN.

In the spirit of a textbook, every chapter contains a number of elaborated examples and exercises. Some of these exercises are spread throughout the chapter and are intended to help the reader to incrementally put into action concepts and techniques exposed in the chapter in concrete scenarios. These "in-chapter" exercises are paired with sample solutions at the end of the chapter. In addition, every chapter closes with a number of further exercises for which no solutions are provided. Instructors may wish to use these latter exercises for assignments.

Most chapters also contain "highlighted boxes" that provide complementary insights into a specific topic. These boxes are tangential to the flow of the book and may be skipped by readers who wish to concentrate on the essential concepts. Similarly, every chapter closes with a "Further Readings" section that provides external pointers for readers wishing to deepen their understanding of a specific topic.

To better serve our readership, we have set up a website to collect course materials: http://fundamentals-of-bpm.org. This website includes slides, lecture recordings, sample exams, links to related resources and additional exercises.

The book is designed to support courses of a wide variety. An in-depth course on BPM could cover all chapters in a balanced way. In order to fit the content into one semester though, it may be necessary to sacrifice one or two chapters. If this was required, our suggestion would be to skip Chap. 4 or 10. An introductory BPM course could skip Chaps. 2, 4, 7 and 10 while still providing a consistent picture of the field. A course on process automation for IT students could skip Chaps. 2, 5 and 6. A course on process modeling would focus on Chaps. 2 to 5, and possibly Chap. 9 if the intention is to produce executable process models. Chapters 3 and 4 can be integrated into a broader semester-long course on systems modeling. Finally, a process improvement course for business students might focus on Chap. 3 and Chaps. 5 to 8. Naturally, Chap. 1 could find its place in any of the above courses.

Each chapter can be delivered as a combination of lectures and classwork sessions. Shorter chapters (1, 2, 3, 5, 6 and 10) can be delivered in one lecture and one classwork session. Chapters 4, 8 and 9 may require two lectures and two classwork sessions each. Chapter 7 can be delivered across two lectures and two classwork sessions, or it can be delivered in one lecture and one classwork session by skipping the content on queues and flow analysis.

This textbook is the result of many years of educational practice both at the undergraduate and postgraduate levels in more than half a dozen institutions, including Eindhoven University of Technology (The Netherlands), Queensland University of Technology (Australia), Humboldt University of Berlin (Germany), University of Tartu (Estonia), Vienna University of Economics and Business (Austria) and National University of Colombia. The material in this textbook has also served as a basis for professional training courses delivered to organizations in Australia, The Netherlands and elsewhere. We are grateful to the thousands of students who over the past years have given us constructive feedback and encouragement.

We also owe a lot to our many colleagues who encouraged us and provided us with feedback throughout the entire idea-to-textbook process. We would like to thank Wil van der Aalst, Raffaele Conforti, Monika Malinova, Johannes Prescher, Artem Polyvyanyy, Manfred Reichert, Jan Recker, Michael Rosemann, Matthias Schrepfer, Arthur ter Hofstede, Irene Vanderfeesten, J. Leon Zhao and Michael zur Muehlen, who all provided constructive feedback on drafts of the book. Fabio Casati and Boualem Benatallah provided us with initial encouragement to start the writing process. Special mentions are due to Matthias Weidlich who provided us with detailed and comprehensive suggestions, and Remco Dijkman who shared with us teaching material that served as input to Chaps. 2 and 9.

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Contents

Acronyms

6 M	Machine, Method, Material, Man, Measurement, Milieu
4 P	Policies, Procedures, People, Plant/Equipment
7PMG	Seven Process Modeling Guidelines
ABC	Activity-Based Costing
APQC	American Productivity and Quality Center
ATAMO	And Then, A Miracle Occurs
B2B	Business-to-Business
BAM	Business Activity Monitoring
BOM	Bill-of-Material
BPA	Business Process Analysis
BPEL	Web Service Business Process Execution Language
BPM	Business Process Management
BPMN	Business Process Model & Notation
BPMS	Business Process Management System
BPR	Business Process Reengineering
BTO	Build-to-Order
BVA	Business Value-Adding
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CIO	Chief Information Officer
CMMI	Capability Maturity Model Integrated
COO	Chief Operations Officer
CPO	Chief Process Officer
CRM	Customer Relationship Management
CPN	Colored Petri Net
CT	Cycle Time
DBMS	Database Management System
DCOR	Design Chain Operations Reference (product design)
DES	Discrete-Event Simulation
DMR	Department of Main Roads
DMS	Document Management System

DUR	Drug Utilization Review
EPA	Environment Protection Agency
EPC	Event-driven Process Chain
ERP	Enterprise Resource Planning
eTOM	Enhanced Telecom Operations Map
FIFO	First-In-First-Out
HR	Human Resources
IDEF3	Integrated Definition for Process Description Capture Method
ISP	Internet Service Provider
IT	Information Technology
ITIL	Information Technology Infrastructure Library
KM	Knowledge Management
KPI	Key Performance Indicator
NRW	Department of Natural Resources and Water
NVA	Non-Value-Adding
OASIS	Organization for the Advancement of Structured Information Standards
OMG	Object Management Group
OS	Operating System
PCF	Process Classification Framework
PD	Product Development
PDCA	Plan-Do-Check-Act
PO	Purchase Order
POS	Point-of-Sale
PPM	Process Performance Measurement
RBAC	Role-based Access Control
RFID	Radio-Frequency Identification
RFQ	Request for Quote
ROI	Return-On-Investment
SCAMPI	Standard CMMI Appraisal Method for Process Improvement
SCOR	Supply Chain Operations Reference Model
Smart eDA	Smart Electronic Development Assessment System
SOA	Service-Oriented Architecture
STP	Straight-Through-Processing
TCT	Theoretical Cycle Time
TOC	Theory of Constraints
TQM	Total Quality Management
UIMS	User Interface Management System
UEL	Universal Expression Language
UML	Unified Modeling Language
UML AD	UML Activity Diagram
VA	Value-Adding
VCH	Value Creation Hierarchy
VCS	Value Creation System
VRM	Value Reference Model

WIP	Work-In-Progress
WfMC	Workflow Management Coalition
WfMS	Workflow Management System
WS-BPEL	Web Service Business Process Execution Language
WSDL	Web Service Definition Language
XES	Extensible Event Stream
XML	Extensible Markup Language
XSD	XML Schema Definition
YAWL	Yet Another Workflow Language

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Chapter 1
Introduction to Business Process Management

Ab ovo usque ad mala.
Horace (65 BCE–8 BCE)

Business Process Management (BPM) is the art and science of overseeing how work is performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities. In this context, the term "improvement" may take different meanings depending on the objectives of the organization. Typical examples of improvement objectives include reducing costs, reducing execution times and reducing error rates. Improvement initiatives may be one-off, but also display a more continuous nature. Importantly, BPM is not about improving the way individual activities are performed. Rather, it is about managing entire chains of events, activities and decisions that ultimately add value to the organization and its customers. These "chains of events, activities and decisions" are called *processes*.

In this chapter, we introduce a few essential concepts behind BPM. We will start with a description of typical processes that are found in contemporary organizations. Next, we discuss the basic ingredients of a business process and we provide a definition for the concept as well as of BPM. In order to place BPM in a broader perspective, we then provide a historical overview of the BPM discipline. Finally, we discuss how a BPM initiative in an organization typically unfolds. This discussion leads us to the definition of a BPM lifecycle around which the book is structured.

1.1 Processes Everywhere

Every organization—be it a governmental body, a non-profit organization, or an enterprise—has to manage a number of processes. Typical examples of processes that can be found in most organizations include:

- *Order-to-cash*: This is a type of process performed by a vendor, which starts when a customer submits an order to purchase a product or a service and ends when the product or service in question has been delivered to the customer and the customer has made the corresponding payment. An order-to-cash process encompasses activities related to purchase order verification, shipment (in the case of physical products), delivery, invoicing, payment receipt and acknowledgment.

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- *Quote-to-order*: This type of process typically precedes an order-to-cash process. It starts from the point when a supplier receives a "Request for Quote" (RFQ) from a customer and ends when the customer in question places a purchase order based on the received quote. The order-to-cash process takes the relay from that point on. The combination of a quote-to-order and the corresponding order-to-cash process is called a *quote-to-cash* process.
- *Procure-to-pay*: This type of process starts when someone in an organization determines that a given product or service needs to be purchased. It ends when the product or service has been delivered and paid for. A procure-to-pay process includes activities such as obtaining quotes, approving the purchase, selecting a supplier, issuing a purchase order, receiving the goods (or consuming the service), checking and paying the invoice. A procure-to-pay process can be seen as the dual of quote-to-cash process in the context of business-to-business interactions. For every procure-to-pay process there is a corresponding quote-to-cash process on the supplier's side.
- *Issue-to-resolution*. This type of process starts when a customer raises a problem or issue, such as a complaint related to a defect in a product or an issue encountered when consuming a service. The process continues until the customer, the supplier, or preferably both of them, agree that the issue has been resolved. A variant of this process can be found in insurance companies that have to deal with "insurance claims". This variant is often called *claim-to-resolution*.
- *Application-to-approval.* This type of process starts when someone applies for a benefit or privilege and ends when the benefit or privilege in question is either granted or denied. This type of process is common in government agencies, for example when a citizen applies for a building permit or when a businessman applies for a permit to open a business (e.g. a restaurant). Another process that falls into this category is the admissions process in a university, which starts when a student applies for admission into a degree. Yet another example is the process for approval of vacation or special leave requests in a company.

As the above examples illustrate, business processes are what companies do whenever they deliver a service or a product to customers. The way processes are designed and performed affects both the "quality of service" that customers perceive and the efficiency with which services are delivered. An organization can outperform another organization offering similar kinds of service if it has better processes and executes them better. This is true not only of customer-facing processes, but also of internal processes such as the procure-to-pay process, which is performed for the purpose of fulfilling an internal need.

As we go along this book, we will use a concrete example of a procure-to-pay process for renting construction equipment, as described below.

Example 1.1 Procure-to-pay process at BuildIT.

BuildIT is a construction company specialized in public works (roads, bridges, pipelines, tunnels, railroads, etc.). Within BuildIT, it often happens that engineers working at a construction site (called *site engineers*) need a piece of equipment, such as a truck, an excavator,

a bulldozer, a water pump, etc. BuildIT owns very little equipment and instead it rents most of its equipment from specialized suppliers.
The existing business process for renting equipment goes as follows. When site engineers need to rent a piece of equipment, they fill in a form called "Equipment Rental Request" and send this request by e-mail to one of the clerks at the company's depot. The clerk at the depot receives the request and, after consulting the catalogs of the equipment suppliers, selects the most cost-effective equipment that complies with the request. Next, the clerk checks the availability of the selected equipment with the supplier via phone or e-mail. Sometimes the selected option is not available and the clerk has to select an alternative piece of equipment and check its availability with the corresponding supplier.
Once the clerk has found a suitable piece of equipment available for rental, the clerk adds the details of the selected equipment to the rental request. Every rental request has to be approved by a works engineer, who also works at the depot. In some cases, the works engineer rejects the equipment rental request. Some rejections lead to the cancellation of the request (no equipment is rented at all). Other rejections are resolved by replacing the selected equipment with another equipment—such as a cheaper piece of equipment or a more appropriate piece of equipment for the job. In the latter case, the clerk needs to perform another availability enquiry.
When a works engineer approves a rental request, the clerk sends a confirmation to the supplier. This confirmation includes a Purchase Order (PO) for renting the equipment. The PO is produced by BuildIT's financial information system using information entered by the clerk. The clerk also records the engagement of the equipment in a spreadsheet that is maintained for the purpose of tracking all equipment rentals.
In the meantime, the site engineer may decide that the equipment is no longer needed. In this case, the engineer asks the clerk to cancel the request for renting the equipment.
In due time, the supplier delivers the rented equipment to the construction site. The site engineer then inspects the equipment. If everything is in order, the engineer accepts the engagement and the equipment is put into use. In some cases, the equipment is sent back because it does not comply with the requirements of the site engineer. In this case, the site engineer has to start the rental process all over again.
When the rental period expires, the supplier comes to pick up the equipment. Sometimes, the site engineer asks for an extension of the rental period by contacting the supplier via e-mail or phone 1–2 days before pick-up. The supplier may accept or reject this request.
A few days after the equipment is picked up, the equipment's supplier sends an invoice to the clerk by e-mail. At this point, the clerk asks the site engineer to confirm that the equipment was indeed rented for the period indicated in the invoice. The clerk also checks if the rental prices indicated in the invoice are in accordance with those in the PO. After these checks, the clerk forwards the invoice to the financial department and the finance department eventually pays the invoice.

1.2 Ingredients of a Business Process

The above example shows that a business process encompasses a number of *events* and *activities*. Events correspond to things that happen atomically, meaning that they have no duration. The arrival of an equipment at a construction site is an event. This event may trigger the execution of series of activities. For example, when a piece of equipment arrives, the site engineer inspects it. This inspection is an activity, in the sense that it takes time.

When an activity is rather simple and can be seen as one single unit of work, we call it a *task*. For example, if the inspection that the site engineer performs is quite

simple—e.g. just checking that the equipment received corresponds to what was ordered—we can say that the equipment inspection is a task. If on the other hand the equipment inspection requires many steps—such as checking that the equipment fulfills the specification included in the purchase order, checking that the equipment is in working order, and checking the equipment comes with all the required accessories and safety devices—we will call it an activity.

In addition to events and activities, a typical process involves *decision points*, that is, points in time when a decision is made that affects the way the process is executed. For example, as a result of the inspection, the site engineer may decide that the equipment should be returned or that the equipment should be accepted. This decision affects what happens later in the process.

A process also involves a number of actors (human actors, organizations, or software systems acting on behalf of human actors or organizations), physical objects (equipment, materials, products, paper documents) and immaterial objects (electronic documents and electronic records). For example, the equipment rental process involves three types of human actor (clerk, site engineer and works engineer) and two types of organizational actor (BuildIT and the equipment suppliers). The process also involves physical objects (the rented equipment), electronic documents (equipment rental requests, POs, invoices) and electronic records (equipment engagement records maintained in a spreadsheet).

Finally, the execution of a process leads to one or several *outcomes*. For example, the equipment rental process leads to an equipment being used by BuildIT, as well as a payment being made to the equipment's supplier. Ideally, an outcome should deliver value to the actors involved in the process, which in this example are BuildIT and the supplier. In some cases, this value is not achieved or is only partially achieved. For example, when an equipment is returned, no value is gained, neither by BuildIT nor by the supplier. This corresponds to a *negative outcome*, as opposed to a *positive outcome* that delivers value to the actors involved.

Among the actors involved in a process, the one who consumes the output of the process plays a special role, namely the role of the *customer*. For example, in the above process, the customer is the site engineer, since it is the site engineer who puts the rented equipment to use. It is also the site engineer who will most likely be dissatisfied if the outcome of the process is unsatisfactory (negative outcome) or if the execution of the process is delayed. In this example, the customer is internal to BuildIT, meaning that the customer is an employee of the organization. In other processes, such as an order-to-cash process, the customer is external to the organization. Sometimes, there are multiple customers in a process. For example, in a process for selling a house, there is a buyer, a seller, a real estate agent, one or multiple mortgage providers, and at least one notary. The outcome of the process is a sales transaction. This outcome provides value both to the buyer who gets the house and to the seller who monetizes the house. Therefore, both the buyer and the seller can be seen as customers in this process, while the remaining actors provide various services.

Exercise 1.1 Consider the following process for the admission of graduate students at a university.

In order to apply for admission, students first fill in an online form. Online applications are recorded in an information system to which all staff members involved in the admissions process have access to. After a student has submitted the online form, a PDF document is generated and the student is requested to download it, sign it, and send it by post together with the required documents, which include:

- Certified copies of previous degree and academic transcripts.
- Results of English language test.
- Curriculum vitae.

When these documents are received by the admissions office, an officer checks the completeness of the documents. If any document is missing, an e-mail is sent to the student. The student has to send the missing documents by post. Assuming the application is complete, the admissions office sends the certified copies of the degrees to an academic recognition agency, which checks the degrees and gives an assessment of their validity and equivalence in terms of local education standards. This agency requires that all documents be sent to it by post, and all documents must be certified copies of the originals. The agency sends back its assessment to the university by post as well. Assuming the degree verification is successful, the English language test results are then checked online by an officer at the admissions office. If the validity of the English language test results cannot be verified, the application is rejected (such notifications of rejection are sent by e-mail).
Once all documents of a given student have been validated, the admission office forwards these documents by internal mail to the corresponding academic committee responsible for deciding whether to offer admission or not. The committee makes its decision based on the academic transcripts and the CV. The committee meets once every 2 to 3 weeks and examines all applications that are ready for academic assessment at the time of the meeting. At the end of the committee meeting, the chair of the committee notifies the admissions office of the selection outcomes. This notification includes a list of admitted and rejected candidates. A few days later, the admission office notifies the outcome to each candidate via e-mail. Additionally, successful candidates are sent a confirmation letter by post.

With respect to the above process, consider the following questions:

1. Who are the actors in this process?
2. Which actors can be considered to be the customer (or customers) in this process?
3. What value does the process deliver to its customer(s)?
4. What are the possible outcomes of this process?

In light of the above, we define a business process as *a collection of inter-related events, activities and decision points that involve a number of actors and objects, and that collectively lead to an outcome that is of value to at least one customer*. Figure 1.1 depicts the ingredients of this definition and their relations.

Armed with this definition of a business process, we define BPM as *a body of methods, techniques and tools to discover, analyze, redesign, execute and monitor business processes*. This definition reflects the fact that business processes are the focal point of BPM, and also the fact that BPM involves different phases and activities in the lifecycle of business processes, as we will discuss later in this chapter.

Other disciplines besides BPM deal with business processes in different ways as explained in the box "Related Disciplines". One of the features commonly associated to BPM is its emphasis on the use of process models throughout the lifecycle of business processes. Accordingly, process models are present in one way or an-

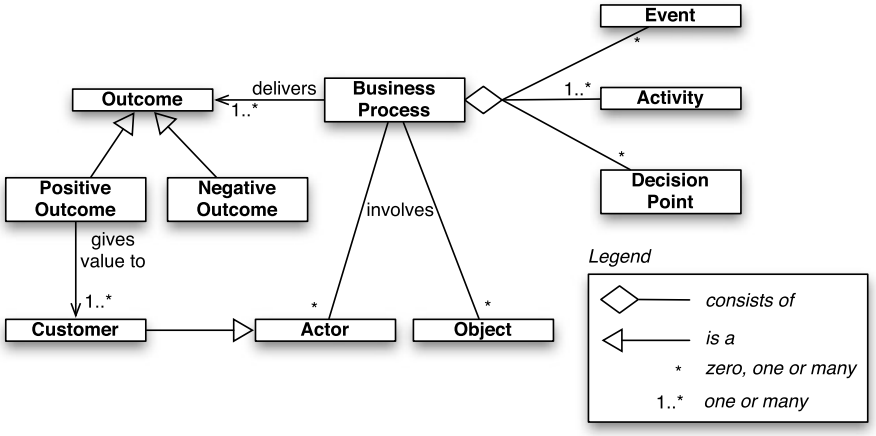

Fig. 1.1 Ingredients of a business process

other in virtually all chapters of this book and two chapters are dedicated to process modeling.

In any case, while it is useful to know that multiple disciplines share the aim of improving business processes, we should remain pragmatic and not pitch one discipline against the other as if they were competitors. Instead, we should embrace any technique that helps us to improve business processes, whether or not this technique is perceived as being part of the BPM discipline (in the strict sense) and regardless of whether or not the technique in question uses process models.

RELATED DISCIPLINES

BPM is by no means the only discipline that is concerned with improving the operational performance of organizations. Below, we briefly introduce some related disciplines and identify key relations and differences between these disciplines and BPM.

Total Quality Management (TQM) is an approach that both historically preceded and inspired BPM. The focus of TQM is on continuously improving and sustaining the quality of products, and by extension also of services. In this way, it is similar to BPM in its emphasis on the necessity of *ongoing* improvement efforts. But where TQM puts the emphasis on the products and services themselves, the view behind BPM is that the quality of products and services can best be achieved by focusing on the improvement of the processes that create these products and services. It should be admitted that this view is somewhat controversial, as contemporary TQM adepts would rather see BPM as one of the various practices that are commonly found within a TQM program. Not so much a theoretical distinction but an empir-

ical one is that applications of TQM are primarily found in manufacturing domains—where the products are tangible—while BPM is more oriented to service organizations.

Operations Management is a field concerned with managing the *physical* and *technical* functions of a firm or organization, particularly those relating to production and manufacturing. Probability theory, queuing theory, decision analysis, mathematical modeling, and simulation are all important techniques for optimizing the efficiency of operations from this perspective. As will be discussed in Chap. 7, such techniques are also useful in the context of BPM initiatives. What is rather different between operations management and BPM is that operations management is generally concerned with controlling an existing process without necessarily changing it, while BPM is often concerned with making changes to an existing process in order to improve it.

Lean is a management discipline that originates from the manufacturing industry, in particular the engineering philosophy of Toyota. One of the main principles of Lean is the *elimination of waste*, i.e. activities that do not add value to the customer as we will discuss in Chap. 6. The customer orientation of Lean is similar to that of BPM and many of the principles behind Lean have been absorbed by BPM. In that sense, BPM can be seen as a more encompassing discipline than Lean. Another difference is that BPM puts more emphasis on the use of information technology as a tool to improve business processes and to make them more consistent and repeatable.

Six Sigma is another set of practices that originate from manufacturing, in particular from engineering and production practices at Motorola. The main characteristic of Six Sigma is its focus on the minimization of defects (errors). Six Sigma places a strong emphasis on measuring the output of processes or activities, especially in terms of quality. Six Sigma encourages managers to systematically compare the effects of improvement initiatives on the outputs. In practice, Six Sigma is not necessarily applied alone, but in conjunction with other approaches. In particular, a popular approach is to blend the philosophy of Lean with the techniques of Six Sigma, leading to an approach known as *Lean Six Sigma*. Nowadays, many of the techniques of Six Sigma are commonly applied in BPM as well. In Chap. 6, we will introduce a few business process analysis techniques that are shared by Six Sigma and BPM.

In summary, we can say that BPM inherits from the continuous improvement philosophy of TQM, embraces the principles and techniques of operations management, Lean and Six Sigma, and combines them with the capabilities offered by modern information technology, in order to optimally align business processes with the performance objectives of an organization.

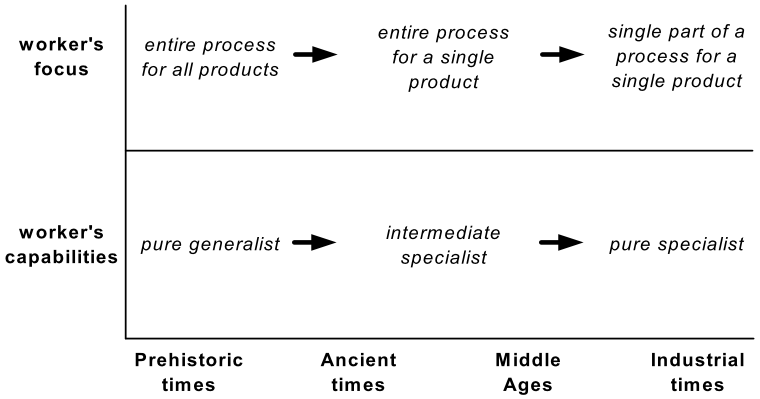

Fig. 1.2 How the process moved out of focus through the ages

1.3 Origins and History of BPM

To better understand why organizations engage in BPM and what benefits it brings to them, it is worth looking at the reasons why BPM has emerged and evolved over time. Below we look into the drivers of the BPM discipline from a historical perspective. We start with the emergence of functional organizations, continue with the introduction of process thinking, towards the innovations and failures of business process re-engineering. This discussion provides the basis for the definition of the BPM lifecycle afterwards.

1.3.1 The Functional Organization

The key idea of BPM is to focus on processes when organizing and managing work in an organization. This idea may seem intuitive and straightforward at first glance. Indeed, if one is concerned with the quality of a particular product or service and the speed of its delivery to a customer, why not consider the very steps that are necessary to produce it? Even though intuitive, it took several evolutionary steps before this idea became integral part of the work structures of organizations. Figure 1.2 provides an overview of some historical developments relevant to BPM.

In prehistoric times, humans mostly supported themselves or the small groups they lived in by producing their own food, tools, and other items. In such early societies, the consumers and producers of a given good were often the same persons. In industrial terms, people carried out their own production processes. As a result, they had knowledge of how to produce many different things. In other words, they were generalists.

In ancient times, in parallel with the rise of cities and city states, this work structure based on generalists started to evolve towards what can be characterized as an *intermediate level of specialism*. People started to specialize in the art of delivering

one specific type of goods, such as pottery, or providing one particular type of services, such as lodging for travelers. This widespread development towards a higher level of specialism of the workforce culminated in the guilds of the craftsmen during the Middle Ages. These guilds were essentially groups of merchants and artisans concerned with the same economic activity, such as barbers, shoemakers, masons, surgeons, and sculptors. Workers in this time would have a good understanding of an entire process that they were involved in, but not so much about the processes that produced the goods or services they obtained from others.

This higher degree of specialization of the medieval worker shifted further towards a form of pure specialization during the Second Industrial Revolution, between the second half of the 19th century and the First World War. A name that is inseparably linked to it is that of Frederick W. Taylor (1856–1915), who proposed a set of principles known as *scientific management*. A key element in Taylor's approach was an extreme form of labor division. By meticulously studying labor activities, such as the individual steps that were required to handle pig iron in steel mills, Taylor developed very specific work instructions for laborers. Laborers would only be involved with carrying out one of the many steps in the production process. Not only in industry, but also in administrative settings, such as government organizations, the concept of division of labor became the most dominant form of organizing work. The upshot of this development was that workers became pure specialists who would be concerned with only a single part of one business process.

A side-effect of the ideas of Taylor and his contemporaries was the emergence of an altogether new class of professionals, that of *managers*. After all, someone needed to oversee the productivity of groups of workers concerned with the same part of a production process. Managers were responsible for pinning down the productivity goals for individual workers and making sure that such goals were met. In contrast to the masters of the medieval guilds, who could only attain such a rank on the basis of a masterpiece produced by themselves, managers are not necessarily experts in carrying out the job they oversee. Their main interest is to optimize how a job is done with the resources under their supervision.

After the emergence of managers, organizations became structured along the principles of labor division. A next and obvious challenge arose then: How to differentiate between the responsibilities of all these managers? The solution was to create functional units in which people with a similar focus on part of the production process were grouped together. These units were overseen by managers with different responsibilities. Moreover, the units and their managers were structured hierarchically: for example, groups are under departments, departments are under business units, etc. What we see here is the root of the functional units that are familiar to us today when we think about organizations: purchasing, sales, warehousing, finance, marketing, human resource management, etc.

The *functional organization* that emerged from the mindset of the Second Industrial Revolution, dominated the corporate landscape for the greatest part of the 19th and 20th centuries. Towards the end of the 1980s, however, major American companies such as IBM, Ford, and Bell Atlantic (now Verizon) came to realize that their emphasis on functional optimization was creating inefficiencies in their operations that were affecting their competitiveness. Costly projects that introduced

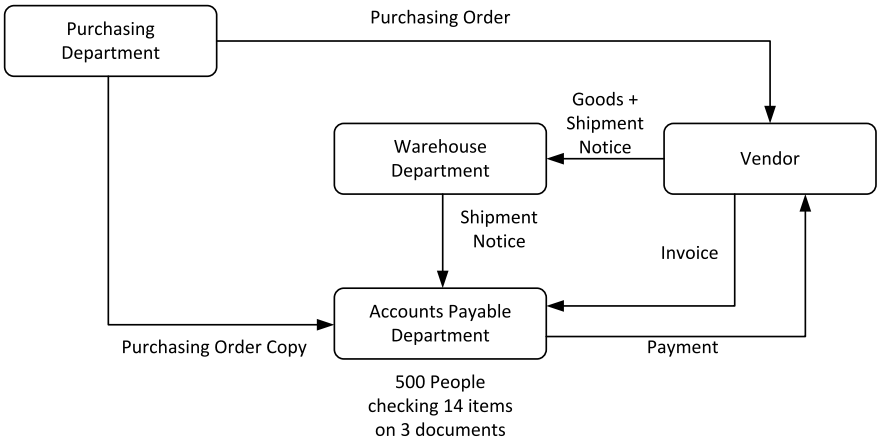

Fig. 1.3 Purchasing process at Ford at the initial stage

new IT systems or reorganized work within a functional department with the aim of improving its efficiency, were not notably helping these companies to become more competitive. It seemed as if customers remained oblivious to these efforts and continued to take their business elsewhere, for example to Japanese competitors.

1.3.2 The Birth of Process Thinking

One of the breakthrough events for the development of BPM was Ford's acquisition of a big financial stake in Mazda during the 1980s. When visiting Mazda's plants, one of the things that observant Ford executives noticed was that units within Mazda seemed considerably understaffed in comparison with comparable units within Ford, yet operated normally. A famous case study illustrating this phenomenon, first narrated by Michael Hammer [26] and subsequently analyzed by many others, deals with Ford's purchasing process. Figure 1.3 depicts the way purchasing was done within Ford at the time.

Every purchase that Ford would make needed to go through the purchasing department. On deciding that a particular quantity of products indeed had to be purchased, this department sent out an order to the vendor in question. It would also send a copy of that order to accounts payable. When the vendor followed up, the ordered goods would be delivered at Ford's receiving warehouse. Along with the goods came a shipping notice, which was passed on to accounts payable. The vendor would also send out an invoice to accounts payable directly.

Against this background, it becomes clear that the main task of accounts payable was to check the consistency between three different documents (purchase order copy, shipping notice, invoice), where each document consists of roughly 14 data items (type of product, quantity, price, etc.). Not surprisingly, various types of discrepancy were discovered every day and sorting out these discrepancies occupied

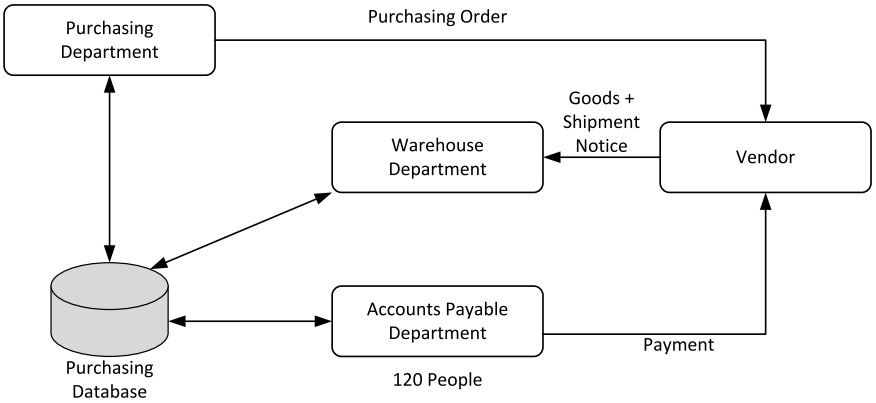

Fig. 1.4 Purchasing process at Ford after redesign

several hundred people within Ford. In contrast, at Mazda only five people worked at this department, while Mazda was not 100 times smaller than Ford in any relevant measure. Fundamentally, the problem is that Ford was detecting and resolving with problems (in this case discrepancies) one by one, while Mazda instead was avoiding the discrepancies in the first place. After a more detailed comparison with Mazda, Ford carried out several changes in its own purchasing process, leading to the redesigned process depicted in Fig. 1.4.

First of all, a central database was developed to store information on purchases. This database was used by the purchasing department to store all the information on purchase orders. This database replaced one of the original paper streams. Secondly, new computer terminals were installed at the warehouse department which gave direct access to that database. When goods arrived, the warehouse personnel could immediately check whether the delivery actually matched what was originally purchased. If this was not the case, the goods were simply not accepted: this put the onus on the vendor to ensure that what was delivered was what was requested and nothing else. In cases where a match was found between the delivered goods and the recorded purchase order, the acceptance of the goods was registered. So, the only thing left to do for accounts payable was to pay what was agreed upon in the original purchase order. Following this new set-up, Ford managed to bring down their workforce in accounts payable from roughly 500 people down to 120 people (a 76 % reduction).

Exercise 1.2 Consider the purchasing process at Ford.

1. Who are the actors in this process?
2. Which actors can be considered to be the customer (or customers) in this process?
3. What value does the process deliver to its customer(s)?
4. What are the possible outcomes of this process?

A key element in this case study is that a problematic performance issue (i.e. an excessive amount of time and resources spent on checking documents in accounts payable) is approached by considering an entire process. In this case, the accounts payable department plays an important role in the overall purchasing process, but the process also involves tasks by staff at the purchasing department, the warehouse, and by the vendor. Regardless of these barriers, changes are made across the process and these changes are multi-pronged: They include informational changes (information exchanges), technological changes (database, terminals), and structural changes (checks, policies).

This characteristic view on how to look at organizational performance was put forward in a seminal article by Tom Davenport and James Short [11]. In this article, the authors urged managers to look at entire processes when trying to improve the operations of their business, instead of looking at one particular task or business function. Various cases were discussed where indeed this particular approach proved to be successful. In the same paper, the important role of IT was emphasized as an enabler to come up with a redesign of existing business processes. Indeed, when looking at the Ford–Mazda example it would seem difficult to change the traditional procedure without the specific qualities of IT, which in general allows access to information in a way that is independent of time and place.

1.3.3 The Rise and Fall of BPR

The work by Davenport and Short, as well as that of others, triggered the emergence and widespread adoption of a management concept that was referred to as *Business Process Redesign* or *Business Process Re-engineering*, often conveniently abbreviated to *BPR*. Numerous white papers, articles, and books appeared on the topic throughout the 1990s and companies all over the world assembled BPR teams to review and redesign their processes.

The enthusiasm for BPR faded down, however, by the late 1990s. Many companies terminated their BPR projects and stopped supporting further BPR initiatives. What had happened? In a retrospective analysis, a number of factors can be distinguished:

1. Concept misuse: In some organizations, about every change program or improvement project was labeled BPR even when business processes were not the core of these projects. During the 1990s, many corporations initiated considerable reductions of their workforce (downsizing) which, since they were often packaged as process redesign projects, triggered intense resentment among operational staff and middle management against BPR. After all, it was not at all clear that operational improvement was really driving such initiatives.
2. Over-radicalism: Some early proponents of BPR, including Michael Hammer, emphasized from the very start that redesign had to be radical, in the sense that a new design for a business process had to overhaul the way the process was initially organized. A telling indication is one of Michael Hammer's early papers

on this subject which bore the subtitle: "Don't automate, Obliterate". While a radical approach may be justified in some situations, it is clear that many other situations require a much more gradual (incremental) approach.

3. Support immaturity: Even in projects that were process-centered from the start and took a more gradual approach to improving the business process in question, people ran into the problem that the necessary tools and technologies to implement such a new design were not available or sufficiently powerful. One particular issue centered around the fact that much logic on how processes had to unfold were hard-coded in the supporting IT applications of the time. Understandably, people grew frustrated when they noted that their efforts on redesigning a process were thwarted by a rigid infrastructure.

Subsequently, two key events revived some of the ideas behind BPR and laid the foundation for the emergence of BPM. First of all, empirical studies appeared showing that organizations that were process-oriented—that is, organizations that sought to improve processes as a basis for gaining efficiency and satisfying their customers—factually did better than non-process-oriented organizations. While the initial BPR guru's provided compelling case studies, such as the one on Ford–Mazda, it remained unclear to many whether these were exceptions rather than the rule. In one of the first empirical studies on this topic, Kevin McCormack [49] investigated a sample of 100 US manufacturing organizations and found that process-oriented organizations showed better overall performance, tended to have a better esprit de corps in the workplace, and suffered less from inter-functional conflicts. Follow-up studies confirmed this picture, giving renewed credibility to process thinking.

A second important development was technological in nature. Different types of IT system emerged, most notably Enterprise Resource Planning (ERP) systems and Workflow Management Systems (WfMSs). ERP systems are essentially systems that store all data related to the business operations of a company in a consistent manner, so that all stakeholders who need access to these data can gain such access. This idea of a single shared and centralized database enables the optimization of information usage and information exchanges, which is a key enabler of process improvement (cf. Chap. 8).[1] WfMSs on the other hand are systems that distribute work to various actors in a company on the basis of process models. By doing so, a WfMS make it easier to implement changes to business processes (e.g. to change the order in which steps are performed) because the changes made in the process model can be put into execution with relative ease, compared to the situation where the rules for executing the process are hard-coded inside complex software systems and buried inside tens of thousands of lines of code. Also, a WfMS very closely supports the idea of working in a process-centered manner.

[1] In reality, ERP systems are much more than a shared database. They also incorporate numerous modules to support typical functions of an organization such as accounting, inventory management, production planning, logistics, etc. However, from the perspective of process improvement, the shared database concept behind ERP systems is a major enabler.

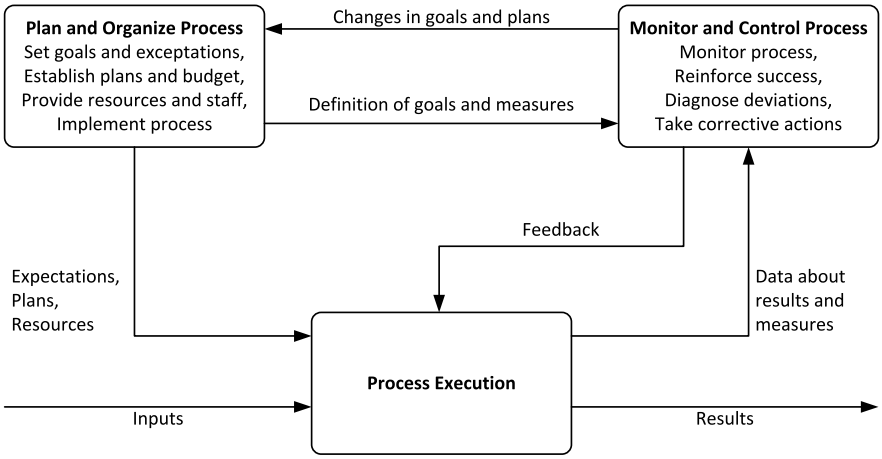

Fig. 1.5 Job functions of a manager responsible for a process (a.k.a. process owner)

Originally, WfMSs were concerned mainly with routing work between human actors. Later on, these systems were little by little extended with modules to monitor and analyze the execution of business processes. In parallel, the emergence of Web services made it easier to connect a WfMS with other systems, in particular ERP systems. As WfMSs became more sophisticated and better integrated with other enterprise systems, they became known as Business Process Management Systems (BPMSs). The functionality of BPMSs and their role in the automation of business processes will be discussed in Chap. 9.

The above historical view suggests that BPM is a revival of BPR, as indeed BPM adopts the process-centered view on organizations. Some caution is due though when BPR and BPM are being equated. The relation is much better understood on the basis of Fig. 1.5.

This figure shows that a manager that is responsible for a business process—also called the *process owner*—is concerned with planning and organizing the process on the one hand and monitoring the process on the other. The figure allows us to explain the differences in *scope* between BPR and BPM. While both approaches take the business process as a starting point, BPR is primarily concerned with planning and organizing the process. By contrast, BPM provides concepts, methods, techniques, and tools that cover all aspects of managing a process—plan, organize, monitor, control–as well as its actual execution. In other words, BPR should be seen as a subset of techniques that can be used in the context of BPM.

This discussion highlights that BPM encompasses the entire lifecycle of business processes. Accordingly, the next section provides an overview of the concepts, methods, techniques, and tools that compose the BPM discipline through the lens of the *BPM lifecycle*. This lens provides a structured view of how a given process can be managed.

1.4 The BPM Lifecycle

In general, the first question that a team embarking on a BPM initiative needs to clarify is "what business processes are we intending to improve"? Right at the outset and before the possibility of applying BPM is put on the table, there will probably already be an idea of what operational problems the team has to address and what business processes are posing those operational problems. In other words, the team will not start from scratch. For example, if the problem is that site engineers complain that their job is being hampered by difficulties in securing construction equipment when needed, and knowing that this equipment is to a large extent rented, it is clear that this problem should be addressed by looking at the equipment rental process. Still, one has to delimit this process. In particular, one has to answer questions such as: Does the process start right from the moment when rental suppliers are selected? Does it end when the rented equipment is delivered to the construction site or does it end when the equipment is returned back to the supplier, or does it continue until the fee for equipment rental has been paid to the supplier?

These questions might be easy or hard to answer depending on how much *process thinking* has taken place in the organization beforehand. If the organization has engaged in BPM initiatives before, it is likely that an inventory of business processes is available and that the scope of these processes has been defined, at least to some extent. In organizations that have not engaged in BPM before, the BPM team has to start by at least identifying the processes that are relevant to the problem on the table, delimiting the scope of these processes, and identifying relations between these processes, such as for example part-of relations (i.e. one process being part of another process). This initial phase of a BPM initiative is termed *process identification*. This phase leads to a so-called *process architecture*, which typically takes the form of a collection of processes and links between these processes representing different types of relation.

In general, the purpose of engaging in a BPM initiative is to ensure that the business processes covered by the BPM initiative lead to consistently positive outcomes and deliver maximum value to the organization in servicing its clients. Measuring the *value* delivered by a process is a crucial step in BPM. As renowned software engineer, Tom DeMarco, once famously put it: "You can't control what you can't measure". So before starting to analyze any process in detail, it is important to clearly define the *process performance measures* (also called *process performance metrics*) that will be used to determine whether a process is in "good shape" or in "bad shape".

Cost-related measures are a recurrent class of measures in the context of BPM. For example, coming back to the equipment rental process, a possible performance measure is the total cost of all equipment rented by BuildIT per time interval (e.g. per month). Another broad and recurrent class of measures are those related to time. An example is the average amount of time elapsed between the moment an equipment rental request is submitted by a site engineer and the delivery of the equipment to the construction site. This measure is generally called *cycle time*. Finally, a third class of recurrent measures are those related to quality, and specifically error rates.

Error rate is the percentage of times that an execution of the process ends up in a negative outcome. In the case of the equipment rental process, one such measure is the number of pieces of equipment returned because they are unsuitable, or due to defects in the delivered equipment. The identification of such performance measures (and associated performance objectives) is crucial in any BPM initiative. This identification is generally seen as part of the process identification phase, although in some cases it may be postponed until later phases.

Exercise 1.3 Consider the student admission process described in Exercise 1.1. Taking the perspective of the customer, identify at least two performance measures that can be attached to this process.

Once a BPM team has identified which processes they are dealing with and which performance measures should be used, the next phase for the team is to understand the business process in detail. We call this phase *process discovery*. Typically, one of the outcomes of this phase is one or several *as-is* process models. These as-is process models should reflect the understanding that people in the organization have about how work is done. Process models are meant to facilitate communication between stakeholders involved in a BPM initiative. Therefore, they have to be easy to understand. In principle, we could model a business process by means of textual descriptions, like the textual description in Example 1.1. However, such textual descriptions are cumbersome to read and easy to misinterpret because of the ambiguity inherent in free-form text. This is why it is common practice to use diagrams in order to model business processes. Diagrams allow us to more easily comprehend the process. Also, if the diagram is made using a notation that is understood by all stakeholders, there is less room for any misunderstanding. Note that these diagrams may still be complemented with textual descriptions in fact it is common to see analysts documenting a process using a combination of diagrams and text.

There are many languages for modeling business processes diagrammatically. Perhaps one of the oldest ones are *flowcharts*. In their most basic form, flowcharts consist of rectangles, representing activities, and diamonds, representing points in the process where a decision is made. More generally, we can say that regardless of the specific notation used, a diagrammatic process model typically consists of two types of node: activity nodes and control nodes. Activity nodes describe units of work that may be performed by humans or software applications, or a combination thereof. Control nodes capture the flow of execution between activities. Although not all process modeling languages support it, a third important type of element in process models are event nodes. An event node tells us that something may or must happen, within the process or in the environment of the process, that requires a reaction, like for example the arrival of a message from a customer asking to cancel their purchase order. Other types of node may appear in a process model, but we can say that activity nodes, event nodes and control nodes are the most basic ones.

Several extensions of flowcharts exist, like cross-organizational flowcharts, where the flowchart is divided into so-called *swimlanes* that denote different organizational units (e.g. different departments in a company). If you are familiar with the

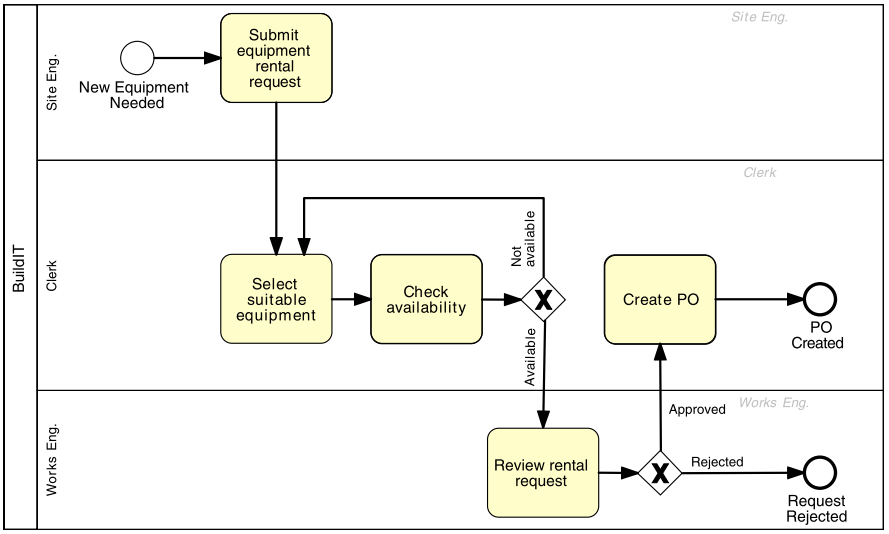

Fig. 1.6 Process model for an initial fragment of the equipment rental process

Unified Modeling Language (UML), you probably will have come across *UML Activity Diagrams*. At their core, UML Activity Diagrams are cross-organizational flowcharts. However, UML Activity Diagrams go beyond cross-organizational flowcharts by providing symbols to capture data objects, signals and parallelism among other aspects. Yet another language for process modeling are *Event-driven Process Chains* (*EPCs*). EPCs have some similarities with flowcharts but they differ from flowcharts in that they treat events as first-class citizens. Other languages used for process modeling include data-flow diagrams and *IDEF3*, just to name two.

It would be mind-boggling to try to learn all these languages at once. Fortunately, nowadays there is a widely used standard for process modeling, namely the Business Process Model and Notation (BPMN). The latest version of BPMN is BPMN 2.0. It was released as a standard by the Object Management Group (OMG) in 2011. In BPMN, activities are represented as rounded rectangles. Control nodes (called *gateways*) are represented using diamond shapes. Activities and control nodes are connected by means of arcs (called flows) that determine the order in which the process is executed. Figure 1.6 provides a model representing an initial fragment of the equipment rental process, up to the point where the works engineer accepts or rejects the equipment rental request. This process model shows two decision points. In the first one, the process takes one of two paths depending on whether the equipment is available or not. In the second, the equipment rental request is either approved or rejected. The model also shows the process participants involved in this fragment of the process, namely the site engineer, the clerk and the works engineer. Each of these participants is shown as a separate *lane* containing the activities performed by the participant in question.

The process model in Fig. 1.6 is captured at a high level of abstraction. At best, it can serve to give to an external person a summary of what happens in this process. In some cases, however, the model needs more details for it to be useful. Which additional details should be included in a process model depends on the purpose. Oftentimes, process models are intended to serve as documentation of the way an organization works. In this case, the key characteristics of process models are simplicity and understandability. Accordingly, additional text annotations might be added to the process model to clarify the meaning of certain activities or events, but beyond such annotations, not much additional detail would be added. In other cases, process models are intended to be analyzed in detail, for example in order to measure process performance. In this case, further details may be required such as how much time each task takes (on average). Finally, in a few cases, process models are intended to be deployed into a BPMS for the purpose of coordinating the execution of the process (cf. Sect. 1.3.3). In the latter case, the model needs to be extended with a significant amount of details regarding the inputs and outputs of the process and each its activities.

Having understood the as-is process in detail, the next step is to identify and analyze the issues in this process. One potential issue in BuildIT's equipment rental process is that the cycle time is too high. As a result, site engineers do not manage to get the required equipment on time. This may cause delays in various construction tasks, which may ripple down into delays in the construction projects. In order to analyze these issues, an analyst would need to collect information about the time spent in each task of the process, including both the amount of time that process participants spend actually doing work and the amount of idle time, meaning the amount of time when the equipment request is blocked, waiting for something to happen. This idle time is also called *waiting time*. Also, the analyst would need to gather information regarding the amount of rework that takes place in the process. Here, rework means that one or several tasks are repeated because something went wrong. For example, when the clerk identifies a suitable piece of equipment in a supplier's catalog, but later finds out that the piece of equipment is not available on the required dates, the clerk might need to search again for an alternative piece of equipment from another supplier. Valuable time is spent by the clerk going back and forth between consulting the catalogs and contacting the suppliers to check the availability of plants. In order to analyze this issue, the analyst would need to find out in what percentage of cases the availability check fails and thus how often the clerk needs to do some rework in order to identify alternative pieces of equipment and check for their availability. Given this information, a process analyst can employ various techniques to be discussed throughout this book, in order to trace down the cause(s) of long cycle times and to identify ways of changing the process in order to reduce the cycle time.

Another potential issue in BuildIT's equipment rental process is that sometimes the equipment delivered at the construction site is unsuitable, and the site engineer has to reject it. This is an example of a negative outcome. To analyze this issue, an analyst would need to find out how often such negative outcomes are occurring. Secondly, the analysts would need to obtain information that would allow them to understand why such negative outcomes are happening. In other words, where

did things go wrong in the first place? Sometimes, this negative outcome might stem from miscommunication, for example between the site engineer and the clerk. Otherwise it might come from inaccurate data (e.g. errors in the description of the equipment) or from an error on the supplier's side. Only by identifying, classifying and ultimately understanding the main causes of such negative outcomes can an analyst find out what would be the most suitable way of addressing this issue. The identification and assessment of issues and opportunities for process improvement is hereby called the *process analysis* phase.

We observe that the two issues discussed above are tightly related to performance measures. For example, the first issue above is tied to cycle time and waiting time, both of which are typical performance measures of a process. Similarly, the second issue is tied to the "percentage of equipment rejections", which is essentially an error rate—another typical performance measure. Thus, assessing the issues of a process often goes hand-in-hand with measuring the current state of the process with respect to certain performance measures.

Exercise 1.4 Consider again the student admission process described in Exercise 1.1. Taking the perspective of the customer, think of at least two issues that this process might have.

Once issues in a process have been analyzed and possibly quantified, the next phase is to identify and analyze potential remedies for these issues. At this point, the analyst will consider multiple possible options for addressing a problem. In doing so, the analyst needs to keep in mind that a change in a process to address one issue may potentially cause other issues down the road. For example, in order to speed-up the equipment rental process, one might think of removing the approval steps involving the works engineer. If pushed to the extreme, however, this change would mean that the rented equipment might sometimes not be optimal since the works engineer viewpoint is not taken into account. The works engineer has a global view on the construction projects and may be able to propose alternative ways of addressing the equipment needs of a construction project in a more effective manner.

Changing a process is not as easy as it sounds. People are used to work in a certain way and might resist changes. Furthermore, if the change implies modifying the information system(s) underpinning the process, the change may be costly or may require changes not only in the organization that coordinates the process, but also in other organizations. For example, one way to eliminate the rework that the clerk has to do when checking for availability of equipment, would be that the suppliers provide information regarding the availability of plants. This way, the clerk would use the same interface to search for suitable equipment and to check the availability of the equipment for the required period of time. However, this change in the process would require that the suppliers change their information system, so that their system exposes up-to-date equipment availability information to BuildIT. This change is at least partially outside the control of BuildIT. Assuming that suppliers would be able to make such changes, a more radical solution that could be considered would be to provide mobile devices and Internet connection to the site engineers, so

that they can consult the catalog of equipment (including availability information) anytime and anywhere. This way, the clerk would not need to be involved in the process during the equipment search phase, therefore avoiding miscommunications between the site engineer and the clerk. Whether or not this more radical change is viable would require an in-depth analysis of the cost of changing the process in this way versus the benefits that such change would provide.

Exercise 1.5 Given the issues in the admissions process identified in Exercise 1.4, what possible changes do you think could be made to this process in order to address these issues?

Equipped with an understanding of one or several issues in a process and a candidate set of potential remedies, analysts can propose a redesigned version of the process, in other words a *to-be* process which would address the issues identified in the as-is process. This to-be process is the main output of the *process redesign phase*. Here, it is important to keep in mind that analysis and redesign are intricately related. There may be multiple redesign options and each of these options needs to be analyzed, so that an informed choice can be made as to which option should be chosen.

Once redesigned, the necessary changes in the ways of working and the IT systems of the organization should be implemented so that the to-be process can eventually be put into execution. This phase is called *process implementation*. In the case of the equipment rental process, the process implementation phase would mean putting in place an information system to record and to track equipment rental requests, POs associated to approved requests and invoices associated to these POs. Deploying such an information system means not only developing the IT components of this system. It would also relate to training the process participants so that they perform their work in the spirit of the redesigned process and make the best use of the IT components of the system.

More generally, process implementation may involve two complementary facets: *organizational change management* and *process automation*. Organizational change management refers to the set of activities required to change the way of working of all participants involved in the process. These activities include:

- Explaining the changes to the process participants to the point that they understand both what changes are being introduced and why these changes are beneficial to the company.
- Putting in place a change management plan so that stakeholders know when will the changes be put into effect and what transitional arrangements will be employed to address problems during the transition to the to-be process.
- Training users to the new way of working and monitoring the changes in order to ensure a smooth transition to the to-be process.

On the other hand, process automation involves the configuration or implementation of an IT system (or the re-configuration of an existing IT system) to support the "to-be" process. This system should support process participants in the performance

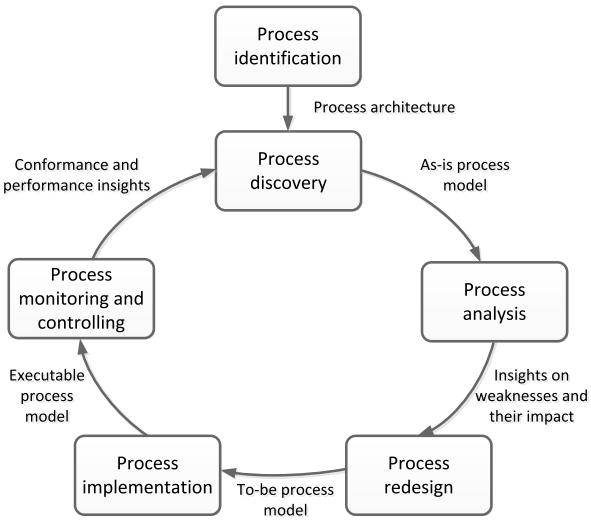

Fig. 1.7 BPM lifecycle

of the tasks of the process. This may include assigning tasks to process participants, helping process participants to prioritize their work, providing process participants with the information they need to perform a task, and performing automated cross-checks and other automated tasks where possible. There are several ways to implement such an IT system. This book focuses on one particular approach, which consists of extending the to-be process model obtained from the process redesign phase in order to make it executable by a BPMS (cf. Sect. 1.3.3).

Over time, some adjustments might be required because the implemented business process does not meet expectations. To this end, the process needs to be monitored and analysts ought to scrutinize the data collected by monitoring the process in order to identify needed adjustments to better control the execution of the process. These activities are encompassed by the *process monitoring and controlling* phase. This phase is important because addressing one or a handful of issues in a process is not the end of the story. Instead, managing a process requires a continuous effort. Lack of continuous monitoring and improvement of a process leads to degradation. As Michael Hammer once put it: "every good process eventually becomes a bad process", unless continuously adapted and improved to keep up with the ever-changing landscape of customer needs, technology and competition. This is why the phases in the BPM lifecycle should be seen as being circular: the output of monitoring and controlling feeds back into the discovery, analysis and redesign phases.

To sum up, we can view BPM as continuous cycle comprising the following phases (see Fig. 1.7):

- *Process identification.* In this phase, a business problem is posed, processes relevant to the problem being addressed are identified, delimited and related to each other. The outcome of process identification is a new or updated process architecture that provides an overall view of the processes in an organization and their relationships. In some cases, process identification is done in parallel with per-

formance measure identification. In this book, however, we will associate performance measure identification with the process analysis phase, given that performance measures are often used for process analysis.

- *Process discovery (also called as-is process modeling).* Here, the current state of each of the relevant processes is documented, typically in the form of one or several as-is process models.[2]
- *Process analysis.* In this phase, issues associated to the as-is process are identified, documented and whenever possible quantified using performance measures. The output of this phase is a structured collection of issues. These issues are typically prioritized in terms of their impact, and sometimes also in terms of the estimated effort required to resolve them.
- *Process redesign* (also called *process improvement*). The goal of this phase is to identify changes to the process that would help to address the issues identified in the previous phase and allow the organization to meet its performance objectives. To this end, multiple change options are analyzed and compared in terms of the chosen performance measures. This entails that process redesign and process analysis go hand-in-hand: As new change options are proposed, they are analyzed using process analysis techniques. Eventually, the most promising change options are combined, leading to a redesigned process. The output of this phase is typically a to-be process model, which serves as a basis for the next phase.
- *Process implementation.* In this phase, the changes required to move from the as-is process to the to-be process are prepared and performed. Process implementation covers two aspects: organizational change management and process automation. Organizational change management refers to the set of activities required to change the way of working of all participants involved in the process. Process automation on the other hand refers to the development and deployment of IT systems (or enhanced versions of existing IT systems) that support the to-be process. In this book, our focus with respect to process implementation is on process automation, as organizational change management is an altogether separate field. More specifically, the book presents one approach to process automation wherein an executable process model is derived from the to-be process model and this executable model is deployed in a BPMS.
- *Process monitoring and controlling.* Once the redesigned process is running, relevant data are collected and analyzed to determine how well is the process performing with respect to its performance measures and performance objectives. Bottlenecks, recurrent errors or deviations with respect to the intended behavior are identified and corrective actions are undertaken. New issues may then arise, in the same or in other processes, requiring the cycle to be repeated on a continuous basis.

[2]This phase is also called *process design* in the literature. However, process discovery is arguably a more appropriate term since the process already exists, at least implicitly in the heads of the actors who perform it. The goal of this phase is generally to discover the process rather than to design it. In rare cases (e.g. new companies) no process is yet in place so the discovery and analysis phases are not required and the process has to be designed for the first time rather than redesigned.

The BPM lifecycle helps to understand the role of technology in BPM. Technology in general, and especially Information Technology (IT), is a key instrument to improve business processes. Not surprisingly, IT specialists such as system engineers often play a significant role in BPM initiatives. However, to achieve maximum efficacy, system engineers need to be aware that technology is just one instrument for managing and executing processes. System engineers need to work together with process analysts in order to understand what the main issues affecting a given process, and how to best address these issues, be it by means of automation or by other means. As a renowned technology businessman, Bill Gates, once famously put it: "The first rule in any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency". This means that learning how to design and improve processes—and not only how to build an IT system to automate a narrow part of a business process—is a fundamental skill that should be in the hands of any IT graduate. Reciprocally, business graduates need to understand how technology, and particularly IT, can be used to optimize the execution of business processes. This book aims at bridging these two viewpoints by presenting an integrated viewpoint covering the whole BPM lifecycle.

A complementary viewpoint on the BPM lifecycle is given by the box "Stakeholders in the BPM lifecycle". This box summarizes the roles in a company that are directly or indirectly involved in BPM initiatives.[3] The list of roles described in the box highlights the fact that BPM is inter-disciplinary. A typical BPM initiative involves managers at different levels in the organization, administrative and field workers (called process participants in the box), business and system analysts and IT teams. Accordingly, the book aims at giving a balanced view of techniques both from management science and IT, as they pertain to BPM.

STAKEHOLDERS IN THE BPM LIFECYCLE

There are different stakeholders involved with a business process throughout its lifecycle. Among them we can distinguish the following individuals and groups.

- *Management Team*. Depending on how the management of a company is organized, one might find the following positions. The *Chief Executive Officer* (*CEO*) is responsible for the overall business success of the company. The *Chief Operations Officer* (*COO*) is responsible for defining the way operations are set-up. In some companies, the COO is also responsible for process performance, while in other companies, there is a dedicated posi-

[3]The role of the customer is not listed in the box as this role is already discussed in previous sections.

tion of *Chief Process Officer* (*CPO*) for this purpose. The *Chief Information Officer* (*CIO*) is responsible for the efficient and effective operation of the information system infrastructure. In some organizations, process redesign projects are driven by the CIO. The *Chief Financial Officer* (*CFO*) is responsible for the overall financial performance of the company. The CFO may also be responsible for certain business processes, particularly those that have a direct impact on financial performance. Other management positions that have a stake in the lifecycle of processes include the *Human Resources* (*HR*) *director*. The HR director and their team play a key role in processes that involve significant numbers of process participants. In any case, the management team is responsible for overseeing all processes, initiating process redesign initiatives, and providing resources and strategic guidance to stakeholders involved in all phases of the business process lifecycle.

- *Process Owners*. A process owner is responsible for the efficient and effective operation of a given process. As discussed in the context of Fig. 1.5, a process owner is responsible on the one hand for planning and organizing, and on the other hand for monitoring and controlling the process. In their planning and organizing role, the process owner is responsible for defining performance measures and objectives as well as initiating and leading improvement projects related to their process. They are also responsible for securing resources so that the process runs smoothly on a daily basis. In their monitoring and controlling role, process owners are responsible for ensuring that the performance objectives of the process are met and taking corrective actions in case they are not met. Process owners also provide guidance to process participants on how to resolve exceptions and errors that occur during the execution of the process. Thus, the process owner is involved in process modeling, analysis, redesign, implementation and monitoring. Note that the same individual could well be responsible for multiple processes. For example, in a small company, a single manager might be responsible both for the company's order-to-cash process and for the after-sales customer service process.
- *Process Participants*. Process participants are human actors who perform the activities of a business process on a day-to-day basis. They conduct routine work according to the standards and guidelines of the company. Process participants are coordinated by the process owner, who is responsible to deal with non-routine aspects of the process. Process participants are also involved as domain experts during process discovery and process analysis. They support redesign activities and implementation efforts.
- *Process Analysts*. Process analysts conduct process identification, discovery (in particular modeling), analysis and redesign activities. They coordinate process implementation as well as process monitoring and controlling. They report to management and process owners and closely interact

with process participants. Process analyst typically have one of two backgrounds. Process analysts concerned with organizational requirements, performance, and change management have a business background. Meanwhile, process analysts concerned with process automation have an IT background.

- *System Engineers*. System engineers are involved in process redesign and implementation. They interact with process analysts to capture system requirements. They translate requirements into a system design and they are responsible for the implementation, testing and deployment of this system. System engineers also liaise with the process owner and process participants to ensure that the developed system supports their work in an effective manner. Oftentimes, system implementation, testing and deployment are outsourced to external providers, in which case the system engineering team will at least partially consist of contractors.
- The *BPM Group* (also called *BPM Centre of Excellence*). Large organizations that have been engaged in BPM for several years would normally have accumulated valuable knowledge on how to plan and execute BPM projects as well as substantial amounts of process documentation. The BPM Group is responsible for preserving this knowledge and documentation and ensuring that they are used to meet the organization's strategic goals. Specifically, the BPM group is responsible for maintaining the process architecture, prioritizing process redesign projects, giving support to the process owners and process analysts, and ensuring that the process documentation is maintained in a consistent manner and that the process monitoring systems are working effectively. In other words, the BPM group is responsible for maintaining a BPM culture and ensuring that this BPM culture is supporting the strategic goals of the organization. Not all organizations have a dedicated BPM Group. BPM Groups are most common in large organizations with years of BPM experience.

In the rest of the book, we will dive consecutively into each of the phases of the BPM lifecycle. Chapter 2 deals with the process identification phase. Chapters 3–4 provide an introduction to process modeling, which serves as background for subsequent phases in the BPM lifecycle. Chapter 5 deals with the process discovery phase. Chapters 6–7 present a number of process analysis techniques. We classify these techniques into qualitative (Chap. 6) and quantitative (Chap. 7) ones. A quantitative technique is one that takes raw data or measurements as input (e.g. performance measures at the level of tasks) and produces aggregated measurements and quantitative summaries as output. On the other hand, a qualitative technique involves human judgment, for example in order to classify tasks or issues according to subjective criteria. Note that qualitative techniques may involve quantitative assessment in addition to human judgment, as these two sources of insights often serve complementary purposes. Next, Chap. 8 gives an overview of process redesign techniques,

while Chap. 9 discusses process implementation with a focus on automation aspects. Finally, Chap. 10 introduces process intelligence tools and techniques, which form the backbone of modern process monitoring practices.

1.5 Recap

We should retain from this chapter that a process is a collection of events, activities and decisions that collectively lead to an outcome that brings value to an organization's customers. Every organization has processes. Understanding and managing these processes in order to ensure that they consistently produce value is a key ingredient for the effectiveness and competitiveness of organizations. Through its focus on processes, organizations are managing those assets that are most important to serve their customers well.

If we wanted to capture BPM in a nutshell, we could say that BPM is a body of principles, methods and tools to design, analyze, execute and monitor business processes. We have also seen that process models and performance measures can be seen as foundational pillars for managing processes. It is on top of them that much of the art and science of BPM builds upon. The provided definition encompasses the main phases of the BPM lifecycle and the various related disciplines that complement BPM, such as Lean, Six Sigma and Total Quality Management. The aim of this chapter was to give a "sneak peek" of the activities and stakeholders involved in each of these phases. The rest of the book aims to shed light onto many of the principles and methods that are used in each of these phases.

1.6 Solutions to Exercises

Solution 1.1

1. Admissions officer, applicant, academic recognition agency and academic committee. The admissions office as an organizational unit can also be recognized as a separate actor.
2. The applicant.
3. One can argue that the *value* that the process provides to the applicant is the assessment of the application and the subsequent decision to accept or reject. In this case, the process delivers value both if the applicant is accepted or rejected, provided that the application is processed in due order. Another viewpoint would be to say that the process only gives value to the applicant only if the applicant is accepted, and not if the applicant is rejected. Arguments can be put forward in favor of either of these two viewpoints.
4. Applicant rejected due to incomplete documents; Applicant rejected due to English language test results; Applicant rejected due to assessment of academic recognition agency; Applicant rejected due to academic committee decision;

Applicant accepted. A more in-depth analysis could reveal other possible outcomes such as "Application withdrawn by applicant" or "Applicant conditionally accepted subject to providing additional documents". However, there are not enough elements in the description of the process to determine if these latter outcomes are possible.

Solution 1.2

1. The unit with a purchasing need, purchasing department, the vendor, the warehouse, and the accounts payable department.
2. The unit with a purchasing need.
3. The *value* that the process provides to the unit with a purchasing need is the timely, accurate, and cost-efficient provision of a particular purchasing item. In this case, the process delivers value both if the need for purchasing item is satisfied by an timely, accurate, and cost-efficient shipment of a vendor, accompanied with an accurate payment procedure.
4. The shipment of goods can be accepted if accurate, leading to a corresponding payment, or they can be rejected if the amount or type of shipment is not correct.

Solution 1.3 Possible measures include:

1. Average time between the moment an application is received and the moment it is accepted or rejected (cycle time). Note that if the University advertises a predefined deadline for notifying acceptance/rejection, an alternative performance measure would be the percentage of times that this deadline is met.
2. Percentage of applications rejected due to incomplete documents. Here we could distinguish between two variants of this measure: one that counts all cases where applications are initially rejected due to incomplete documents, and another one that counts the number of cases where applications are rejected due to incomplete documents and where the applicant does not re-submit the completed application, for example because the deadline for applications has expired before the applicant gathers the required documents.
3. Percentage of applications rejected due to expired, invalid or low English language test results.
4. Percentage of applications rejected due to advice from academic recognition.
5. Percentage of accepted applications.

Note that the cost incurred by the University per application is not a measure that is relevant from the perspective of the applicant, but it may be relevant from the perspective of the University.

Solution 1.4 Possible issues include:

1. Long execution times
2. Inconvenience of gathering and submitting all required documents.
3. Potentially: mishandled applications due to handovers of paper documents between process participants.

Solution 1.5

To reduce cycle time as well as mishandled applications, applications could be shared in electronic format between admissions office and academic committee. To reduce inconvenience of submission, applications could be evaluated in two stages. The first stage would involve purely electronically submitted documents (e.g. scanned copies instead of physical copies). Only applicants accepted by the academic committee would then need to go through the process of submitting certified copies of degrees by post for verification by the academic recognition agency.

1.7 Further Exercises

Exercise 1.6 Consider the following process at a pharmacy.

Customers drop off their prescriptions either in the drive-through counter or in the front counter of the pharmacy. Customers can request that their prescription be filled immediately. In this case, they have to wait between 15 minutes and one hour depending on the current workload. Most customers are not willing to wait that long, so they opt to nominate a pick-up time at a later point during the day. Generally, customers drop their prescriptions in the morning before going to work (or at lunchtime) and they come back to pick up the drugs after work, typically between 5pm and 6pm. When dropping their prescription, a technician asks the customer for the pick-up time and puts the prescription in a box labeled with the hour preceding the pick-up time. For example, if the customer asks to have the prescription be ready at 5pm, the technician will drop it in the box with the label 4pm (there is one box for each hour of the day).

Every hour, one of the pharmacy technicians picks up the prescriptions due to be filled in the current hour. The technician then enters the details of each prescription (e.g. doctor details, patient details and medication details) into the pharmacy system. As soon as the details of a prescription are entered, the pharmacy system performs an automated check called *Drug Utilization Review* (DUR). This check is meant to determine if the prescription contains any drugs that may be incompatible with other drugs that had been dispensed to the same customer in the past, or drugs that may be inappropriate for the customer taking into account the customer data maintained in the system (e.g. age).

Any alarms raised during the automated DUR are reviewed by a pharmacist who performs a more thorough check. In some cases, the pharmacist even has to call the doctor who issued the prescription in order to confirm it.

After the DUR, the system performs an insurance check in order to determine whether the customer's insurance policy will pay for part or for the whole cost of the drugs. In most cases, the output of this check is that the insurance company would pay for a certain percentage of the costs, while the customer has to pay for the remaining part (also called the *co-payment*). The rules for determining how much the insurance company will pay and how much the customer has to pay are very complicated. Every insurance company has different rules. In some cases, the insurance policy does not cover one or several drugs in a prescription, but the drug in question can be replaced by another drug that is covered by the insurance policy. When such cases are detected, the pharmacist generally calls the doctor and/or the patient to determine if it is possible to perform the drug replacement.

Once the prescription passes the insurance check, it is assigned to a technician who collects the drugs from the shelves and puts them in a bag with the prescription stapled to it. After the technician has filled a given prescription, the bag is passed to the pharmacist who

double-checks that the prescription has been filled correctly. After this quality check, the pharmacist seals the bag and puts it in the pick-up area. When a customer arrives to pick up a prescription, a technician retrieves the prescription and asks the customer for payment in case the drugs in the prescription are not (fully) covered by the customer's insurance.

With respect to the above process, consider the following questions:

1. What type of process is the above one: order-to-cash, procure-to-pay or issue-to-resolution?
2. Who are the actors in this process?
3. What value does the process deliver to its customer(s)?
4. What are the possible outcomes of this process?
5. Taking the perspective of the customer, what performance measures can be attached to this process?
6. What potential issues do you foresee this process might have? What information would you need to collect in order to analyze these issues?
7. What possible changes do you think could be made to this process in order to address the above issues?

Acknowledgement This exercise is partly inspired by *Andrew McAfee: "Pharmacy Service Improvement at CVS (A)". Harvard Business Publishing, 2005*.

Exercise 1.7 Consider the following process at a company of around 800 employees.

A purchase request is initiated when an employee at the company fills in and signs a form on paper. The purchase request includes information about the good to be purchased, the quantity, the desired delivery date, the approximate cost. The employee can also nominate a specific vendor. Employees often request quotes from vendors in order to get the required information. Completing the entire form can take a few days as the requestor often does not have the required data. The quote is attached to the purchase request. This completed request is signed by two supervisors. One supervisor has to provide a *financial approval*, while the other supervisor has to approve the necessity of the purchase and its conformance with company's policy (e.g. does a requested software form part of the standard operating environment?). Collecting the signatures from the two supervisors takes on average five days. If it is urgent, the employee can hand-deliver the form, otherwise it is circulated via internal mail. A rejected purchase request is returned to the employee. Some employees make some minor modifications and try in a second attempt other supervisors in order to get approval.

Once a purchase request is approved, it is returned to the employee who initiated the purchase requisition. The employee then forwards the form to the Purchasing Department. Many employees make a copy of the form for their own record, in case the form gets lost. The central purchasing Department checks the completeness of the purchase request and returns it to the employee if it is incomplete.

Based on attached quotes and other information, the purchasing Department enters the approved purchase request into the company's Enterprise System. If the employee has not nominated any vendors, a clerk at the purchasing Department will select one based either on the quotes attached to the purchase requisition, or based on the list of vendors (also called *Master Vendor List*) available in the company's Enterprise System.

Sometimes the initial quote attached to the request has expired in the meantime. In this case, updated quote is requested from the corresponding vendor. In other cases, the vendor

who submitted the quote is not recorded in the company's Enterprise System. In this case, the purchasing Department should give preference to other vendors who are registered in the Enterprise System. If no such vendors are available or if the registered vendors offer higher prices than the one in the submitted quote, the purchasing Department can add the new vendor into the Enterprise System.

When a vendor is selected, a purchase order is automatically generated by the Enterprise System. Then, a fax is generated and sent to the vendor. A copy of the purchase order is sent to Accounts Payable Office, which is part of the Financial Department, which uses an accounting system that is not integrated with the Enterprise System.

The goods are always delivered to the Goods Receipt Department. When a good is received, a clerk at this Department selects the corresponding purchase order in the Enterprise System. The clerk checks the quantity and quality and (in the positive case) generates a document called *goods receipt form* from the purchase order stored in the Enterprise System. The goods are then forwarded to the employee who initiated the purchase requisition. A printout of the goods receipt form is sent to the Accounts Payable Office. If there are any issues with the good, it is returned to the vendor and a paper-based note is sent to the Purchasing Department and to the Accounts Payable Office.

The vendor eventually sends the invoice directly to the Accounts Payable Office. A clerk at this office compares the purchase order, the goods receipt and the invoice—a task that is usually called "three-way matching". Three-way matching can be quite time-consuming. If there are any discrepancies as it has to be investigated, if it was an error of the vendor or a data entry error. The duration of the payment process unfortunately takes sometimes so long that the discount for paying in a certain period expires.

A bank transfer is finally triggered and a payment notice is sent to the vendor. Some vendors explicitly indicate in their invoice the bank account number where they want the transfer to occur. It may happen that the bank account number and name indicated in the invoice differs from the one recorded in the vendor database. Sometimes payments bounce back, in which case the vendor is contacted by phone, e-mail or postal mail. If new bank details are given, the transfer is attempted again. If the issue is still not resolved, the Accounts Payable Office has to contact again the vendor in order to trace the cause of the bounced payment.

1. What type of process is the above one: order-to-cash, procure-to-pay or issue-to-resolution?
2. Who are the actors in this process? Who is/are the customer(s)?
3. What value does the process deliver to its customer(s)?
4. What are the possible outcomes of this process?
5. Taking the perspective of the customer, what performance measures can be attached to this process?
6. What potential issues do you foresee this process might have? What information would you need to collect in order to analyze these issues?
7. What possible changes do you think could be made to this process in order to address the above issues?

Acknowledgement This exercise is adapted from a similar exercise developed by Michael Rosemann, Queensland University of Technology.

Exercise 1.8 Consider the phases of the BPM lifecycle. Which of these phases are no included in a business process re-engineering project?

1.8 Further Reading

Geary Rummler is considered one of the earliest advocates of process thinking as an approach to address the shortcomings of purely functional organizations. His work on process thinking, developed during the 1970s and 1980s, was popularized by a book co-authored with Alan Brache: "Improving Performance: How to Manage the White Space on the Organizational Chart" [80]. A paper published two decades later by Rummler and Ramias [81] gives a condensed summary of Rummler's methodology for structuring organizations around processes.

Two key articles that popularized process thinking as a management concept are those of Hammer [26] and Davenport and Short [11] as discussed in this chapter. While Rummler's work deals more broadly with structuring organizations based on processes, Hammer, Davenport and Short focus on how to redesign individual business processes to increase their performance.

A comprehensive and consolidated treatment of BPM from a business management perspective is provided by Paul Harmon in his book Business Process Change [31]. Harmon's book presents the so-called BPTrends methodology for BPM. Harmon is also editor of the BPTrends newsletter and portal (http://www.bptrends.com) which features numerous articles and resources related to BPM. A good overview of the field is also provided in books by Becker et al. [6] and by Rosemann and vom Brocke [102, 103].

As mentioned in this chapter, BPM is related to several other fields, including TQM and Six Sigma. In this respect, Elzinga et al. [15] discuss the relation between BPM and TQM, while the application of Six Sigma techniques in the context of BPM is discussed by Harmon [31, Chap. 12], Laguna and Marklund [43, Chap. 2] and Conger [8].

Chapter 2
Process Identification

Things which matter most must never be at the mercy of things which matter least.
Johann Wolfgang von Goethe (1749–1832)

Process identification is a set of activities aiming to systematically define the set of business processes of a company and establish clear criteria for prioritizing them. The output of process identification is a *process architecture*, which represents the business processes and their interrelations. A process architecture serves as a framework for defining the priorities and the scope of process modeling and redesign projects.

In this chapter, we present a method for process identification that is based on two phases: designation and evaluation. The designation phase is concerned with the definition of an initial list of processes. The evaluation phase considers suitable criteria for defining priorities of these processes. After that, we discuss and illustrate a method for turning the output of this method into a process architecture.

2.1 Focusing on Key Processes

Few organizations have the resources required to model all their processes in detail, to rigorously analyze and redesign each of them, to deploy automation technology in order to support each of these processes, and finally to continuously monitor the performance of all processes in detail. Even if such resources were available, it would not be cost-effective to spend them in this way. BPM is not free. Like any other investment, investments in BPM have to pay off. Thus, it is imperative in every organization engaged in BPM to focus the attention on a subset of processes.

Some processes need to receive priority because they are of strategic importance to an organization's survival. Other processes might show striking problems, which should be resolved for the sake of all involved stakeholders. In other words, the processes that an organization should focus on are found in areas where there is either great value created or significant trouble present (or both). To make things more complex, the subset of high-priority processes in an organization is subject to the dynamics of time. Some processes may be problematic at one point, but once

M. Dumas et al., *Fundamentals of Business Process Management*,
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the issues have been identified and resolved by a process improvement program, an organization can do with only periodic inspections for some time. For example, an insurance company suffering from high levels of customer dissatisfaction will naturally tend to focus on its customer-oriented processes, say its claims handling process. Once this process has improved and customer satisfaction is again within the desired range, the emphasis might move to its risk assessment processes, which are important for the long-term viability and competitiveness of the company.

Beyond the dynamics of time, what may be processes that are of strategic importance to an organization at some point may grow less important as time elapses. Market demands may change and new regulations or the introduction of new products may limit what was once a profitable business activity. For example, the arrival of new competitors offering discount insurance policies through Web-based channels may push an established company to redesign its insurance sales processes to make them leaner, faster, and accessible from the Web.

To address the imperative of focusing on a subset of key processes, the management team, process analysts and process owners need to have answers to the following two questions: (i) what processes are executed in the organization? and (ii) which ones should the organization focus on? In other words, an organization engaged in BPM initiatives needs to keep a map of its processes as well as clear criteria for determining which processes have higher priority. We have seen in Chap. 1 that there is a range of stakeholders involved in the management and execution of a business process. Generally, only a handful of such stakeholders have a full overview of all the business processes in an organization. Yet, it is precisely this insight that is required in order to identify the subset of processes that need to be closely managed or improved. Capturing this knowledge and keeping it up-to-date is precisely the aim of process identification.

More specifically, process identification is concerned with two successive phases: designation and evaluation. The objective of the *designation phase* is to gain an understanding of the processes an organization is involved in as well as their interrelationships. The *evaluation phase*, based on the understanding that is established in the previous phase, intends to develop a prioritization among these for process management activities (modeling, redesign, automation, monitoring, etc.). Note that *neither* of these phases is concerned with the development of detailed process models. The key activities that are involved with process identification which we will describe closely follow those as identified by Davenport in [10].

2.1.1 The Designation Phase

If an organization is at the very start of turning into a process-centered organization, the first difficult task it faces is to come up with a meaningful enumeration of its existing processes. One difficulty here arises from the hierarchical nature of business processes: different criteria can be considered for determining which chains of operations can be seen as forming an independent business process and which ones

are seen as being part of another process. There are various views on how to categorize business processes (see the box "Categories of Processes according to Porter"). Some of these support the idea that there are actually *very few* processes within any organization. For example, some researchers have argued for the existence of only two processes: (1) managing the product line, and (2) managing the order cycle. Others identify three major processes: developing new products, delivering products to customers, and managing customer relationships.

CATEGORIES OF PROCESSES ACCORDING TO PORTER

Different categorizations for business processes have been proposed. One of the most influential is Michael Porter's Value Chain model. It distinguishes two categories of processes: core processes (called primary activities) and support processes (support activities). Core processes cover the essential value creation of a company, that is, the production of goods and services for which customers pay. Porter mentions inbound logistics, operations, outbound logistics, marketing and sales, and services. Support processes enable the execution of these core processes. Porter lists infrastructure, human resources, technology development, and procurement as such support processes. As a third category, other authors extend this set of two categories with management processes. For example, the periodic process to assess the strength of competitors is such a management process. The distinction of core, support, and management processes is of strategic importance to a company. Therefore, if such a distinction is made explicit, e.g. at the stage of process identification or while creating a process architecture, it is likely to be a heavily disputed topic.

The question is whether an overly coarse-grained view on processes, without *any further subdivision*, is useful for an organization that strives to become process-centered. Remember that the idea of process management is to actively manage business processes in the pursuit of satisfying its specific customers. If one selects business processes to be such large entities, then the result may be that these cannot be easily managed separately, both in terms of scope and speed of action. Consider, for example, how difficult it would be to model or redesign a process when it covers half of all the operations within an organization. A realistic model of such a business process would take a very long time to develop and could become extremely complex. Also, redesigning such a large process would be a time-consuming affair, let alone the implementation of such a redesign. Depending on the situation, an organization may not have that time.

The main conclusion from this is that the number of processes that are identified in the designation phase must represent a trade-off between *impact* and *manageability*. The smaller the number of the processes one wishes to identify, the bigger their individual scope is. In other words, if only a small number of processes is identified then each of these will cover numerous operations. The main advantage

of a large process scope is that it potentially increases the *impact* one can have with actively managing such a process. The more operations are considered to be part of a process, the easier it will become, for example, to spot opportunities for efficiency gains by rooting out redundant work.

On the other hand, a large scope of a business process brings along a range of issues that make it more difficult to *manage* it as a process:

- the involvement of a large number of staff will make effective communication among them problematic
- it will become more difficult to keep models of a large process up-to-date, and
- improvement projects that are related to a large process are more complex

To balance the advantages and disadvantages of a large process scope, Davenport has suggested that it may be useful to identify both *broad* and *narrow* processes. Broad processes are identified in those areas where an organization feels it is important to completely overhaul the existing operations at some point, for example because of fierce competitive forces. Imagine that an organization may have found that its procurement costs are overly high compared to its competitors. They select procurement as a broad process, which covers all of the services and products the company acquires from other parties. By contrast, narrow processes are not targeted for major overhauls; they do need to be actively monitored and are subjected to continuous fine-tuning and updating. A narrow process may be, for example, how the same company deals with improvement suggestions of its own employees.

Exercise 2.1 Explain how the trade-off between impact and manageability works out for broad and narrow processes, respectively.

Any enumeration of business processes should strive for a reasonably detailed outcome, which needs to be aligned with the organization's specific goals of process management. For most organizations, as a rule of thumb, this will boil down to a dozen to a couple of dozens of business processes. Very large and diversified organizations might be better off with identifying a couple of hundred processes. To illustrate this: Within a multi-national investment firm, which employs close to 3,000 staff and holds assets in the range of € 300 billion, 120 different business processes have been identified. To each of these business processes a process owner is assigned, who oversees the performance of the process and monitors the achievement of its objectives in terms of customer satisfaction, profitability, and accountability. Detailed process models are kept up-to-date, both as a means for documenting planned changes to any process and for satisfying the requirements of financial authorities. By contrast, for a small medical clinic in the Netherlands, which employs medical specialists, nurses, and administrative staff, 10 different treatment processes have been identified. A few of these have been mapped in the form of process models and are now in the process of being automated with a business process management system. For all other processes, it is sufficient to be aware of the distinctive treatment options they can provide to different patient categories.

Exercise 2.2 What are the potential drivers for the described investment firm to identify a large number of processes?

In addition to a rather detailed view on what business processes exist, an understanding must be developed about the *relations* between the various processes. In a situation where organizations define both narrow and broad processes, to avoid confusion, it is important to map how narrow processes relate to broader processes. A broad process like order management, for example, can be related to the more narrowly defined processes of order booking, billing, shipment, and delivery. All of these can be considered sub-processes of order management. We can call this an example of *hierarchical* relations between processes. Processes may also be related to one another differently. Billing, in the example we just used, is an *upstream* process compared to shipment: for the same order the bill is sent out usually *before* the ordered goods are shipped. Another way of expressing this relation is, of course, that shipment can be considered a *downstream* process in comparison to billing. This illustrates how processes can be *sequentially* related.

Exercise 2.3 Discuss in how far order management might be sequentially related to booking, billing, shipment, and delivery.

Most of the time, the insight into the relations between processes may be less than strictly exact. The most important goal of capturing dependent relations is to gain an understanding of how the performance of a process is related to that of another. If one would, for example, redesign an existing process it is useful to understand which processes depend on the outcomes of such a process. Such downstream processes may need to be prepared for receiving information or goods in another frequency or form than before and measures should be taken to prevent any disruptions.

Exercise 2.4 At this point, we discussed hierarchical and sequential relations between business processes. Can you think of other types of relation that are useful to distinguish between processes? As a hint, you might want to think about the purpose of identifying the relations between business processes.

While the designation of business processes and their inter-relationships is subject to different design choices and preferences, some general guidance is available. First of all, several so-called reference models for business process identification exist. These are developed by a range of industry consortia, non-profit associations, government research programs and academia. The best-known examples are the Information Technology Infrastructure Library (ITIL), the Supply Chain Operations Reference Model (SCOR) by the Supply Chain Council, the Process Classification Framework (PCF) by the American Productivity and Quality Center (APQC), the Value Reference Model (VRM) by the Value Chain Group, and the Performance Framework of Rummler–Brache. Reference models standardize what can be seen as different processes, with unique characteristics and delivering distinguishable products, and how their performance can be measured. Their largest value is in the identification of regulatory or highly industry-specific processes, or when performance

benchmarking against peers and competitors is the issue that a process-centered organization is after. In other cases, these reference models may still be useful in identification exercises in the form of a checklist. For example, an organization can use the APQC's PCF to inventory the processes in the framework they use, flag those they do not use, and add its own unique processes. We will take a closer look at the PCF in Sect. 2.2.

A second stream of support is available in the form of specific design approaches to develop a so-called *process architecture*. A process architecture is an organized overview of the processes that exist within an organizational context, which is often accompanied with guidelines on how they should be organized. Design approaches for business process architectures use a certain logic to arrive at an identification of business processes. In Sect. 2.2, we will go into more detail with respect to a specific design approach.

Finally, what is worth noting with respect to the designation phase is that processes change over time, deliberately or not. This naturally implies that process identification is of a continuous nature. To avoid the situation that one becomes bogged down in the stage of process identification, the activity should be considered as an exploratory and iterative endeavor. When a certain stable overview is created it may very well be usable for a period of two to three years.

2.1.2 The Evaluation Phase

As stated before, not all processes are equally important and not all processes can receive the same amount of attention. Process management involves commitment, ownership, investment in performance enhancement, and optimization. Therefore, processes that create loss or risk demand for consolidation, decommissioning, or outright elimination. Various criteria have been proposed to steer this evaluation. The most commonly used ones are the following.

Importance This criterion is concerned with assessing the strategic relevance of each process. The goal is to find out which processes have the greatest impact on the company's strategic goals, for example considering profitability, continuity, or contribution to a public cause. It makes sense to select those processes for active process management that most directly relate to the strategic goals of an organization.

Dysfunction This criterion aims to render a high-level judgment of the "health" of each process. The question here is to determine which processes are in the deepest trouble. These processes are the ones that may profit most from process-centered initiatives.

Feasibility For each process, it should be determined how susceptible they are to process management initiatives, either incidental or on a continuous basis. Most notably, culture and politics involved in a particular process may be obstacles to achieve results from such initiatives. In general, process management should focus on those processes where it is reasonable to expect benefits.

Note that all of these criteria assume that there is certain information available. For example, to assess the strategic *importance* of a process it is of the utmost importance that an organization has an idea of its strategic course. It is sufficient if such strategic considerations are defined at a very abstract level. At this point, for example, many organizations see the strategic benefit of being able to change the kind of products it provides to the demands of customers. Zara, the Spanish clothing retailer, is a prime example of an organization that follows a measure-and-react strategy. It sends out agents to shopping malls to see what people already wear for determining the styles, fabrics, and colors of the products it wants to deliver. Such an organization may look with specific interest at the production and logistic business processes that are best able to support this strategy.

Similarly, to determine the *potential dysfunction* of a business process an organization needs information. Here, we do encounter a "chicken and egg" problem. Many organizations that are not working in a process-centered way do not have a good, quantitative insight into the performance of their individual processes. One of the process-centered initiatives that such an organization may be after would exactly be to put the systems and procedures in place to collect the data that are needed for a performance assessment. In such cases, an organization will need to use more qualitative approaches to determine which of their processes do not perform well, for example depending on the impressions that management or process participants have about the efficiency or effectiveness of the various processes. Another approach would be to rely on customer evaluations, either gathered by surveys or spontaneously delivered in the form of complaints.

The criterion of *feasibility* needs some attention too. It has become common practice for organizations to undergo a continuous stream of programs to improve their performance in one dimension or the other. Consider Philips, the multinational electronics company. It has gone through an intermittent range of improvement programs since the 1980s to boost its performance. The same phenomenon can now be observed within many telecommunications and utility organizations. Since the profitability of products sharply changes from one year over the other, this requires continuous changes to product portfolios and market priorities. In these kinds of volatile context, it may happen that managers and process participants become tired of or outright hostile towards new initiatives. This kind of situation is not a good starting point for process management initiatives. After all, like other organizational measures, such initiatives also depend on the cooperation and good intentions of those directly involved. While we will not deal with the subject of change management in much detail in this textbook, it is important to realize that political sensitivities within an organization may have an effect on the success rate of process management efforts too.

BPM MATURITY ASSESSMENT

A more detailed approach to look at the evaluation phase is based on maturity. BPM maturity assessment is a body of techniques to determine the level

of systematic process thinking in an organization. A BPM maturity assessment essentially involves two aspects. The first aspect is to assess to what extent a given organization covers the range of processes that are ideally expected from it. The second aspect is to assess to what degree these processes are documented and supported. Therefore, a maturity assessment is aimed at establishing a baseline for discussing the completeness and the quality of the set of processes executed in an organization.

One of the most widely used frameworks for maturity assessment is the Capability Maturity Model Integrated (CMMI) framework. This framework distinguishes a number of so-called process areas. Several of these areas are specific to a particular domain in the various CMMI specifications. The domain-independent areas include: process management, project management, and support.

The coverage of process areas and the degree of their support provide the basis for a maturity assessment in terms of the five CMMI maturity levels:

Level 1 (Initial): At this initial stage, the organization runs its processes in an ad-hoc fashion, without any clear definition of these processes. Control is missing.

Level 2 (Managed): At this stage, project planning along with project monitoring and control have been put into practice. Measurement and analysis is established as well as process and product quality assurance.

Level 3 (Defined): Organizations at this stage have adopted a focus on processes. Process definitions are available and organizational training is provided to enable stakeholders across the organization to be engaged in process documentation and analysis. Integrated project and risk management are in place. Decision analysis and resolution are also in place.

Level 4 (Quantitatively Managed): At this stage, organizational process performance is tracked. Project management is performed using quantitative techniques.

Level 5 (Optimizing): At this stage of maturity, the organization has established organizational performance management accompanied with causal analysis and resolution.

The assessment of an organization in terms of these levels leads to a so-called *appraisal*. Appraisals can be conducted internally within an organization (also called self-appraisals) or by an external organization with expertise in maturity assessment. Different types of appraisal are distinguished and defined in the Standard CMMI Appraisal Method for Process Improvement (SCAMPI).

Question Given all the discussed criteria, does an assessment of the importance, dysfunctioning, and feasibility always point me to the same processes to actively manage?

No, there is no guarantee for that. It may very well be that a strategically important process is also the process that can be expected to be the most difficult one to manage, simply because so many earlier improvement efforts have already failed. An organization may not have a choice in such a situation. If a strategic process cannot be improved, this may turn out to be fatal for an organization as a whole. Think of a situation where the process to come up with new products creates much turmoil and conflicts within an organization: If the issues cannot be sorted out, the company may stop functioning quickly. In other settings, it may be more important to gain credibility with process management activities first. This can be accomplished by focusing on problematic processes of milder strategic importance but where there is a great desire to change. If successful, an improvement project at such a place may give credibility to the process management approach. These are not choices that can be easily prescribed without taking the specific context into situation. The various evaluation outcomes should be balanced to reach a list of those processes that should receive priority over others.

Question Should all processes that are dysfunctional, of strategic importance, and feasible to manage be subjected to process management initiatives?

The general answer to this question is that for most organizations this is not feasible. Recall again that process management consumes resources. Even when there is a clear incentive to, for example, redesign various existing business processes, most organizations lack sufficient resources—people, funds, and time—to do so. Only the largest organizations are able to support more than a handful of process improvement projects at the same time. A good case in point is IBM, an organization known to have process improvement projects going on within all its existing business processes on a continuous basis. Another caveat of carrying out many simultaneous process management efforts is that these will create coordination complexity. Remember that processes may be linked to each other in various respects, such that measures taken for one process should be synchronized with those taken for other. As Davenport [10] describes:

> Most companies choose to address a small set of business processes in order to gain experience with innovation initiatives, and they focus their resources on the most critical processes. Each successful initiative becomes a model for future efforts.

What *is* happening in some organizations is that widespread efforts are made to at least *model* all important business processes, delaying the decision to make the step to more advanced BPM efforts (e.g. process redesign or automation). The idea is that process models are a cornerstone of any further BPM efforts in any case and that their existence will help to better understand where improvements can be gained. Creating a model of a process leads to the valuable insight how that process works at all, and can provide a good basis for small improvements that can easily be implemented. On the downside, such an approach bears the risk that major improvements are missed and stakeholders develop a feeling of a lack of return for the efforts. It should be stressed here, too, that the actual modeling of business processes is not an element of the process identification stage.

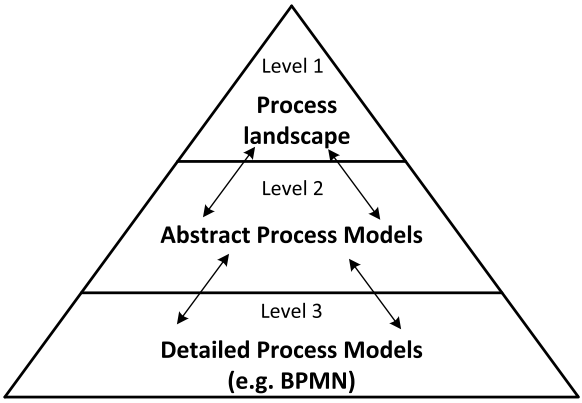

Fig. 2.1 The different levels of detail in a process architecture

In this section, we have described the process designation and evaluation phases on a high level of discourse. Now, we will turn to a specific technique to come up with a process design architecture.

2.2 Designing a Process Architecture

A process architecture is a conceptual model that shows the processes of a company and makes their relationships explicit. Typically, these relationships are defined in two directions. On the one hand, processes can be in a consumer–producer relationship. This means that one process provides an output that the other process takes as an input. In the first part of the book, we distinguished the quote-to-order process and order-to-cash processes. The output of the first one (the order) is the input to the second one. Note that this is the same kind of ordering as the upstream-downstream relation we distinguished earlier. Beyond the consumer–producer relation, a process architecture defines different levels of detail. This is illustrated as a pyramid in Fig. 2.1.

The part of the process architecture that covers the processes on level one is known as the *process landscape model* or simply the process architecture for level one. It shows the main processes on a very abstract level. Each of the elements of the process landscape model points to a more concrete business processes on level two. This level two shows the processes at a finer degree of granularity, but still in a quite abstract way. Each element on level two points further to a process model on level three. The process models on this third level show the detail of the processes including control flow, data inputs and outputs, and assignment of participants, as we will discuss in the modeling chapters.

The most important challenge for the definition of a process architecture is the definition of the process landscape model, i.e. capturing the processes on level one. The process architecture on level one has to be understandable in the first place, showing not much more than approximately 20 categories of business processes of

a company. Furthermore, it has to be sufficiently complete such that all employees of the company can relate to it with their daily work, and accept it as a consensual description of the company. Therefore, it is important to define the process architecture in a systematic way, with a specific focus on the derivation of the process landscape model.

Several perspectives and approaches have been defined for process architecture definition. Here, we will concentrate on an approach developed by Dijkman [14]. This specific approach leads to a process architecture on level one along two dimensions: case type and business function. The *case type* dimension classifies the types of cases that are handled by an organization. A case is something that an organization (or part of it) handles. Typically, a case is a product or service that is delivered by an organization to its customers, such as an insurance (a service) or a toy (a product). Note that, depending on the part of the organization for which the process architecture is designed, the cases can represent products or services that are delivered to the customers of the organization. However, they can also refer to products or services that are delivered by one department of the organization to another department. For example, think of setting up a workplace for a new employee by the facilities department.

Cases can be deliberately classified, using any number of properties. For example, an insurance company handles insurances, which can be classified according to product type (home insurance, car insurance and life insurance), but also according to the channel that the company uses to interact with its customers (telephone, office, and internet). A combination of these properties can also be used to classify cases. In the insurance example, cases would then be classified using both product type and channel (home-insurance via telephone, home-insurance via office, car-insurance via telephone, etc.).

The *function* dimension classifies the functions of an organization. A function is, simply put, something that an organization does. Typically, a hierarchical decomposition of functions can be made: A function consists of sub-functions, which, in turn, consist of sub-sub-functions, etc. For example, a production company performs purchasing, production, and sales functions. The purchasing function, in turn, can be decomposed into vendor selection and operational procurement functions. Figure 2.2 shows an example of a business process architecture for a harbor authority, which uses the case type and function dimensions to structure its processes.

The figure shows an organization of processes by *case type* in the horizontal dimension and by *business function* in the vertical dimension. The function dimension shows what the organization does: handling pre-arrival of sea ships, which involves notifying the relevant parties about the estimated time of arrival of the ship and what the ship is carrying; handling the actual arrival of the ship, which involves guiding the ship to its dock; etc. The case type dimension shows the types of cases that the organization handles: sea ships, trucks, trains, and inland transportation by barge. There are three processes that are created to handle these types of cases, using the different functions. These three are shown as covering the various functions and case types. The inbound planning process is used for handling pre-arrival of sea ships. The inbound handling process is used for handling arrival and trans-shipment of sea

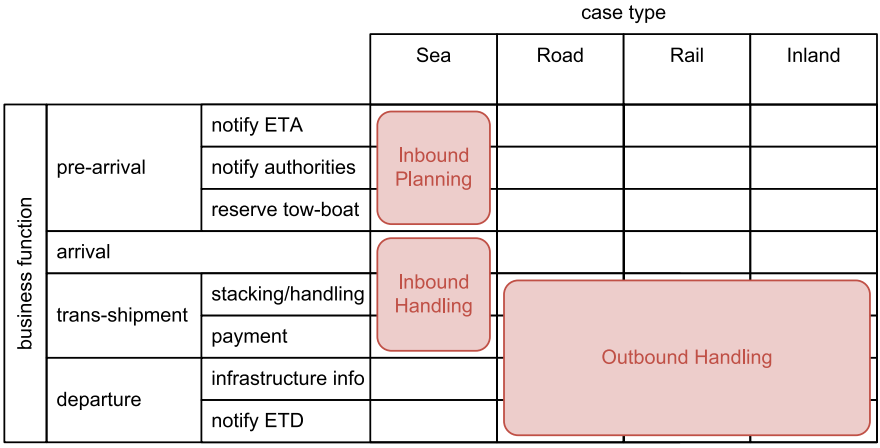

Fig. 2.2 A process architecture for a harbor authority

ships and the outbound handling process is used for handling trans-shipment and departure of trucks, trains, and barges.

To arrive at a business process architecture in a similar sense as we described here, we propose an approach that consists of the following four steps:

1. identify case types
2. identify functions for case types
3. construct one or more case/function matrices, and
4. identify processes

We will now discuss these steps in more detail.

2.2.1 Identify Case Types

In the first step, a classification of case types is developed for the organization. This is done by selecting the case properties that will be used for the classification. The main purpose for identifying different classes in this dimension of the process architecture is to determine the different ways in which (similar) processes are handled in the organization. It is important to have this in mind, because the only properties that should be included in the classification are the ones that lead to different organizational behavior. Properties that may distinguish cases yet do not lead to different behavior should not be included. For example, a stationary store sells many different types of product. However, it sells all these types of product in the same manner. Therefore, 'product type' is not a useful dimension when classifying the cases that are handled by a retail store. An insurance company also sells different types of product (insurances) and, in contrast to the retail store, the products that it sells are handled differently. For example, for a life insurance a declaration of health must be

filled out, but for a car insurance this is not a requirement. Therefore, the 'product type' is indeed a useful property to classify the types of cases that are handled by an insurance company; this is not the so for classifying the types of cases that are handled by a retail store.

A classification of the types of cases that an organization handles can be developed using any number of properties. However, some of the more commonly used properties are:

- Product type: this property identifies the types of products that are handled by an organization. These can be hierarchically decomposed. For example, an insurance company handles damages and life insurance products. In the class of damage insurances, a further decomposition is possible into car insurance and home insurance; similarly, within the class of life insurance a further decomposition is possible into healthcare insurance and accident insurance.
- Service type: if (a part of) an organization handles services rather than products, this property identifies the types of services that the organization handles, similar to the way in which product type identifies the types of tangible deliverables.
- Channel: this property represents the channel through which the organization contacts its customers. We can, for example, distinguish: face-to-face contact (over the counter), telephone or internet contact.
- Customer type: this property represents the types of customer that the organization deals with. An airline, for example, may distinguish frequent flyers from regular travelers.

Note again that, although these are the most commonly used properties to distinguish different case types, there are certainly other properties that can be used. Any property that distinguishes types of cases that are handled differently can be used. For example, if an organization does things differently in North America than in Europe, cases may be classified according to location. Another example: if cases are handled differently depending on the expertise that is required to handle them, they may be classified according to expertise.

Also, note again that the classification can be developed using any number and combination of properties. If a company sells insurances in both North America and Europe and handling of insurances differs on those continents because of local regulations, then a classification of cases according to both product type and location can be used.

Exercise 2.5 Consider the case of a bank and the classification criteria product type, service type, channel, and customer type. In how far are these criteria related to each other?

2.2.2 Identify Functions for Case Types

In the second step, a classification is developed of the business functions that are performed on the different case types. This step requires that each of the case types

is examined in detail and for each case type the functions that can be performed on it are identified. Potentially, the functions that are performed in an organization can be related to existing classifications that are proposed by reference models. We already mentioned a number of these. A small part of APQC's PCF is shown in Table 2.1. Such reference models can serve as a starting point to develop a classification of business functions and may be adapted to the specific needs of the organization.

Whether this identification of functions starts with a reference model or not, it requires interviews with different people in the organization. These interviews serve to either identify the functions directly, or to check to which extent the functions from a reference model apply to the organization. The interviews must both be held with employees that are involved in the different cases that the organization handles and with product (and service) managers of the different products and services that the organization handles. It is, therefore, important to observe that the different people involved may very well use different terms for similar business functions. Homonyms and synonyms are problematic in this context. For example, what is called 'acquisition' in one part of the organization may be called 'market survey' in another (synonym). At the same time, two functions called 'implementation' may represent different activities: one may represent the implementation of software, while the other represents the implementation of new regulations in the organization (homonym). Apart from being aware of the various terms that are being used, an intricate understanding of the operations of an organization is important to sort these issues out. Frameworks like APQC's PCF can help to avoid terminological issues right from the start.

In addition, functions may be organized differently. Consider, for example, Fig. 2.3. It is taken from a real-world case and shows parts of the functional decompositions of two departments from the same organization, one in Europe and one in North America. The European department distinguishes between purchasing and sales, where both purchasing and sales are split up into operational functions. These functions concern sourcing and order-to-pay for purchasing on the one hand and marketing and sales operations for sales on the other. The North American department distinguishes between sourcing, marketing, and order handling. Here, order handling involves both order-to-pay and operational sales activities (but is not decomposed any further).

Clearly, in the example of this organization, a negotiation step may be required between the different people involved to unify the functional decompositions across its European and North-American parts. This is particularly called for if the functional decomposition is more than just a modeling exercise. It may also represent actual organizational properties. In the case that is illustrated in Fig. 2.3, managers are in place for the different functions at the different levels of decomposition. In Europe, a manager is appointed for sales, another for procurement, and lower-level managers for sourcing, order-to-pay, marketing, and operational sales. In North America, there are managers in place for sourcing, marketing, and order management. Therefore, when the functional decompositions of the departments needs to be harmonized, the management structure also must be subjected to harmonization.

A functional decomposition should not be confused with a decomposition according to case type. It is possible that an organization is structured according to

Table 2.1 Level one and level two of the APQC process classification framework

1.0 Develop Vision and Strategy
1.1 Define the business concept and long-term vision
1.2 Develop business strategy
1.3 Manage strategic initiatives

2.0 Develop and Manage Products and Services
2.1 Manage product and service portfolio
2.2 Develop products and services

3.0 Market and Sell Products and Services
3.1 Understand markets, customers, and capabilities
3.2 Develop marketing strategy
3.3 Develop sales strategy
3.4 Develop and manage marketing plans
3.5 Develop and manage sales plans

4.0 Deliver Products and Services
4.1 Plan for and align supply chain resources
4.2 Procure materials and services
4.3 Produce/Manufacture/Deliver product
4.4 Deliver service to customer
4.5 Manage logistics and warehousing

5.0 Manage Customer Service
5.1 Develop customer care/customer service strategy
5.2 Plan and manage customer service operations
5.3 Measure and evaluate customer service operations

6.0 Develop and Manage Human Capital
6.1 Develop and manage human resources (HR) planning, policies, and strategies
6.2 Recruit, source, and select employees
6.3 Develop and counsel employees
6.4 Reward and retain employees
6.5 Redeploy and retire employees
6.6 Manage employee information

7.0 Manage Information Technology
7.1 Manage the business of information technology
7.2 Develop and manage IT customer relationships
7.3 Develop and implement security, privacy, and data protection controls
7.4 Manage enterprise information
7.5 Develop and maintain information technology solutions
7.6 Deploy information technology solutions
7.7 Deliver and support information technology services

8.0 Manage Financial Resources
8.1 Perform planning and management accounting
8.2 Perform revenue accounting
8.3 Perform general accounting and reporting
8.4 Manage fixed-asset project accounting
8.5 Process payroll
8.6 Process accounts payable and expense reimbursements
8.7 Manage treasury operations
8.8 Manage internal controls
8.9 Manage taxes
8.10 Manage international funds/consolidation

9.0 Acquire, Construct, and Manage Assets
9.1 Design and construct/acquire nonproductive assets
9.2 Plan maintenance work
9.3 Obtain and install assets, equipment, and tools
9.4 Dispose of productive and nonproductive assets

10.0 Manage Enterprise Risk, Compliance, and Resiliency
10.1 Manage enterprise risk
10.2 Manage business resiliency
10.3 Manage environmental health and safety

11.0 Manage External Relationships
11.1 Build investor relationships
11.2 Manage government and industry relationships
11.3 Manage relations with board of directors
11.4 Manage legal and ethical issues
11.5 Manage public relations program

12.0 Develop and Manage Business Capabilities
12.1 Manage business processes
12.2 Manage portfolio, program, and project
12.3 Manage quality
12.4 Manage change
12.5 Develop and manage enterprise-wide knowledge management (KM) capability
12.6 Measure and benchmark

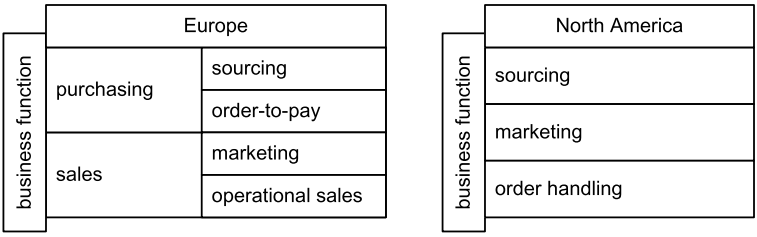

Fig. 2.3 Different functional decompositions within the same organization

both business function and other properties. It may then be tempting to develop the functional decomposition further according to these other properties. However, these other properties should be reflected in the case type dimension rather than the function dimension. For example, an organization can be structured according to business functions into a sales and a procurement department with managers leading each of the departments. It can be further structured according to location, having both a sales and a procurement department in Europe as well as in North America. In this situation, the functional decomposition ends with the decomposition into sales and procurement. Should a further decomposition according to location be relevant, then this decomposition should be reflected in the case type dimension, not in the function dimension.

An important decision that must be made when developing the functional decomposition is to determine the appropriate level of decomposition at which the functional decomposition ends. In theory, the functional decomposition can be performed up to a level that represents the tasks that are performed by the individual employee (fill-out form, check correctness of information on form, have colleague check correctness of information on form, etc.). However, for a process architecture a more coarse level of decomposition is usually chosen. Two rules of thumb that can be used to choose the level of decomposition at which the functional decomposition ends, are the following.

1. The functional decomposition should at least be performed down to a level at which functions correspond to different organizational units (with corresponding managers). For example, if an organization has both a sourcing and an order-to-pay department and both have their own managers, this is a strong indication that the functional decomposition should contain the functions that are performed by these departments.
2. The functional decomposition should include different functions for the different roles in each department. For example, if the sourcing department has buyers, who do requirements analysis and vendor selection, as well as senior buyers, who do vendor relationship management and contract management, this may lead to a decision to include requirements analysis, vendor selection, vendor relationship management and contract management as functions.

		Private Customers	Corporate Customers	Internal Customers
Management	Process			X
	Line			X
	Project			X
Operations	Savings	X	X	
	Loans	X	X	
	Checking	X	X	
Support	HRM			X
	ICT			X
	Finance			X
	Marketing			X

Fig. 2.4 A case/function matrix

Observe that these are rules of thumb, which leave room for handling them flexibly. They merely provide an aid for determining the lowest level of decomposition that should be used.

Exercise 2.6 Consider the case of a university and the level one processes listed in the APQC's PCF. What kind of more specific functions does a university typically cover in categories 2.0 Develop and Manage Products and Services and in 5.0 Manage Customer Service?

2.2.3 Construct Case/Function Matrices

The previous two steps of the described approach lead to a matrix that has the different case types as columns and the different functions as rows. A cell in the matrix contains an 'X', if the corresponding function can be performed for the corresponding case type. Figure 2.4 shows an example of a case/function matrix. The matrix shows a decomposition of case types by customer type, resulting in three case types: one for private customers, one for corporate customers, and one for internal customers. The figure also shows a functional decomposition into three main functions and a subsequent decomposition of those main functions into ten sub-functions. Management and support functions are only performed for internal customers, while operational functions are performed for private and corporate customers.

A case/function matrix can be split up into multiple matrices for the purpose of improving readability. We would typically split up a case/function matrix in case a partition of the matrix' functions and case types is possible such that all X's are

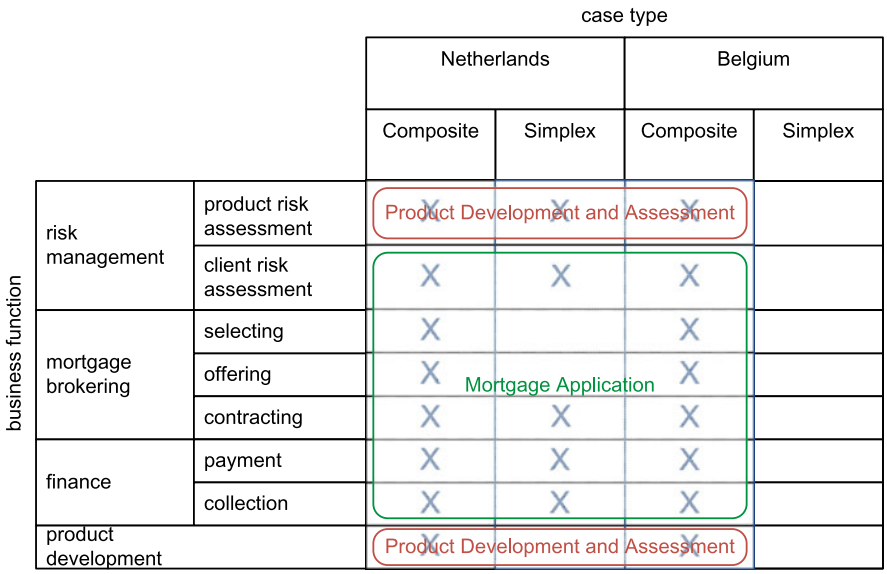

Fig. 2.5 A case/function matrix evolving into a process landscape model (applying Guideline 1)

preserved. For example, the matrix from Fig. 2.4 can be partitioned into, on the one hand, a matrix that contains the management and support functions and the internal customers and, on the other, a matrix that contains the operational functions and the private and corporate customers.

2.2.4 Identify Processes

In the fourth and final step of the proposed approach, we determine which combinations of business functions and case types form a business process. To determine this, we need to find a trade-off between two extremes, one in which the entire matrix forms one big process and one in which each single cross in the matrix forms a process. We establish this trade-off by the use of the general rule that, in principle, the entire matrix forms one big process which will only be split up in case certain rules apply. These rules can be formulated as eight guidelines. When a guideline applies, this may lead to a separation of processes between rows (a vertical split) or to a separation of processes between columns (a horizontal split). Some of the guidelines (Guidelines 5, 6, and 8) can only lead to vertical splits, while others (Guidelines 1–4) can only lead to horizontal splits. Note that the guidelines are not absolute: they may or may not apply to a particular organization and they are not the only rules that should be considered in specific cases.

Figure 2.5 shows the running example that we will use to explain the guidelines. The figure shows a case/function matrix for a mortgage broker, which brokers mortgages both in the Netherlands and in Belgium. It distinguishes between simplex

and composite mortgages. A composite mortgage can be adapted to the specific requirements of a customer, by composing it from different types of loans, savings accounts, life insurances and investment accounts. A simplex mortgage consists of a pre-defined package of a loan, a savings account and a life insurance. On these different types of mortgages, various business functions can be performed. Risk assessment involves assessment of risk of both individual clients, who are in the process of applying for a mortgage, and mortgage products as a whole. Mortgage brokerage involves the selection of a particular mortgage package based on the requirements of a particular customer and subsequently offering that package to the customer and closing the contract. The financial functions involve paying out the mortgage and subsequently collecting the monthly payments. Finally, product development is the periodic review of the mortgage products and their components.

Guideline 1: If a process has different flow objects, it can be split up vertically. A flow object is an object in the organization that flows through a business process. It is the object on which business process activities are being carried out. Typically, each business process has a single flow object, such that flow objects can be used to identify business processes. Consequently, if multiple flow objects can be identified in a business process, this is a strong indication that the process should be split up.

Figure 2.5 illustrates the application of Guideline 1 to our running example. One flow object for the mortgage brokering process is a mortgage application on which activities are carried out during a mortgage application by a client. These activities include a risk assessment and paying out the mortgage to the client. Another flow object in the mortgage brokering process is a mortgage product on which activities are carried out periodically to assess the risk of the product as a whole and to evaluate and develop the product. Consequently, we can split up the mortgage brokering process into two processes, one that has a mortgage application as a flow object and one that has a mortgage product as a flow object. We call the former the mortgage application process and the latter the product development and assessment process.

Guideline 2: If the flow object of a process changes multiplicity, the process can be split up vertically. This is due to the fact that in a business process a single flow object is sometimes used, while at other times multiple flow objects of the same type are used. This is typical for batch processing, in which certain activities are performed for multiple customer cases in batch at the same time. If, in the same process, the number of flow objects that is processed per activity differs this may be a reason for splitting up the process.

Have a look at Fig. 2.5, where the mortgage application process is performed for a single mortgage application. By contrast, the collection of payments happens for all mortgages in batch by the end of each month. Using Guideline 2, this may be taken as the reason for splitting the process and having Mortgage Collection as a separate process.

Guideline 3: If a process changes transactional state, it can be split up vertically. According to the action-workflow theory, a business process goes through a num-

ber of transactional states. In particular, we distinguish: the initiation, the negotiation, the execution and the acceptance state. In the initiation state, contact between a customer and a provider is initiated. In the negotiation state, the customer and the provider negotiate about the terms of service or delivery of a product. During the execution state, the provider delivers the product or service to the customer and during the acceptance state, the customer and the provider negotiate about the acceptance and payment of the delivery. A transition in a process from one state to another is an indication that the process can be split up.

To illustrate this guideline, consider again Fig. 2.5. Suppose that during the negotiation state the mortgage broker and the customer negotiate about the selection of mortgage products, ultimately leading to a contract being signed by both parties. Only during the execution state the mortgage is paid out to the customer and the monthly payments will be collected. By the logic of Guideline 3, we therefore split up the process into a mortgage application process and a Mortgage Payment process.

Guideline 4: If a process contains a logical separation in time, it can be split up vertically. A process contains a logical separation in time, if its parts are performed at different time intervals. Intervals that can typically be distinguished include: once per customer request, once per day, once per month and once per year.

To clarify Guideline 4, consider Fig. 2.5 again. Mortgage selection, offering, and contracting are performed once per mortgage application, while payment and collection for mortgages is performed once per month. By the logic of Guideline 4, it would make sense to split up mortgage selection, offering, and contracting from mortgage payment collection. Note that the passing of time in itself is not a reason for splitting up a process, because within each single process, time passes. For example, between the activity of entering mortgage details into a computer system and approval of the mortgage, time passes, but the unit of time remains the same: both activities happen once per mortgage application. Therefore, we would not split up the process between these activities. Another way of looking at Guideline 4 is that the process can be split up, if it must wait for a time trigger or a trigger by a new flow object. For example, the approval of a mortgage can be performed directly after the mortgage details are entered, without having to wait for a trigger. However, after having processed the mortgage application, the process must wait for the payment collection date trigger to continue with payment collection. Therefore, we would split up the process between these functions by the same logic of Guideline 4.

Guideline 5: If a process contains a logical separation in space, it can be split up horizontally. A process contains a logical separation in space, if it is performed at multiple locations and is performed differently at those locations. It is important to note that it is not sufficient for processes to just be separated in space. The separation must be such that there is no choice but to perform the processes differently for the different logical units.

To clarify this guideline: in case a process is performed at different locations within the same country, there is not necessarily a reason to perform it differently

at those locations. Consequently, there is no reason to split it up. In fact, organizations should strive to make their processes as uniform as possible, to benefit from economies of scale. Indeed many organizations nowadays started projects in which they aim to make their processes more uniform across different locations, where processes became different purely for historic reasons or because the different locations did not share information about their process flow. As another example, the processes from Fig. 2.5 are performed at two different locations in different countries. However, still not all of these processes should differ at these two locations. For example, mortgage payment and collection may be the same in Belgium and the Netherlands. However, risk assessment, mortgage brokering and product development may differ between the Netherlands and Belgium, due to country-specific rules and regulations.

Guidelines 6 and 7 are more straightforward and can be described as follows.

Guideline 6: If a process contains a logical separation in another relevant dimension, it can be split up horizontally. Like with the separation in space, it is not sufficient for processes to just be separated. The separation must be such that there is no choice but to perform the processes differently for the different logical units.

Guideline 7: If a process is split up in a reference model, it can be split up. A reference process architecture is an existing process architecture that is pre-defined as a best-practice solution. It structures a collection of processes. For example, if a reference financial services process architecture exists, its structure can be used as an example or starting point to structure your own process architecture.

Figure 2.6 shows the results of applying Guidelines 2 through to 7 to the case/function matrix from Fig. 2.5, which itself resulted from applying Guideline 1 to our running example. Figure 2.6 shows that after applying Guidelines 2 through 7 as discussed above, there are six processes: Product Development and Assessment Netherlands (PD NL), Product Development and Assessment Belgium (PD BE), Mortgage Application Netherlands, Mortgage Application Belgium, Mortgage Payment, and Mortgage Collection.

The final guideline that we discuss here is the following.

Guideline 8: If a process covers (many) more functions in one case type than in another, it can be split up horizontally. The application of this last rule depends upon the current decomposition of processes. If applied, it is necessary to look at the current decomposition of processes and check if, within a process, (many) more functions are performed for one case type than for another, i.e.: whether a process has many more crosses in one column than in another. If so, this is a strong indication that the process should be split up for these two case types.

For example, when looking at Fig. 2.6, we see that the Mortgage Application Netherlands process has many more function for composite mortgages than for simplex mortgages. By the logic of Guideline 8, we would split up this process for composite and simplex application. The application of all of these eight guidelines yields a process architecture for level one. The result can be seen in Fig. 2.7, which is the finalized process landscape model for our example.

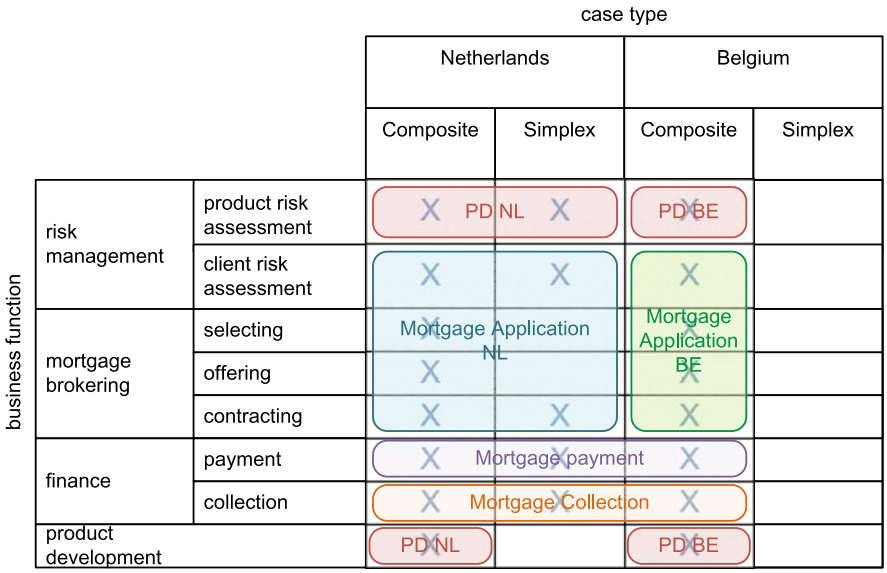

Fig. 2.6 A case/function matrix evolving into a process landscape model (applying Guidelines 2–7)

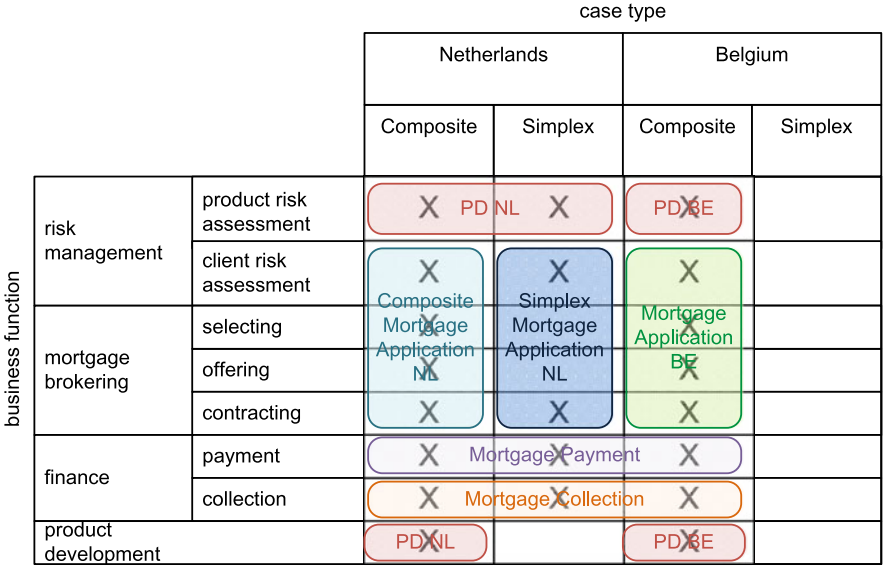

Fig. 2.7 A case/function matrix evolving into a process landscape model (applying Guideline 8)

Table 2.2
Consumer–producer relationships between processes

Consumer	Producer
Mortgage Payment	Composite Mortgage Application NL
Mortgage Payment	Simplex Mortgage Application NL
Mortgage Payment	Mortgage Application BE

2.2.5 Complete the Process Architecture

The approach that we discussed previously and which we emphasize in this part of the book leads to a process landscape model that covers the processes on level one of the pyramid in Fig. 2.1. As stated, this level only provides a very abstract insight into each process within the process landscape: It mainly shows how processes differ from each other in terms of the cases and functions they cover.

There are two things that are missing with respect to the general, encompassing characteristics of a process architecture as we discussed in Sect. 2.2: (1) the consumer–producer relationships between the processes, and (2) the levels of detail as provided by the pyramid in Fig. 2.1.

With respect to the consumer–producer relationships, we can take a broad or narrow perspective on the use of an output from one process as the input of another. For our running example, it may be that the product development process uses aggregated figures about how the mortgage application process is carried to determine what the needs of clients are and, in this way, what attractive new products may be. This would be a rather broad interpretation of the consumer–producer relationship.

What is often most important to know stems from a narrower perspective, namely which consumer–producer relationships exist between processes with respect to the *same* flow objects. In Fig. 2.7, it can be seen that mortgage application (both in the Netherlands and Belgium) and mortgage payment are split up, which was done following the logic of Guideline 3. This is a situation where the flow object of one process is consumed piecemeal by another; the only difference is the transactional state that the flow object is in. Specifically with respect to redesign initiatives these relations are most important to remember and make explicit, since changing one process has direct implications for the performance of the other. We can capture this narrow interpretation of consumer–producer relationships for our running example as is done in Table 2.2. Each row in this table provides a single consumer–producer relationship, where the consumer process continues to work on a flow object that is the output of the producer process.

Let us now focus on the other aspect that makes a process architecture for level one rather restrictive in comparison to our general notion of a process architecture. This concerns the high level of abstraction of the processes that are distinguished by the process landscape model. To focus on the other levels of the pyramid of Fig. 2.1, the question is what kind of additional detail they should offer. We focus here on the missing insights into (a) the *various steps* that are taken within each process and (b) the *organizational units* that are involved in carrying these out. These two elements should be added to obtain the models for level two of what we mean by

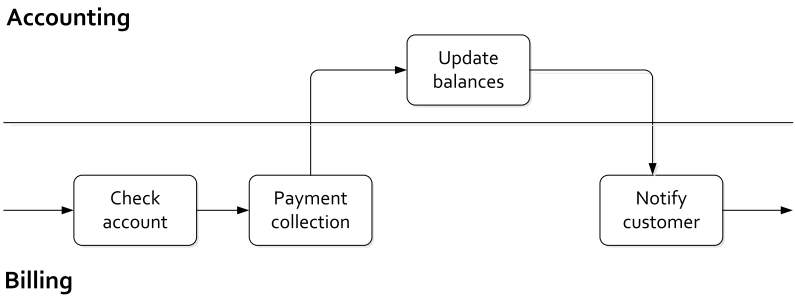

Fig. 2.8 A process map for the mortgage payment process

a process architecture. It is common to refer to a model on this second level as a *process map*.

To provide an example of a process map, we focus on the mortgage payment process that is identified in the process landscape model of Fig. 2.7. The related process map can be seen in Fig. 2.8.

As this figure shows, the identified mortgage payment process from the process landscape model has been decomposed into four main steps that can be associated with this process. Moreover, two organizational units are identified that are associated with these steps, i.e. Accounting and Billing. In other words, a process map provides more detail about the control flow and includes additional information with respect to the involved resources for a process.

Even a process map can still be said to provide an abstract view on a process. First of all, we can still see that the flow throughout the steps in a process map is highly simplified. It is common, like in Fig. 2.8, to only show a linear progress along the various steps in a process map: alternative paths, potential exceptions, iterations, etc. are all left out. For the organizational information that is added in a process map, too, the information is abstract: we can only see references to units but not the specific kind of participants that are involved.

Exercise 2.7 Give an example of an alternative path, a potential exception, and an iteration that would show up in a more detailed model of the mortgage payment process.

Secondly, there are many aspects beyond control flow and resource information that are not covered in *any* level of detail in a process map. Think about the data that are being handled in the process, the reports and files that are passed on, the systems that support the various steps, the time that is involved with carrying out these steps, etc.

In practice, process maps have turned out to provide a deeper level of insight into the processes from the process landscape *regardless* of the goals one pursues for the specific processes. In other words, an insight into the steps and involved organizational units has its value for any type of process-oriented initiative. By contrast, a further insight into, for example, the data that are being processed within each step

would only make sense if someone pursues to automate the process or when the evaluation phase has identified quality issues.

In this textbook, we will not focus on the development of process maps. Instead, we will turn to the more detailed level of models, i.e. those on level three of a process architecture. As will be shown, these models are developed following specific rules and provide the insight that are ideally closely tied to what one likes to achieve with a specific process management initiative. This will be the subject of the following chapters.

2.3 Recap

In this chapter, we have discussed process identification. First, we distinguished and described the phases of designation and evaluation. The designation phase aims at enumerating the major processes within an organization, as well as determining the boundaries between those processes. An insight into the major processes that are being carried out in an organization is important to set up any process management activity. The evaluation phase is dedicated to prioritizing process analysis and redesign efforts. It is good practice to base priorities upon the importance of processes, their potential dysfunction, and the feasibility of improvements.

The designation phase may be used not only to enumerate the most important processes, but also to design a consistent overarching process architecture. A process architecture defines the relationship between the different processes. Often, different levels of detail are distinguished. We discussed a specific approach for the definition of level one of the process architecture. This approach builds on the identification of case types, of the functions for these case types, the construction of a case/function matrix, the identification of processes based on guidelines, and the eventual completion of the architecture.

2.4 Solutions to Exercises

Solution 2.1 Explain how the trade-off between impact and manageability works out for broad and narrow processes, respectively. A broad process has by definition a large scope. Managing it actively potentially can have a large impact on an organization's performance. The flip side is that it is more difficult to actively manage such a broad process or the improvement projects that are related to it. For a narrow process, this is exactly the other way around: given its smaller scope, it is more easily managed but it will probably have a lesser impact on an organization's performance as a whole.

Solution 2.2 The description of the investment firm points at large financial holdings, which may be related to the employment of many different products (investment instruments) for many different customers, both private and institutional. Both

of these dimensions, products and customers, may drive the firm to identify different processes that cater for these. In addition, the description of the firm also mentions 'accountability': for many financial organizations, there are strict requirements on how they must manage and disclose their operation, as imposed on them by regulatory agencies. This, too, may be a driver for the identification of many different processes.

Solution 2.3 Order management is not sequentially related to any of these. As discussed in the text, booking, billing, shipment, and delivery are all sub-processes of order management. So, it is impossible to indicate that any of these sub-processes precedes or follows up on order management; rather, they are subsumed by this process.

Solution 2.4 Organizations wish to accomplish certain *goals*. Processes are a means to achieve these goals. A relation that, therefore, may be important is how processes are related to one another in the sense that they contribute to the same or related goals. Other, context-specific relations may be important for organizations as well. Consider how it may be important for an organization to know on which *technologies* their processes are based; if a particular technology becomes obsolete, such an organization knows which processes are affected. A similar line of reasoning can be taken for geographic areas, regulations, etc.

Solution 2.5 Many banks distinguish different types of customers, and use this distinction for defining product and service types for them as much as channels. For instance, a retail bank customer is typically characterized by a low to average income who requires transaction services and products for building up wealth. Often, banks try to serve these customers via standardized channels like telephone and internet in order to limit transaction costs. On the contrary, private bank customers are typically have high income or possess a considerable fortune. Banks invest much more into personal advise and consulting of these customers and in offering individual packages of products and services. Often, such strategic considerations as of those a bank in this example have the consequence that different classification criteria are often correlated.

Solution 2.6 The products and services of a university relate to teaching and certification, and essentially support the lifecycle of a student towards obtaining a degree. Therefore, the category 2.0 mainly relates to the development and management of curricula and degree programs. The academic entities of a university are concerned with these tasks. The category 5.0 would refer to the management of student services. Usually, tasks belonging to this category are organized in an examinations office of the university assisting in all study-related matters.

Solution 2.7 An example of alternative paths in the mortgage payment process would be that different payment conditions lead to payment collection activities. An example of an exception in this process would be that the account balance is

not sufficient to collect a payment. An example of an iteration would be that after a failed payment collection this is tried again (perhaps after a certain delay).

2.5 Further Exercises

Exercise 2.8 A university provides education and services to its students. This starts with admission of students to the university. When a regular student, i.e. a student who comes from a Dutch high-school, sends in his admission form such a student is registered by the admissions office. Subsequently, the eligibility to study in a certain program is checked based on the information that the student provided on his admission form. For students who arrive from another school, such as a polytechnic, the previous study that the student took, according to his admission form, must be examined in detail. Polytechnic students can either come to the university after completing one year of courses (propedeuse) or after receiving a polytechnic diploma. Students from universities in other countries are also accepted. Also for them, the studies that they took previously must be examined in detail. When students are considered eligible and the courses that they have already followed (if applicable) check out, they are enrolled at the university, which involves sending a letter that they are accepted and entering the details of their enrollment in the information system of the university. The students then become a student of their respective study: industrial engineering, building or construction engineering.

After the students are enrolled, they can take courses or do projects and they can use the services that are provided by the university, which include: language training and sports facilities. Projects are done on an individual basis by a student together with a lecturer. The university recognizes part-time students who do their studies while they are working in a company. These students typically do projects of a more practical nature than the other students, such that the process that is followed during the project are also different for these students.

Design a process architecture as follows:

1. identify the case types that should appear in the process architecture
2. identify the functions that should appear in the process architecture
3. draw a case/function matrix
4. identify the processes in the case function matrix, split up processes if and only if one of the guidelines applies, clearly indicate which guideline you applied where

Exercise 2.9 A consultancy firm provides consultancy, outsourcing, and interim management services. The firm considers acquisition of projects as part of those services. Acquisition can both be done for existing clients and for new clients, because it concerns acquisition of projects rather than clients. Acquisition is typically started at ‘networking events’ by partners of the consultancy firm. It is handled according to a fixed procedure, but no standard document is used. When a client shows interest in a consultancy service, an intake is done with the client. To maintain a long-term relationship with clients as much as possible, the firm will always

try to establish a framework contract with new clients during the intake. For existing clients a framework contract does not have to be established. As another form of relationship management, regular meetings are held with existing clients. During these meetings the client's organization is discussed with the client. This enables the client to decide whether additional work should be done to further improve the organization. At the same time this enables the firm to bring in additional assignments. The intake and the regular meetings happen according to the same form, on which an inventory of the client's wishes can be made.

For consultancy and outsourcing services, a project team must be created directly after a project assignment was given to the consultancy firm. After a project team is created, there is a kick-off meeting with the client and after the kick-off meeting, the project is executed. The kick-off meeting is the same for each type of project, but the way in which the project is executed differs largely per type of service. At the end of the project there always is an evaluation meeting with the client as a means of quality control. The creation of the project team, the kick-off meeting, the execution of the project and the evaluation of the project happen according to a project plan.

The consultancy company has a services department, which takes care of market research for the consultants, manages the leasing of cars and provides secretary services.

Design a process architecture as follows:

1. identify the case types that should appear in the process architecture
2. identify the functions that should appear in the process architecture
3. draw a case/function matrix
4. identify the processes in the case function matrix; split processes if and only if one of the guidelines applies and indicate which guideline you applied where

2.6 Further Reading

The importance of explicit identification of processes was perhaps first discussed by Davenport [10], while a similar perspective is offered by Hammer & Champy [29]. Sharp & McDermott [86] give practical advice on exploring the *process landscape*—an alternative term for process architecture. Another practical book covering process architecture design is that of Ould [64]. One of the questions left open by these books is to what extent it pays off to identify and delineate processes in a company-specific manner as opposed to adopting standardized reference models for this purpose.

Dijkman [14] provides a survey of popular process architecture approaches. One of the findings of this survey is that practitioners tend to apply a mix of styles to derive process architectures and that no single, popular approach is followed. Despite the practical interest in the topic, there is a little academic research into the area of process architectures. Exceptions are the work by Frolov et al. [20] and Zur Muehlen et al. [112]. Both groups of authors emphasize the importance of a hierarchical process architectures. It remains unclear though to what extent prescribed, normative approaches provided by academia are applicable and beneficial in practice.

The concept of value chain—which generally appears at the top of a process architecture—was popularized by Michael Porter [67]. Porter also contributed to popularizing the distinction between core process (which he called primary activity) and support process. A detailed reference model centered around the notion of value chain is the Value Reference Model (VRM) defined by the Value Chain Group (http://www.value-chain.org/).

Related and to some extent complementary to the concept of value chain is the organizational performance framework of Rummler & Brache [80]. In this framework, organizations are viewed as systems whose purpose is to produce value within a certain environment, which includes competitors, suppliers, capital markets, labor markets, regulations, and other external factors. Within this environment, organizations create value by procuring materials or resources from suppliers in order to manufacture or deliver products or services for customers. The created value leads to earnings for shareholders.

Rummler & Ramias [81] describe a variant of Rummler & Brache's framework, namely the Value Creation Hierarchy (VCH). In this framework, the system that transforms resources into products or services is called the Value Creation System (VCS). The VCS is decomposed into processing sub-systems, which in turn are decomposed into end-to-end processes and then into sub-processes, tasks, and subtasks. The VCH thus provides a conceptual framework that goes all the way from the organizational context to the lowest level of a process architecture.

Chapter 3
Essential Process Modeling

Essentially, all models are wrong, but some are useful.
George E.P. Box (1919–)

Business process models are important at various stages of the BPM lifecycle. Before starting to model a process, it is crucial to understand why we are modeling it. The models we produce will look quite differently depending on the reason for modeling them in the first place. There are many reasons for modeling a process. The first one is simply to understand the process and to share our understanding of the process with the people who are involved with the process on a daily basis. Indeed, process participants typically perform quite specialized activities in a process such that they are hardly confronted with the complexity of the whole process. Therefore, process modeling helps to better understand the process and to identify and prevent issues. This step towards a thorough understanding is the prerequisite to conduct process analysis, redesign or automation.

In this chapter we will become familiar with the basic ingredients of process modeling using the BPMN language. With these concepts, we will be able to produce business process models that capture simple temporal and logical relations between activities, data objects and resources. First, we will describe some essential concepts of process models, namely how process models relate to process instances. Then, we will explain the four main structural blocks of branching and merging in process models. These define exclusive decisions, parallel execution, inclusive decisions and repetition. Finally, we will cover information artifacts and resources involved in a process.

3.1 First Steps with BPMN

With over 100 symbols, BPMN is a fairly complex language. But as a learner, there is no reason to panic. A handful of those symbols will already allow you to cover many of your modeling needs. Once you have mastered this subset of BPMN, the remaining symbols will naturally come to you with practice. So instead of describing each and every BPMN symbol at length, we will learn BPMN by introducing its symbols and concepts gradually, by means of examples.

M. Dumas et al., *Fundamentals of Business Process Management*,
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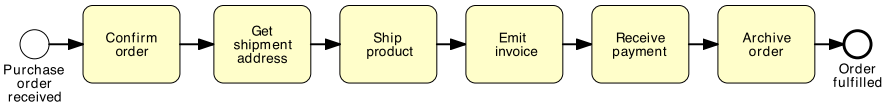


Fig. 3.1 The diagram of a simple order fulfillment process

In this chapter we will become familiar with the core set of symbols provided by BPMN. As stated earlier, a business process involves *events* and *activities*. Events represent things that happen instantaneously (e.g. an invoice has been received) whereas activities represent units of work that have a duration (e.g. an activity to pay an invoice). Also, we recall that in a process, events and activities are logically related. The most elementary form of relation is that of *sequence*, which implies that one event or activity A is followed by another event or activity B. Accordingly, the three most basic concepts of BPMN are event, activity, and arc. Events are represented by circles, activities by rounded rectangles, and arcs (called *sequence flows* in BPMN) are represented by arrows with a full arrow-head.

Example 3.1 Figure 3.1 shows a simple sequence of activities modeling an order fulfillment process in BPMN. This process starts whenever a purchase order has been received from a customer. The first activity that is carried out is confirming the order. Next, the shipment address is received so that the product can be shipped to the customer. Afterwards, the invoice is emitted and once the payment is received the order is archived, thus completing the process.

From the example above we notice that the two events are depicted with two slightly different symbols. We use circles with a thin border to capture start events and circles with a thick border to capture end events. Start and end events have an important role in a process model: the start event indicates when *instances* of the process start whereas the end event indicates when instances complete. For example, a new instance of the order fulfillment process is triggered whenever a purchase order is received, and completes when the order is fulfilled. Let us imagine that the order fulfillment process is carried out at a seller's organization. Every day this organization will run a number of instances of this process, each instance being independent of the others. Once a process instance has been spawned, we use the notion of *token* to identify the progress (or *state*) of that instance. Tokens are created in a start event, flow throughout the process model until they are destroyed in an end event. We depict tokens as colored dots on top of a process model. For example Fig. 3.2 shows the state of three instances of the order fulfillment process: one instance has just started (black token on the start event), another is shipping the product (red token on activity "Ship product"), and the third one has received the payment and is about to start archiving the order (green token in the sequence flow between "Receive payment" and "Archive order").

While it comes natural to give a name (also called *label*) to each activity, we should not forget to give labels to events as well. For example, giving a name to each start event allows us to communicate what triggers an instance of the process,

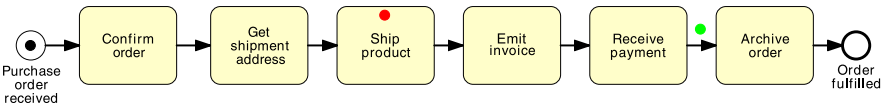


Fig. 3.2 Progress of three instances of the order fulfillment process

meaning, when should a new instance of the process be started. Similarly, giving a label to each end event allows us to communicate what conditions hold when an instance of the process completes, i.e. what the outcome of the process is.

We recommend the following naming conventions. For activities, the label should begin with a verb in the imperative form followed by a noun, typically referring to a business object, e.g. "Approve order". The noun may be preceded by an adjective, e.g. "Issue driver license", and the verb may be followed by a complement to explain how the action is being done, e.g. "Renew driver license via offline agencies". However, we will try to avoid long labels as this may hamper the readability of the model. As a rule of thumb, we will avoid labels with more than five words excluding prepositions and conjunctions. Articles are typically avoided to shorten labels. For events, the label should begin with a noun (again, this would typically be a business object) and end with a verb in past participle form, e.g. "Invoice emitted". The verb is a past participle to indicate something that has just happened. Similar to activity labels, the noun may be prefixed by an adjective, e.g. "Urgent order sent". We capitalize the first word of activity and event labels.

General verbs like "to make", "to do", "to perform" or "to conduct" should be replaced with meaningful verbs that capture the specifics of the activity being performed or the event occurring. Words like "process" or "order" are also ambiguous in terms of their part of speech. Both can be used as a verb ("to process", "to order") and as a noun ("a process", "an order"). We recommend to use such words consistently, only in one part of speech, e.g. "order" always as a noun.

To name a process model we should use a noun, potentially preceded by an adjective, e.g. "order fulfillment" or "claim handling" process. This label can be obtained by nominalizing the verb describing the main action of a business process, e.g. "fulfill order" (the main action) becomes "order fulfillment" (the process label). Nouns in hyphenated form like "order-to-cash" and "procure-to-pay" indicating the sequence of main actions in the process, are also possible.

We do not capitalize the first word of process names, e.g. the "order fulfillment" process. By following such naming conventions we will keep our models more consistent, make them easier to understand for communication purposes and increase their reusability.

The example in Fig. 3.1 represents one possible way of modeling the order fulfillment process. However, we could have produced a quite different process model. For example, we could have neglected certain activities or expanded on certain others, depending on the specific intent of our modeling. The box "A bit on modeling theory" reflects on the properties that underpin a model and relates these to the specific case of process models.

A BIT ON MODELING THEORY

A model is characterized by three properties: mapping, abstraction, and fit for purpose. First, a model implies a *mapping* of a real-world phenomenon—the modeling subject. For example, a residential building to be constructed could be modeled via a timber miniature. Second, a model only documents relevant aspects of the subject, i.e. it *abstracts* from certain details that are irrelevant. The timber model of the building clearly abstracts from the materials the building will be constructed from. Third, a model serves a particular *purpose*, which determines the aspects of reality to omit when creating a model. Without a specific purpose, we would have no indication on what to omit. Consider the timber model again. It serves the purpose of illustrating how the building will look like. Thus, it neglects aspects that are irrelevant for judging the appearance, like the electrical system of the building. So we can say that a model is a means to abstract from a given subject with the intent of capturing specific aspects of the subject.

Fig. 3.3 A building (**a**), its timber miniature (**b**) and its blueprint (**c**). ((**b**): © 2010, Bree Industries; (**c**): used by permission of planetclaire.org)

A way to determine the purpose of a model is to understand the *target audience* of the model. In the case of the timber model, the target audience could be a prospective buyer of the building. Thus, it is important to focus on the appearance of the building, rather than on the technicalities of the construction. On the other hand, the timber model would be of little use to an engineer who has to design the electrical system. In this case, a blueprint of the building would be more appropriate.

Thus, when modeling a business process, we need to keep in mind the specific purpose and target audience for which we are creating the model. There are two main purposes for process modeling: *organizational design* and *application system design*. Process models for organizational design are *business-oriented* . They are built by process analysts and mainly used for understanding and communication, but also for benchmarking and improvement. As such, they need to be intuitive enough to be comprehended by the various stakeholders, and will typically abstract from IT-related aspects. The target audience includes managers, process owners and business analysts. Process models for application system design are *IT-oriented* . They are built by

system engineers and developers, and used for automation. Thus, they must contain implementation details in order to be deployed to a BPMS, or used as blueprints for software development.

In this and in the next chapter we will focus on the business-oriented process models. In Chap. 9 we will learn how to turn these process models executable.

3.2 Branching and Merging

Activities and events may not necessarily be performed sequentially. For example, in the context of a claim handling process, the approval and the rejection of a claim are two activities which exclude each other. So these activities cannot be performed in sequence, since an instance of this process will perform either of these activities. When two or more activities are alternative to each other, we say they are *mutually exclusive*.

Let us consider another situation. In the claim handling process, once the claim has been approved, the claimant is notified and the disbursement is made. Notification and disbursement are two activities which are typically performed by two different business units, hence they are independent of each other and as such they do not need to be performed in sequence: they can be performed in parallel, i.e. at the same time. When two or more activities are not interdependent, they are *concurrent*.

To model these behaviors we need to introduce the notion of *gateway*. The term gateway implies that there is a gating mechanism that either allows or disallows passage of tokens through the gateway. As tokens arrive at a gateway, they can be merged together on input, or split apart on output depending on the gateway type. We depict gateways as diamonds and distinguish them between splits and joins. A *split* gateway represents a point where the process flow diverges while a *join* gateway represents a point where the process flow converges. Splits have one incoming sequence flow and multiple outgoing sequence flows (representing the branches that diverge), while joins have multiple incoming sequence flows (representing the branches to be merged) and one outgoing sequence flow.

Let us now see how examples like the above ones can be modeled with gateways.

3.2.1 Exclusive Decisions

To model the relation between two or more alternative activities, like in the case of the approval or rejection of a claim, we use an *exclusive* (*XOR*) *split*. We use an *XOR-join* to merge two or more alternative branches that may have previously been

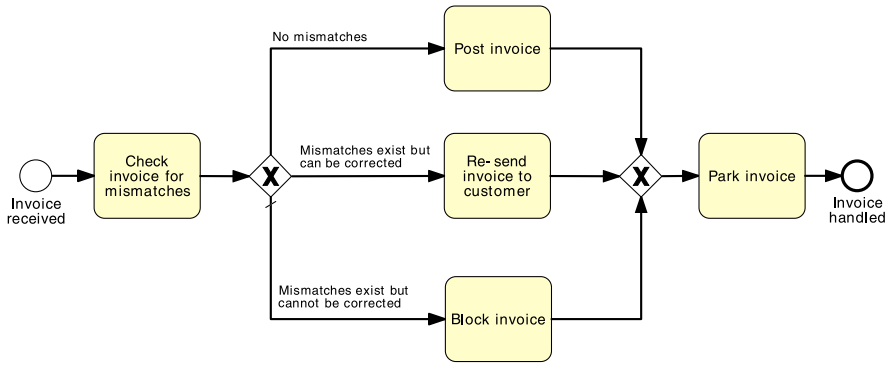


Fig. 3.4 An example of the use of XOR gateways

forked with an XOR-split. An XOR gateway is indicated with an empty diamond or with a diamond marked with an "X". From now on, we will always use the "X" marker.

Example 3.2 Invoice checking process.

> As soon as an invoice is received from a customer, it needs to be checked for mismatches. The check may result in either of these three options: i) there are no mismatches, in which case the invoice is posted; ii) there are mismatches but these can be corrected, in which case the invoice is re-sent to the customer; and iii) there are mismatches but these cannot be corrected, in which case the invoice is blocked. Once one of these three activities is performed the invoice is parked and the process completes.

To model this process we start with a decision activity, namely "Check invoice for mismatches" following a start event "Invoice received". A *decision activity* is an activity that leads to different outcomes. In our example, this activity results in three possible outcomes, which are mutually exclusive; so we need to use an XOR-split after this activity to fork the flow into three branches. Accordingly, three sequence flows will emanate from this gateway, one towards activity "Post invoice", performed if there are no mismatches, another one towards "Re-send invoice to customer", performed if mismatches exist but can be corrected, and a third flow towards "Block invoice", performed if mismatches exist which cannot be corrected (see Fig. 3.4). From a token perspective, an XOR-split routes the token coming from its incoming branch towards one of its outgoing branches, i.e. only one outgoing branch can be taken.

When using an XOR-split, make sure each outgoing sequence flow is annotated with a label capturing the condition upon which that specific branch is taken. Moreover, always use mutually exclusive conditions, i.e. only one of them can be true every time the XOR-split is reached by a token. This is the characteristic of the XOR-split gateway. In our example an invoice can either be correct, or contain mismatches that can be fixed, or mismatches that cannot be fixed: only one of these conditions is true per invoice received.

In Fig. 3.4 the flow labeled "mismatches exist but cannot be corrected" is marked with an oblique cut. This notation is optional and is used to indicate the *default flow*, i.e. the flow that will be taken by the token coming from the XOR-split in case the conditions attached to all the other outgoing flows evaluate to false. Since this arc has the meaning of *otherwise*, it can be left unlabeled. However, we highly recommend to still label this arc with a condition for readability purposes.

Once either of the three alternative activities has been executed, we merge the flow back in order to execute activity "Park invoice" which is common to all three cases. For this we use an XOR-join. This particular gateway acts as a *passthrough*, meaning that it waits for a token to arrive from one of its input arcs and as soon as it receives the token, it sends the token to the output arc. In other words, with an XOR-join we proceed whenever an incoming branch has completed.

Coming back to our example, we complete the process model with an end event "Invoice handled". Make sure to always complete a process model with an end event, even if it is obvious how the process would complete.

Exercise 3.1 Model the following fragment of a business process for assessing loan applications.

> Once a loan application has been approved by the loan provider, an acceptance pack is prepared and sent to the customer. The acceptance pack includes a repayment schedule which the customer needs to agree upon by sending the signed documents back to the loan provider. The latter then verifies the repayment agreement: if the applicant disagreed with the repayment schedule, the loan provider cancels the application; if the applicant agreed, the loan provider approves the application. In either case, the process completes with the loan provider notifying the applicant of the application status.

3.2.2 Parallel Execution

When two or more activities do not have any order dependencies on each other (i.e. one activity does not need to follow the other, nor it excludes the other) they can be executed concurrently, or *in parallel*. The *parallel* (*AND*) *gateway* is used to model this particular relation. Specifically, we use an *AND-split* to model the parallel execution of two or more branches, and an *AND-join* to synchronize the execution of two or more parallel branches. An AND gateway is depicted as a diamond with a "+" mark.

Example 3.3 Security check at the airport.

> Once the boarding pass has been received, passengers proceed to the security check. Here they need to pass the personal security screening and the luggage screening. Afterwards, they can proceed to the departure level.

This process consists of four activities. It starts with activity "Proceed to security check" and finishes with activity "Proceed to departure level". These two activities have a clear order dependency: a passenger can only go to the departure level after

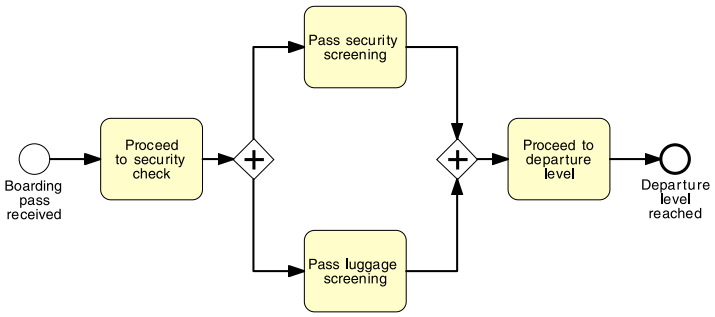


Fig. 3.5 An example of the use of AND gateways

undergoing the required security checks. After the first activity, and before the last one, we need to perform two activities which can be executed in any order, i.e. which do not depend on each other: "Pass personal security screening" and "Pass luggage screening". To model this situation we use an AND-split linking activity "Proceed to security check" with the two screening activities, and an AND-join linking the two screening activities with activity "Proceed to departure level" (see Fig. 3.5).

The AND-split *splits* the token coming from activity "Proceed to security check" into two tokens. Each of these tokens independently flows through one of the two branches. This means that when we reach an AND-split, we take all outgoing branches (note that an AND-split may have multiple outgoing arcs). As we said before, a token is used to indicate the state of a given instance. When multiple tokens of the same color are distributed across a process model, e.g. as a result of executing an AND-split, they collectively represent the state of an instance. For example, if a token is on the arc emitting from activity "Pass luggage screening" and another token of the same color is on the arc incident to activity "Pass personal security screening", this indicates an instance of the security check process where a passenger has just passed the luggage screening but not yet started the personal security screening.

The AND-join of our example waits for a token to arrive from each of the two incoming arcs, and once they are all available, it *merges* the tokens back into one. The single token is then sent to activity "Proceed to departure level". This means that we proceed when all incoming branches have completed (note again that an AND-join may have multiple incoming arcs). This behavior of waiting for a number of tokens to arrive and then merging the tokens into one is called *synchronization*.

Example 3.4 Let us extend the order fulfillment example of Fig. 3.1 by assuming that a purchase order is only confirmed if the product is in stock, otherwise the process completes by rejecting the order. Further, if the order is confirmed, the shipment address is received and the requested product is shipped *while* the invoice is emitted and the payment is received. Afterwards, the order is archived and the process completes.

The resulting model is shown in Fig. 3.6. Let us make a couple of remarks. First, this model has two activities that are mutually exclusive: "Confirm order" and "Re-

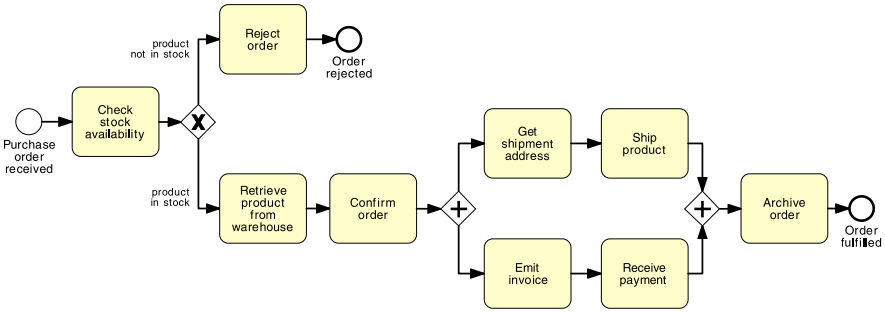


Fig. 3.6 A more elaborated version of the order fulfillment process diagram

ject order", thus we preceded them with an XOR-split (remember to put an activity before an XOR-split to allow the decision to be taken, such as a check like in this case, or an approval). Second, the two sequences "Get shipment address"–"Ship product" and "Emit invoice"–"Receive payment" can be performed independently of each other, so we put them in a block between an AND-split and an AND-join. In fact, these two sets of activities are typically handled by different resources within a seller's organization, like a sales clerk for the shipment and a financial officer for the invoice, and thus can be executed in parallel (note the word "meantime" in the process description, which indicates that two or more activities can be performed at the same time).

Let us compare this new version of the order fulfillment process with that in Fig. 3.1 in terms of events. The new version features two end events while the first version features one end event. In a BPMN model we can have multiple end events, each capturing a different outcome of the process (e.g. balance paid vs. arrears processed, order approved vs. order rejected). BPMN adopts the so-called *implicit termination* semantics, meaning that a process instance completes only when each token flowing in the model reaches an end event. Similarly, we can have multiple start events in a BPMN model, each event capturing a different trigger to start a process instance. For example, we may start our order fulfillment process either when a new purchase order is received or when a revised order is resubmitted. If a revised order is resubmitted, we first retrieve the order details from the orders database, and then continue with the rest of the process. This variant of the order fulfillment model is shown in Fig. 3.7. An instance of this process model is triggered by the first event that occurs (note the use of an XOR-join to merge the branches coming from the two start events).

Exercise 3.2 Model the following fragment of a business process for assessing loan applications.

A loan application is approved if it passes two checks: (i) the applicant's loan risk assessment, done automatically by a system, and (ii) the appraisal of the property for which the loan has been asked, carried out by a property appraiser. The risk assessment requires a

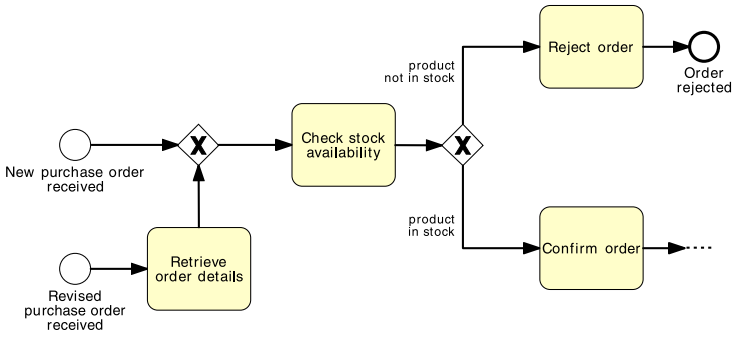


Fig. 3.7 A variant of the order fulfillment process with two different triggers

credit history check on the applicant, which is performed by a financial officer. Once both the loan risk assessment and the property appraisal have been performed, a loan officer can assess the applicant's eligibility. If the applicant is not eligible, the application is rejected, otherwise the acceptance pack is prepared and sent to the applicant.

There are two situations when a gateway can be omitted. An XOR-join can be omitted before an activity or event. In this case, the incoming arcs to the XOR-join are directly connected to the activity/event. An example of this shorthand notation is shown in Fig. 1.6, where there are two incident arcs to activity "Select suitable equipment". An AND-split can also be omitted when it follows an activity or event. In this case, the outgoing arcs of the AND-split emanate directly from the activity/event.

3.2.3 Inclusive Decisions

Sometimes we may need to take one *or more* branches after a decision activity. Consider the following business process.

Example 3.5 Order distribution process.

A company has two warehouses that store different products: Amsterdam and Hamburg. When an order is received, it is distributed across these warehouses: if some of the relevant products are maintained in Amsterdam, a sub-order is sent there; likewise, if some relevant products are maintained in Hamburg, a sub-order is sent there. Afterwards, the order is registered and the process completes.

Can we model the above scenario using a combination of AND and XOR gateways? The answer is yes. However, there are some problems. Figures 3.8 and 3.9 show two possible solutions. In the first one, we use an XOR-split with three alternative branches: one taken if the order only contains Amsterdam products (where the sub-order is forwarded to the Amsterdam warehouse), another taken if the order only contains Hamburg products (similarly, in this branch the sub-order is forwarded

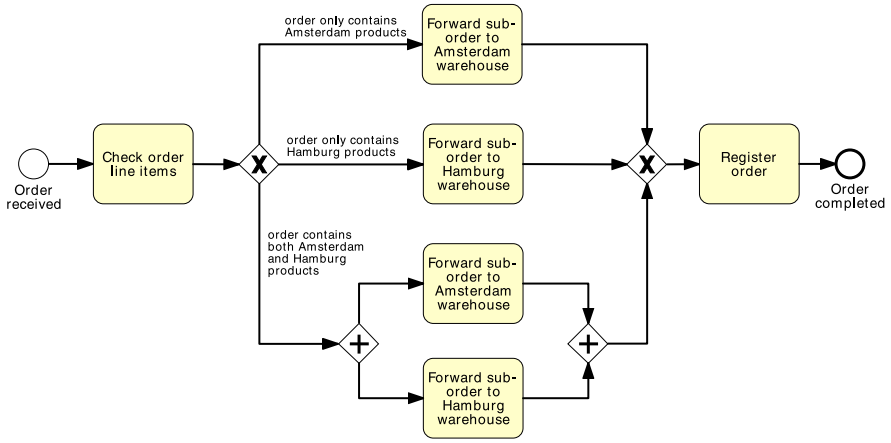


Fig. 3.8 Modeling an inclusive decision: first trial

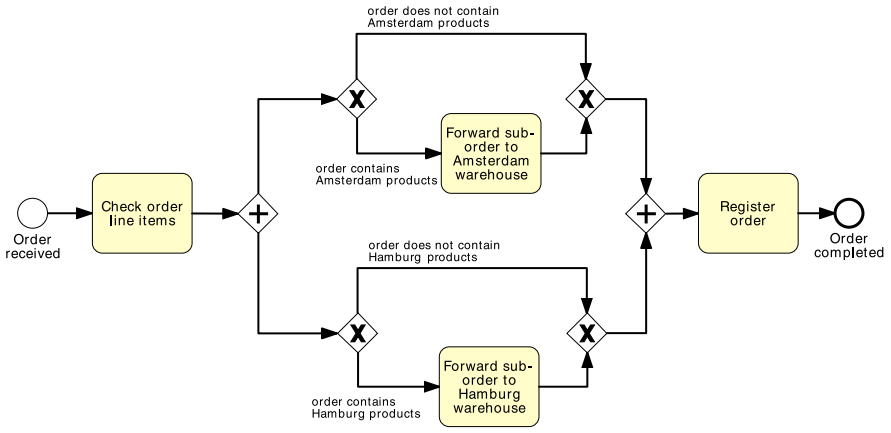


Fig. 3.9 Modeling an inclusive decision: second trial

to the Hamburg warehouse), and a third branch to be taken in case the order contains products from both warehouses (in which case sub-orders are forwarded to both warehouses). These three branches converge in an XOR-join which leads to the registration of the order.

While this model captures our scenario correctly, the resulting diagram is somewhat convoluted, since we need to duplicate the two activities that forward sub-orders to the respective warehouses twice. And if we had more than two warehouses, the number of duplicated activities would increase. For example, if we had three warehouses, we would need an XOR-split with seven outgoing branches, and each activity would need to be duplicated four times. Clearly this solution is not scalable.

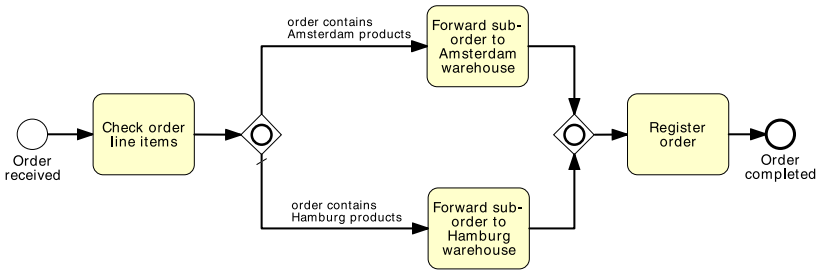


Fig. 3.10 Modeling an inclusive decision with the OR gateway

In the second solution we use an AND-split with two outgoing arcs, each of which leads to an XOR-split with two alternative branches. One is taken if the order contains Amsterdam (Hamburg) products, in which case an activity is performed to forward the sub-order to the respective warehouse; the other branch is taken if the order does not contain any Amsterdam (Hamburg) products, in which case nothing is done until the XOR-join, which merges the two branches back. Then an AND-join merges the two parallel branches coming out of the AND-split and the process completes by registering the order.

What is the problem with this second solution? The example scenario allows three cases: the products are in Amsterdam only, in Hamburg only, or in both warehouses, while this solution allows one more case, i.e. when the products are in neither of the warehouses. This case occurs when the two empty branches of the two XOR-splits are taken and results in doing nothing between activity "Check order line items" and activity "Register order". Thus this solution, despite being more compact than the first one, is wrong.

To model situations where a decision may lead to one or more options being taken at the same time, we need to use an *inclusive* (*OR*) *split gateway*. An *OR-split* is similar to the XOR-split, but the conditions on its outgoing branches do not need to be mutually exclusive, i.e. more than one of them can be true at the same time. When we encounter an OR-split, we thus take one or more branches depending on which conditions are true. In terms of token semantics, this means that the OR-split takes the input token and generates a number of tokens equivalent to the number of output conditions that are true, where this number can be at least one and at most as the total number of outgoing branches. Similar to the XOR-split gateway, an OR-split can also be equipped with a default flow, which is taken only when all other conditions evaluate to false.

Figure 3.10 shows the solution to our example using the OR gateway. After the sub-order has been forwarded to either of the two warehouses or to both, we use an *OR-join* to synchronize the flow and continue with the registration of the order. An OR-join proceeds when all *active* incoming branches have completed. Waiting for an active branch means waiting for an incoming branch that will ultimately de-

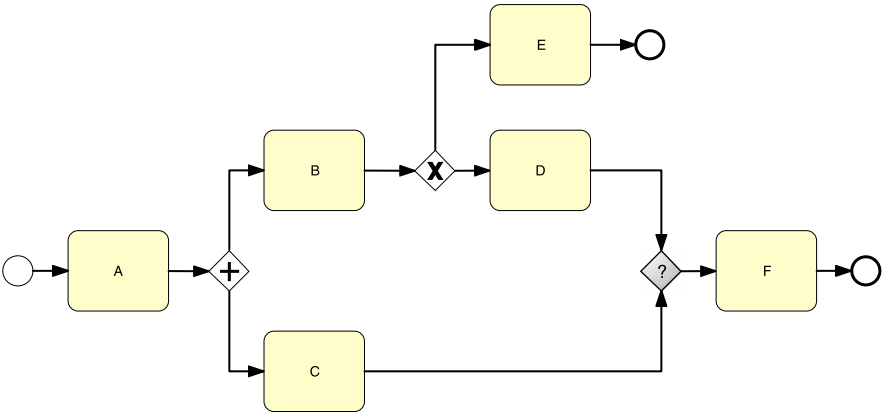


Fig. 3.11 What type should the join gateway have such that instances of this process can complete correctly?

liver a token to the OR-join. If the branch is active, the OR-join will wait for that token, otherwise it will not. Once all tokens of active branches have arrived, the OR-join synchronizes these tokens into one (similarly to what an AND-join does) and sends that token to its output arc. We call this behavior *synchronizing merge* as opposed to the simple merge of the XOR-join and the synchronization of the AND-join.

Let us delve into the concept of active branch. Consider the model in Fig. 3.11, which features a join gateway with undefined type (the one grayed out with a question mark). What type should we assign to this join? Let us try an AND-join to match the preceding AND-split. We recall that an AND-join waits for a token to arrive from each incoming branch. While the token from the branch with activity "C" will always arrive, the token from the branch with activities "B" and "D" may not arrive if this is routed to "E" by the XOR-split. So if activity "D" is not executed, the AND-join will wait indefinitely for that token, with the consequence that the process instance will not be able to progress any further. This behavioral anomaly is called *deadlock* and should be avoided.

Let us try an XOR-join. We recall that the XOR-join works as a passthrough by forwarding to its output branch each token that arrives through one of its input branches. In our example this means that we may execute activity "F" once or twice, depending whether the preceding XOR-split routes the token to "E" (in this case "F" is executed once) or to "D" ("F" is executed twice). While this solution may work, we have the problem that we do not know whether activity "F" will be executed once or twice, and we may actually not want to execute it twice. Moreover, if this is the case, we would signal that the process has completed twice, since the end event following "F" will receive two tokens. And this, again, is something we want to avoid.

The only join type left to try is the OR-join. An OR-join will wait for all incoming active branches to complete. If the XOR-split routes control to "E", the OR-join will not wait for a token from the branch bearing activity "D", since this will never arrive. Thus, it will proceed once the token from activity "C" arrives. On the other hand, if the XOR-split routes control to "D", the OR-join will wait for a token to also arrive from this branch, and once both tokens have arrived, it will merge them into one and send this token out, so that "F" can be executed once and the process can complete normally.

Question When should we use an OR-join?

Since the OR-join semantics is not simple, the presence of this element in a model may confuse the reader. Thus, we suggest to use it only when it is strictly required. Clearly, it is easy to see that an OR-join must be used whenever we need to synchronize control from a preceding OR-split. Similarly, we should use an AND-join to synchronize control from a preceding AND-split and an XOR-join to merge a set of branches that are mutually exclusive. In other cases the model will not have a lean structure like the examples in Fig. 3.8 or 3.10, where the model is made up of nested blocks each delimited by a split and a join of the same type. The model may rather look like that in Fig. 3.11, where there can be entry points into, or exist points from a block-structure. In these cases play the token game to understand the correct join type. Start with an XOR-join; next try an AND-join and if both gateways lead to incorrect models use the OR-join which will work for sure.

Now that we have learned the three core gateways, let us use them to extend the order fulfillment process. Assume that if the product is not in stock, it can be manufactured. In this way, an order can never be rejected.

Example 3.6

If the product requested is not in stock, it needs to be manufactured before the order handling can continue. To manufacture a product, the required raw materials have to be ordered. Two preferred suppliers provide different types of raw material. Depending on the product to be manufactured, raw materials may be ordered from either Supplier 1 or Supplier 2, or from both. Once the raw materials are available, the product can be manufactured and the order can be confirmed. On the other hand, if the product is in stock, it is retrieved from the warehouse before confirming the order. Then the process continues normally.

The model for this extended order fulfillment process is shown in Fig. 3.12.

Exercise 3.3 Model the following fragment of a business process for assessing loan applications.

A loan application may be coupled with a home insurance which is offered at discounted prices. The applicant may express their interest in a home insurance plan at the time of submitting their loan application to the loan provider. Based on this information, if the loan application is approved, the loan provider may either only send an acceptance pack to the applicant, or also send a home insurance quote. The process then continues with the verification of the repayment agreement.

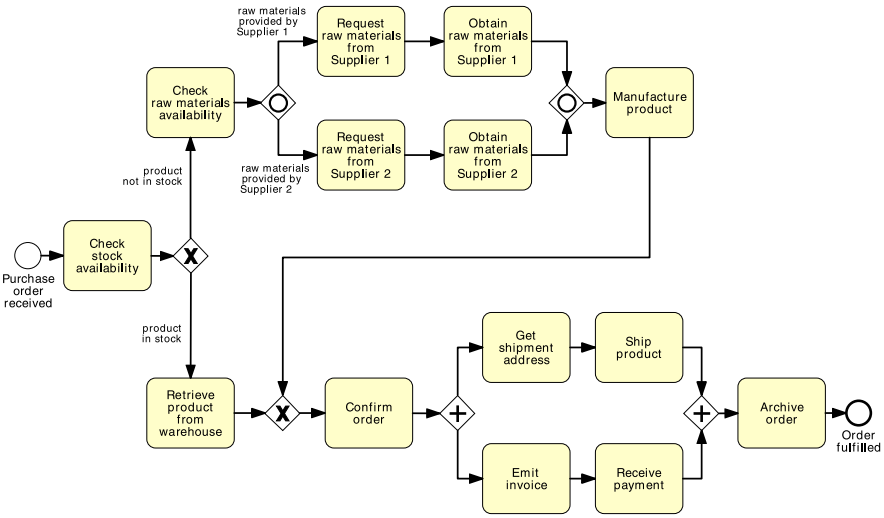


Fig. 3.12 The order fulfillment process diagram with product manufacturing

3.2.4 Rework and Repetition

So far we have seen structures that are linear, i.e. each activity is performed at most once. However, sometimes we may require to repeat one or several activities, for instance because of a failed check.

Example 3.7

> In the treasury minister's office, once a ministerial inquiry has been received, it is first registered into the system. Then the inquiry is investigated so that a ministerial response can be prepared. The finalization of a response includes the preparation of the response itself by the cabinet officer and the review of the response by the principal registrar. If the registrar does not approve the response, the latter needs to be prepared again by the cabinet officer for review. The process finishes only once the response has been approved.

To model rework or repetition we first need to identify the activities, or more in general the fragment of the process, that can be repeated. In our example this consists of the sequence of activities "Prepare ministerial response" and "Review ministerial response". Let us call this our *repetition block*. The property of a repetition block is that the last of its activities must be a decision activity. In fact, this will allow us to decide whether to go back before the repetition block starts, so that this can be repeated, or to continue with the rest of the process. As such, this decision activity should have two outcomes. In our example the decision activity is "Review ministerial response" and its outcomes are: "response approved" (in this case we continue with the process) and "response not approved" (we go back). To model these two outcomes, we use an XOR-split with two outgoing branches: one which allows us to continue with the rest of the process (in our example, this is simply

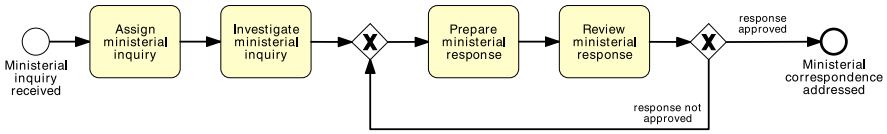


Fig. 3.13 A process model for addressing ministerial correspondence

the end event "Ministerial correspondence addressed"), the other which goes back to before activity "Prepare ministerial response". We use an XOR-join to reconnect this branch to the point of the process model just before the repetition block. The model for our example is illustrated in Fig. 3.13.

Question Why do we need to merge the loopback branch of a repetition block with an XOR-join?

The reason for using an XOR-join is that this gateway has a very simple semantics: it moves any token it receives in its input arc to its output arc, which is what we need in this case. In fact, if we merged the loopback branch with the rest of the model using an AND-join we would deadlock since this gateway would try to synchronize the two incoming branches when we know that only one of them can be active at a time: if we were looping we would receive the token from the loopback branch; otherwise we would receive it from the other branch indicating that we are entering the repetition block for the first time. An OR-join would work but is an overkill since we know that only one branch will be active at a time.

Exercise 3.4 Model the following fragment of a business process for assessing loan applications.

> Once a loan application is received by the loan provider, and before proceeding with its assessment, the application itself needs to be checked for completeness. If the application is incomplete, it is returned to the applicant, so that they can fill out the missing information and send it back to the loan provider. This process is repeated until the application is found complete.

We have learned how to combine activities, events, and gateways to model basic business processes. For each such element we have showed its graphical representation, the rules for combining it with other modeling elements and explained its behavior in terms of token rules. All these aspects fall under the term *components of a modeling language*. If you want to know more about this topic, you can read the box "Components of a modeling language".

COMPONENTS OF A MODELING LANGUAGE

A *modeling language* consists of three parts: syntax, semantics, and notation. The *syntax* provides a set of modeling elements and a set of rules to govern

how these elements can be combined. The *semantics* bind the syntactical elements and their textual descriptions to a precise meaning. The *notation* defines a set of graphical symbols for the visualization of the elements.

For example, the BPMN syntax includes activities, events, gateways, and sequence flows. An example of syntactical rule is that start events only have outgoing sequence flows whereas end events only have incoming sequence flows. The BPMN semantics describes which kind of behavior is represented by the various elements. In essence, this relates to the question how the elements can be executed in terms of token flow. For example, an AND-join has to wait for all incoming branches to complete before it can pass control to its outgoing branch. An example of BPMN notation is the use of labeled rounded boxes to depict activities.

3.3 Information Artifacts

As shown in Chap. 2, a business process entails different organizational aspects such as functions, business artifacts, humans, and software systems. These aspects are captured by different process modeling perspectives. So far we have seen the *functional perspective*, which indicates what activities should happen in the process, and the *control-flow perspective*, which indicates when activities and events should occur. Another important perspective that we ought to consider when modeling business processes is the *data perspective*. The data perspective indicates which information artifacts (e.g. business documents, files) are required to perform an activity and which ones are produced as a result of performing an activity.

Let us enrich the order fulfillment process of Example 3.6 with artifacts. Let us start by identifying the artifacts that each activity requires in order to be executed, and those that each activity creates as a result of its execution. For example, the first activity of the order fulfillment process is "Check stock availability". This requires a Purchase order as input in order to check whether or not the ordered product is in stock. This artifact is also required by activity "Check raw materials availability" should the product be manufactured. Artifacts like Purchase order are called *data objects* in BPMN. Data objects represent information flowing in and out of activities; they can be physical artifacts such as an invoice or a letter on a piece of paper, or electronic artifacts such as an e-mail or a file. We depict them as a document with the upper-right corner folded over, and link them to activities with a dotted arrow with an open arrowhead (called *data association* in BPMN). Figure 3.14 shows the data objects involved in the order fulfillment process model.

We use the direction of the data association to establish whether a data object is an input or output for a given activity. An incoming association, like the one used from Purchase order to activity "Check stock availability", indicates that Purchase order is an input object for this activity; an outgoing association, like the one used

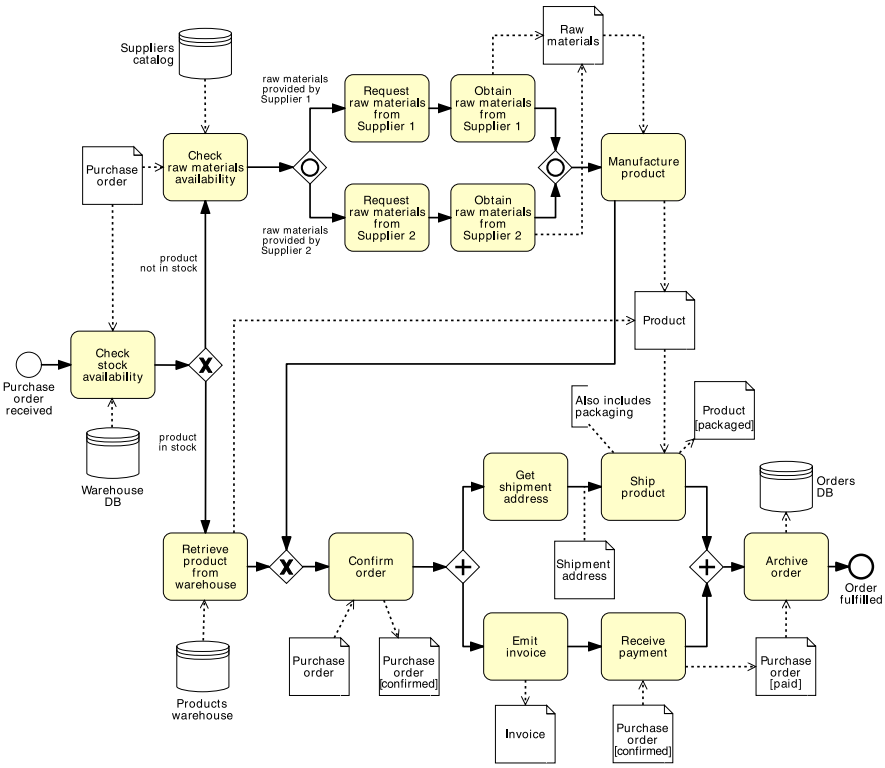


Fig. 3.14 The order fulfillment example with artifacts

from activity "Obtain raw materials from Supplier 1" to Raw materials, indicates that Raw materials is an output object for this activity. To avoid cluttering the diagram with data associations that cross sequence flows, we may repeat a data object multiple times within the same process model. However, all occurrences of a given object do conceptually refer to the same artifact. For example, in Fig. 3.14 Purchase order is repeated twice as input to "Check stock availability" and to "Confirm order" since these two activities are far away from each other in terms of model layout.

Often the output from an activity coincides with the input to a subsequent activity. For example, once Raw materials have been obtained, these are used by activity "Manufacture product" to create a Product. The Product in turn is packaged and sent to the customer by activity "Ship product". Effectively, data objects allow us to model the information flow between process activities. Bear in mind, however, that data objects and their associations with activities cannot replace the sequence flow. In other words, even if an object is passed from an activity A to an activity B, we still need to model the sequence flow from A to B. A shorthand notation for passing an object from an activity to the other is by directly connecting the data object to the sequence flow between two consecutive activities via an undirected association. See for example the Shipment address being passed from activity "Get

shipment address" to activity "Ship product", which is a shorthand for indicating that Shipment address is an output of "Get shipment address" and an input to "Ship product".

Sometimes we may need to represent the *state* of a data object. For instance, activity "Confirm order" takes a Purchase order as input, and returns a "confirmed" Purchase order as output: input and output objects are the same, but the object's state has changed to "confirmed". Similarly, activity "Receive payment" takes as input a "confirmed" Purchase order and transforms it into a "paid" Purchase order. An object can go through a number of states, e.g. an invoice is first "opened", then "approved" or "rejected" and finally "archived". Indicating data objects' states is optional: we can do so by appending the name of the state between square brackets to a data object's label, e.g. "Purchase Order [confirmed]", "Product [packaged]".

A *data store* is a place containing data objects that need to be persisted beyond the duration of a process instance, e.g. a database for electronic artifacts or a filing cabinet for physical ones. Process activities can read/write data objects from/to data stores. For example, activity "Check stock availability" retrieves the Stock levels for the ordered product from the Warehouse database, which contains Stock level information for the various Products. Similarly, activity "Check raw materials availability" consults the Suppliers catalog to check which Supplier to contact. The Warehouse database or the Supplier catalog are examples of data stores used as input to activities. An example of data store employed as output is the Orders database, which is used by activity "Archive order" to store the confirmed Purchase order. In this way, the order just archived will be available for other business processes within the same organization, e.g. for a business process that handles requests for product returns. Data stores are represented as an empty cylinder (the typical database symbol) with a triple upper border. Similar to data objects, they are connected to activities via data associations.

Question Do data objects affect the token flow?

Input data objects are required for an activity to be executed. Even if a token is available on the incoming arc of that activity, the latter cannot be executed until all input data objects are also available. A data object is available if it has been created as a result of completing a preceding activity (whose output was the data object itself), or because it is an input to the whole process (like Purchase order). Output data objects only affect the token flow indirectly, i.e. when they are used by subsequent activities.

Question Do we always need to model data objects?

Data objects help the reader understand the flow of business data from one activity to the other. However, the price to pay is an increased complexity of the diagram. Thus, we suggest to use them only when they are needed for a specific purpose, e.g. to highlight potential issues in the process under analysis (cf. Chaps. 6 and 7) or for automation (cf. Chap. 9).

Sometimes we may need to provide additional information to the process model reader, for the sake of improving the understanding of the model. For example, in the order fulfillment process we may want to specify that activity "Ship product" includes the packaging of the product. Also, we may want to clarify what business rule is followed behind the choice of raw materials from Suppliers. Such additional information can be provided via *text annotations*. An annotation is depicted as an open-ended rectangle encapsulating the text of the annotation, and is linked to a process modeling element via a dotted line (called *association*)—see Fig. 3.14 for an example. Text annotations do not bear any semantics, thus they do not affect the flow of tokens through the process model.

Exercise 3.5 Put together the four fragments of the loan assessment process that you created in Exercises 3.1–3.4.

Hint Look at the labels of the start/end events to understand the order dependencies among the various fragments. Then extend the resulting model by adding all the required artifacts. Moreover, attach annotations to specify the business rules behind (i) checking an application completeness, (ii) assessing an application eligibility, and (iii) verifying a repayment agreement.

3.4 Resources

A further aspect we need to consider when modeling business processes is the *resource perspective*. This perspective, also called the *organizational perspective*, indicates who or what performs which activity. *Resource* is a generic term to refer to anyone or anything involved in the performance of a process activity. A resource can be:

- A *process participant*, i.e. an individual person like the employee John Smith.
- A *software system*, for example a server or a software application.
- An *equipment*, such as a printer or a manufacturing plant.

We distinguish between *active resources*, i.e. resources that can autonomously perform an activity, and *passive resources*, i.e. resources that are merely involved in the performance of an activity. For example, a photocopier is used by a participant to make a copy of a document, but it is the participant who performs the photocopying activity. So, the photocopier is a passive resource while the participant is an active resource. A bulldozer is another example of a passive resource since it is the driver who performs the activity in which the bulldozer is used.

The resource perspective of a process is interested in active resources, so from now on with the term "resource" we refer to an "active resource".

Frequently, in a process model we do not explicitly refer to one resource at a time, like for example an employee John Smith, but instead we refer to a group of resources that are interchangeable in the sense that any member of the group can

perform a given activity. Such groups are called *resource classes*. Examples are a whole organization, an organizational unit or a role.[1]

Let us examine the resources involved in our order fulfillment example.

Example 3.8

> The order fulfillment process is carried out by a seller's organization which includes two departments: the sales department and the warehouse & distribution department. The purchase order received by warehouse & distribution is checked against the stock. This operation is carried out automatically by the ERP system of warehouse & distribution, which queries the warehouse database. If the product is in stock, it is retrieved from the warehouse before sales confirm the order. Next sales emit an invoice and wait for the payment, while the product is shipped from within warehouse & distribution. The process completes with the order archival in the sales department. If the product is not in stock, the ERP system within warehouse & distribution checks the raw materials availability by accessing the suppliers catalog. Once the raw materials have been obtained the warehouse & distribution department takes care of manufacturing the product. The process completes with the purchase order being confirmed and archived by the sales department.

BPMN provides two constructs to model resource aspects: *pools* and *lanes*. Pools are generally used to model resource classes, lanes are used to partition a pool into sub-classes or single resources. There are no constraints as to what specific resource type a pool or a lane should model. We would typically use a pool to model a *business party* like a whole organization such as the seller in our example, and a lane to model a department, unit, team or software system/equipment within that organization. In our example, we partition the Seller pool into two lanes: one for the warehouse & distribution department, the other for the sales department.

Lanes can be nested within each other in multiple levels. For example, if we need to model both a department and the roles within that department, we can use one outer lane for the department, and one inner lane for each role. In the order fulfillment example we nest a lane within Warehouse & Distribution to represent the ERP System within that department.

Pools and lanes are depicted as rectangles within which we can place activities, events, gateways, and data objects. Typically, we model these rectangles horizontally, though modeling them vertically is also possible. The name of the pool/lane is shown vertically on the left-hand side of a horizontal rectangle (or horizontally if the pool/lane is vertical); for pools, and for lanes containing nested lanes , the name is enclosed in a band. Figure 3.15 shows the revised order fulfillment example with resource aspects.

It is important to place an activity within the right lane. For example, we placed activity "Check stock availability" under the ERP System lane of Warehouse & Distribution to indicate that this activity is carried out automatically by the ERP system of that department. It is also important to place events properly within lanes. In our example we put event "Purchase order received" under the ERP system lane to indicate that the process starts within the ERP system of Warehouse & Distribution,

[1] In BPMN the term "participant" is used in a broad sense as a synonym of resource class, though in this book we do not adopt this definition.

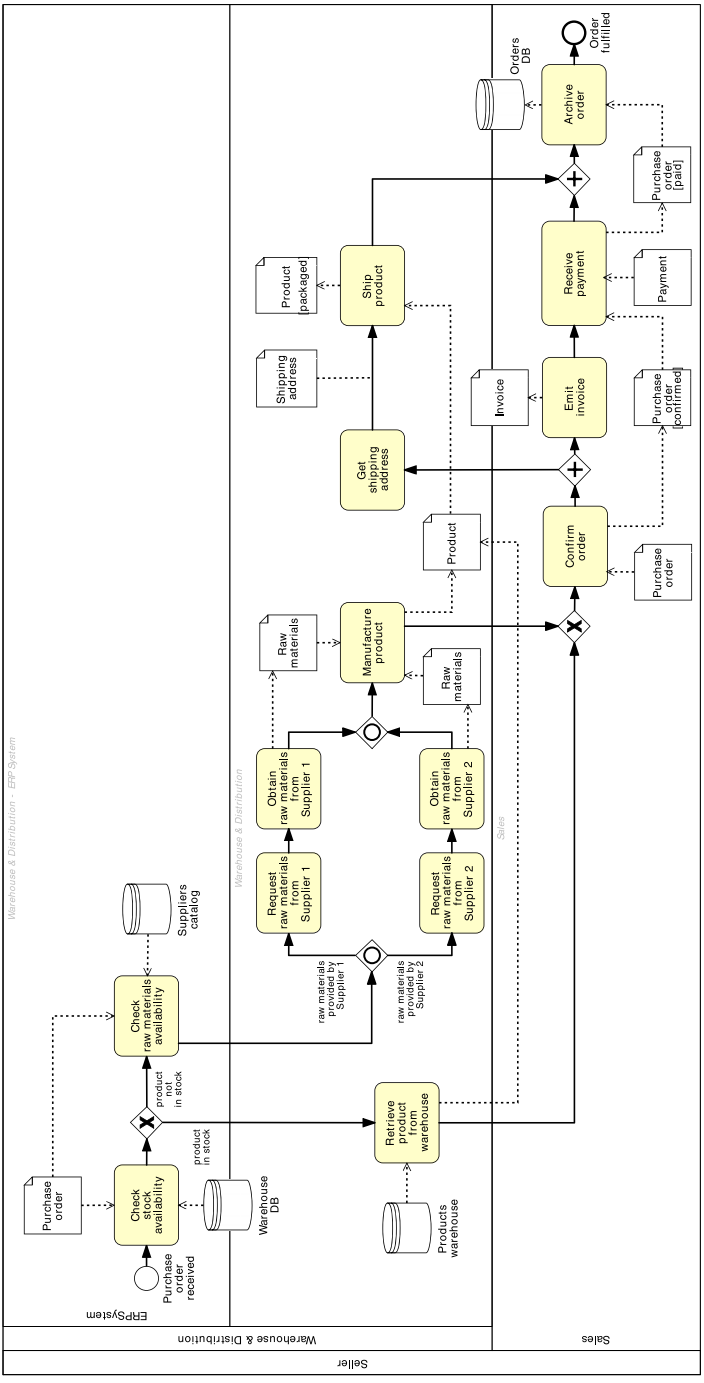


Fig. 3.15 The order fulfillment example with resource information

while we put event "Order fulfilled" under the Sales pool to indicate that the process completes in the sales department. It is not relevant where data objects are put, as they depend on the activities they are linked to. As per gateways, we need to place those modeling (X)OR-splits under the same lane as the preceding decision activity has been put in. On the other hand, it is irrelevant where we place an AND-split and all join gateways, since these elements are passive in the sense that they behave according to their context.

We may organize lanes within a pool in a matrix when we need to model complex organizational structures. For example, if we have an organization where roles span different departments, we may use horizontal lanes to model the various departments, and vertical lanes to model the roles within these departments. Bear in mind, however, that in BPMN each activity can be performed by one resource only. Thus, if an activity sits in the intersection of a horizontal lane with a vertical lane, it will be performed by the resource that fulfills the characteristics of both lanes, e.g. a resource that has that role and belongs to that department.

Exercise 3.6 Extend the business process for assessing loan applications that you created in Exercise 3.5 by considering the following resource aspects.

> The process for assessing loan applications is executed by four roles within the loan provider: a financial officer takes care of checking the applicant's credit history; a property appraiser is responsible for appraising the property; an insurance sales representative sends the home insurance quote to the applicant if this is required. All other activities are performed by the loan officer who is the main point of contact with the applicant.

Often there is more than one business party participating in the same business process. For example, in the order fulfillment process there are four parties: the seller, the customer and the two suppliers.

Each party can be modeled by a pool. In our example we can thus use one pool for the customer, one for the seller and one for each supplier. Each of these pools will contain the activities, events, gateways, and data objects that model the specific portion of the business process occurring at that organization. Or to put it differently, each pool will model the same business process from the perspective of a specific organization. For example, event "Purchase order received" which sits in the Sales pool, will have a corresponding activity "Submit purchase order" occurring in the Customer pool. Similarly, activity "Ship product" from Sales will have a counterpart activity "Receive product" in the Customer pool. So, how can we model the interactions among the pools of two collaborating organizations? We cannot use the sequence flow to connect activities that belong to different pools since the sequence flow cannot cross the boundary of a pool. For this, we need to use a specific element called *message flow*.

A message flow represents the flow of information between two separate resource classes (pools). It is depicted as a dashed line which starts with an empty circle and ends with an empty arrowhead, and bears a label indicating the content of the message, e.g. a fax, a purchase order, but also a letter or a phone call. That is, the

message flow models any type of communication between two organizations, no matter if this is electronic like sending a purchase order via e-mail or transmitting a fax, or manual like making a phone call or handing over a letter on paper.

Figure 3.16 shows the complete order fulfillment process model including the pools for the customer and the two suppliers. Here we can see that message flows are labeled with the piece of information they carry, e.g. "Raw materials" or "Shipment address". An incoming message flow may lead to the creation of a data object by the activity that receives the message. For example, the message flow "Raw materials" is received by activity "Obtain raw materials from Supplier 1" which then creates the data object "Raw materials". This is also the case of the purchase order, which is generated by the start event "Purchase order received" from the content of the incoming message flow. We do not need to create a data object for each incoming message flow, only when the information carried by the message is needed elsewhere in the process. In our case, "Raw materials" is consumed by activity "Manufacture product" so we need to represent it as a data object. Similarly, we do not need to explicitly represent the data object that goes into an outgoing message if this data object is not needed elsewhere in the process. For example, activity "Emit invoice" generates an invoice which is sent to the customer, but there is no data object "Invoice" since this is not consumed by any activity in the Seller pool.

A BPMN diagram that features two or more pools is called *collaboration diagram*. Figure 3.16 shows different uses of a pool in a collaboration diagram. A pool like that for the seller is called *private process*, or *white box* pool, since it shows how effectively the seller organization participates in the order fulfillment process in terms of activities, events, gateways, and data objects. On the contrary, a pool like that for the customer and the two suppliers is called *public process*, or *black box* pool, since it hides how these organizations actually participate in the order fulfillment process. In order to save space, we can represent a black box with a *collapsed pool*, which is an empty rectangle bearing the name of the pool in the middle.

Question Black box or white box?

Modeling a pool as a white box or as a black box is a matter of relevance. When working on a collaboration diagram, an organization may decide whether or not to expose their internal behavior depending on the requirements of the project at hand. For example, if we are modeling the order fulfillment process from the seller's perspective, it may be relevant to expose the business process of the seller only, but not that of the customer and the suppliers. That is, the internal behavior of the customer and that of the suppliers are not relevant for the sake of understanding how the seller should fulfill purchase orders, and as such they can be hidden. On the other hand, if we need to improve the way the seller fulfills purchase orders, we may also want to know what it takes for a supplier to provide raw materials, as a delay in the provision of raw materials will slow down the product manufacturing

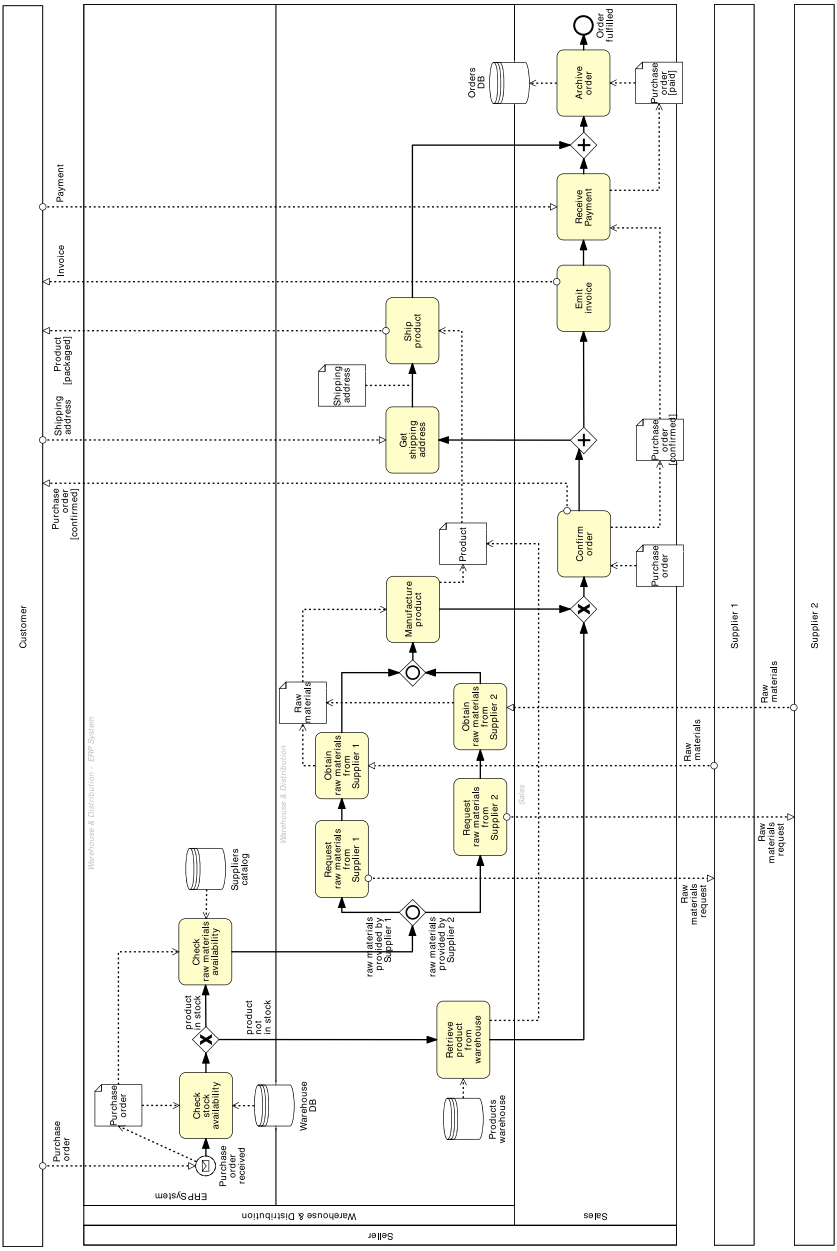


Fig. 3.16 Collaboration diagram between a seller, a customer and two suppliers

at the seller's side. In this case, we should also represent the suppliers using white box pools.

The type of pool affects the way we use the message flow to connect to the pool. Accordingly, a message flow may cross the boundary of a white box pool and connect directly to an activity or event within that pool, like the Purchase order message which is incident to the start event in the Seller pool. On the other hand, since a black box pool is empty, message flows must stop at the boundary or emanate from the boundary of a black box pool. Bear in mind that a message flow is only used to connect two pools and never to connect two activities within the same pool. For that, we use a sequence flow.

An activity that is the source of a message—such as "Emit invoice" in the Seller pool—is called a *send activity*. The message is sent upon completion of the activity's execution. On the other hand, an activity that receives a message—such as "Get shipping address"—is a *receive activity*.[2] The execution of such an activity will not start until the incoming message is available. An activity can act as both a receive and a send activity when it has both an incoming and outgoing message flow, e.g. "Make payment". The execution of this activity will start when both the control-flow token and the incoming message are available. Upon completion of the activity, a control-flow token will be put on the output arc and the outgoing message will be sent out. Finally, when a message flow is incident to a start event like "Purchase order received", we need to mark this event with a light envelope (see Fig. 3.16). This event type is called *message event*. A message event can be linked to an output data object in order to store the content of the incoming message. We will learn more about events in the next chapter.

Exercise 3.7 Extend the model of Exercise 3.6 by representing the interactions between the loan provider and the applicant.

In the order fulfillment example we used pools to represent business parties and lanes to represent the departments and systems within the sales organization. This is because we wanted to focus on the interactions between the seller, the customer and the two suppliers. As mentioned before, this is the typical use for pools and lanes. However, since BPMN does not prescribe what specific resource types should be associated with pools and lanes, we may use these elements differently. For example, if the focus is on the interactions between the departments of an organization, we can model each department with a pool, and use lanes to partition the departments, e.g. in units or roles. In any case, we should avoid to use pools and lanes to capture participants by their names since individuals tend to change frequently within an organization; rather, we should use the participant's role, e.g. financial officer. On the other hand, we can use pools and lanes to represent specific software systems or equipments, e.g. an ERP system, since these change less frequently in an organization.

[2]More specifically, "Emit invoice" is a *send task* and "Get shipping address" is a *receive task*. The distinction between activity and task will be discussed in Chap. 4.

3.5 Recap

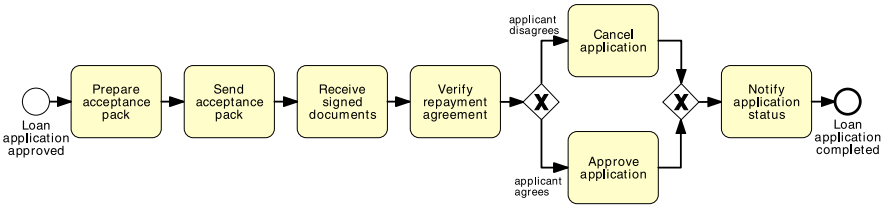
At the end of this chapter, we should be able to understand and produce basic process models in BPMN. A basic BPMN model includes simple activities, events, gateways, data objects, pools, and lanes. Activities capture units of work within a process. Events define the start and end of a process, and signal something that happens during the execution of it. Gateways model exclusive and inclusive decisions, merges, parallelism and synchronization, and repetition. We studied the difference between process model and process instance. A process model depicts all the possible ways a given business process can be executed, while a process instance captures one specific process execution out of all possible ones. The progress, or state, of a process instance is represented by tokens. Using tokens we can define the behavior of gateways.

We also learned how to use data objects to model the information flow between activities and events. A data object captures a physical or an electronic artifact required to execute an activity or trigger an event, or that results from the execution of an activity or an event occurrence. Data objects can be stored in a data store like a database or file cabinet such that they can be persisted beyond the process instance where they are created. Furthermore, we saw how pools and lanes can be used to model both human and non-human resources that perform process activities. Pools generally model resource classes while lanes are used to partition pools. The interaction between pools is captured by message flows. Message flows can be directly attached to the boundary of a pool, should the details of the interaction not be relevant.

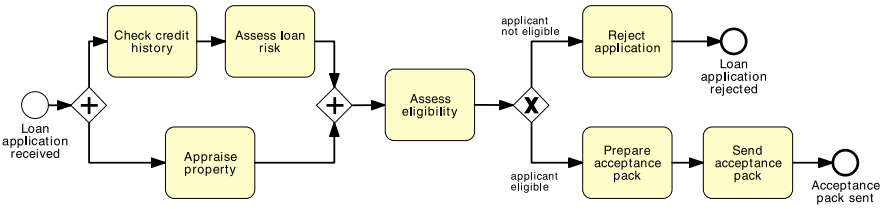
Activities, events, gateways, artifacts, and resources belong to the main modeling perspectives of a business process. The functional perspective captures the activities that are performed in a business process while the control-flow perspective combines these activities and related events in a given order. The data perspective covers the artifacts manipulated in the process while the resource perspective covers the resources that perform the various activities. In the next chapter, we will learn how to model complex business processes by delving into the various extensions of the core BPMN elements that we presented here.

3.6 Solutions to Exercises

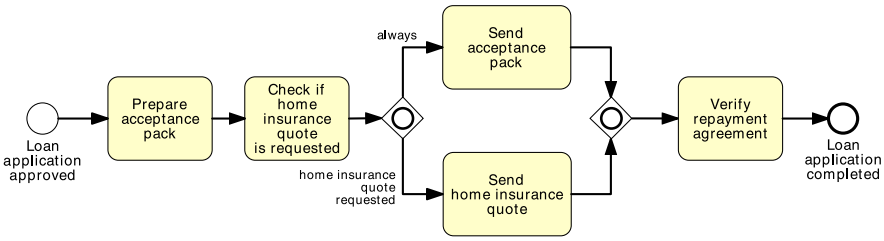
Solution 3.1



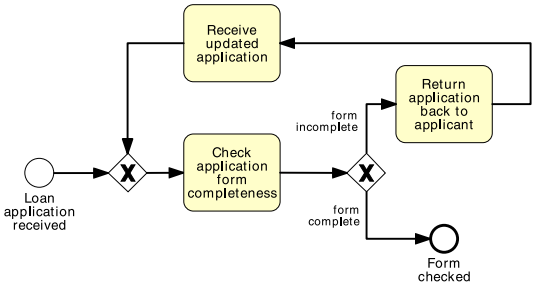
Solution 3.2



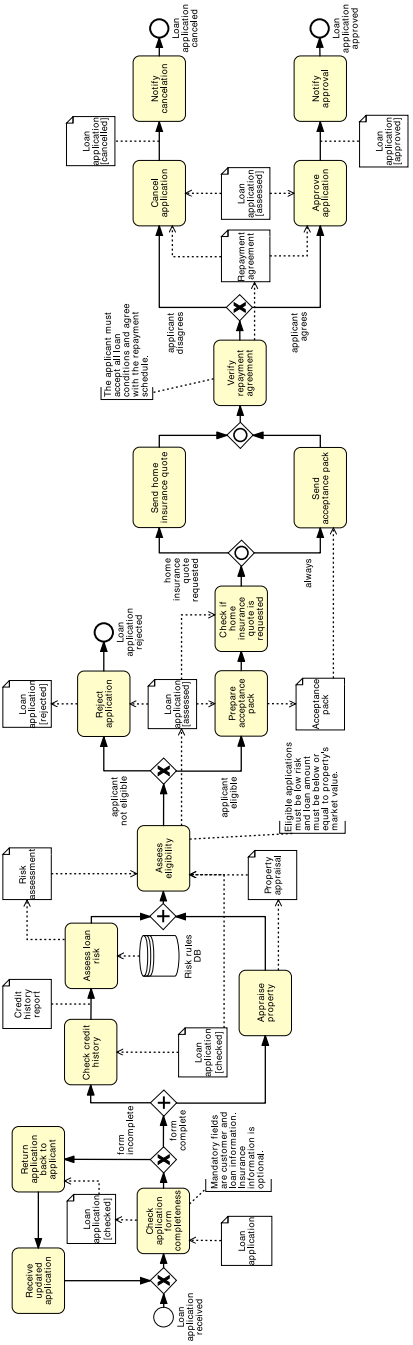
Solution 3.3



Solution 3.4

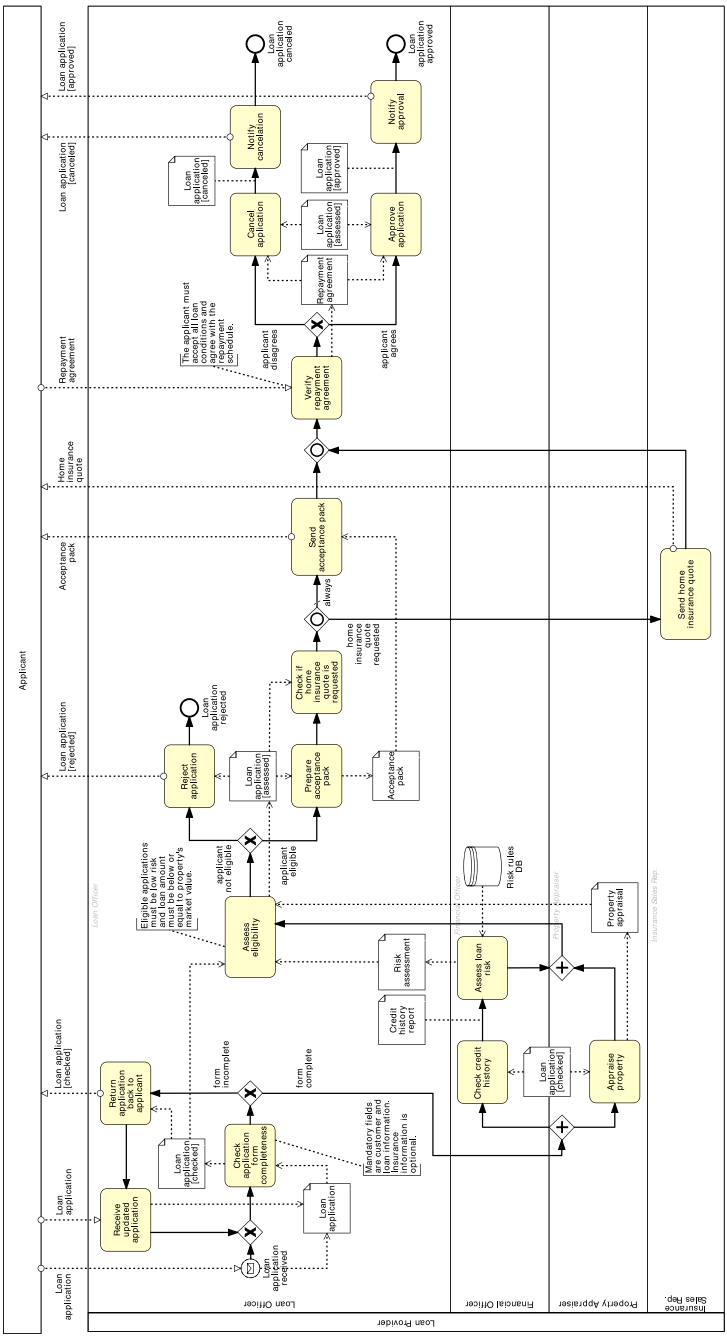


Solution 3.5


Loan application received
Receive updated application
Return application to back to applicant
Check application form completeness
Loan application [checked]
Loan application
Mandatory fields are customer and loan information. Insurance information is optional.
form incomplete
form complete
Check credit history
Credit history report
Loan application [checked]
Assess loan risk
Risk rules DB
Appraise property
Risk assessment
Assess eligibility
Property appraisal
Eligible applications must be low risk and the amount must be below or equal to property's market value.
applicant not eligible
applicant eligible
Reject application
Loan application [rejected]
Loan application [assessed]
Loan application rejected
Prepare acceptance pack
Acceptance pack
Check if home insurance quote is requested
home insurance quote requested
always
Send home insurance quote
Send acceptance pack
Verify repayment agreement
The applicant must accept all loan conditions and agree with the repayment schedule.
applicant disagrees
applicant agrees
Repayment agreement
Cancel application
Loan application [cancelled]
Loan application [assessed]
Approve application
Loan application [approved]
Notify cancelation
Notify approval
Loan application canceled
Loan application approved

Solution 3.6 See the Loan Provider pool in the model of Solution 3.7.

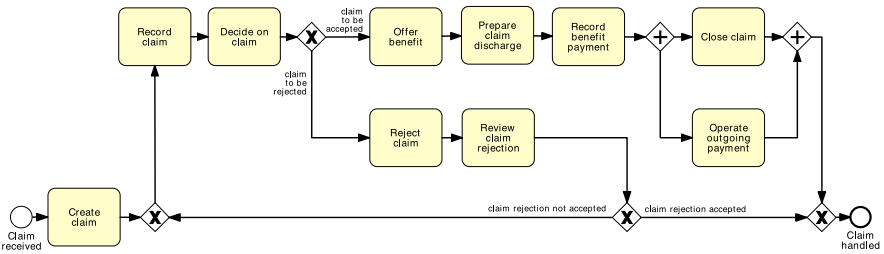
Solution 3.7



3.7 Further Exercises

Exercise 3.8 What types of splits and joins can we model in a process? Make an example for each of them using the security check at an airport as a scenario.

Exercise 3.9 Describe the following process model.



Exercise 3.10 Model the following business process for handling downpayments.

The process for handling downpayments starts when a request for payment has been approved. It involves entering the downpayment request into the system, the automatic subsequent payment, emission of the direct invoice and the clearance of the vendor line items. The clearing of the vendor line items can result in a debit or credit balance. In case of debit balance, the arrears are processed, otherwise the remaining balance is paid.

Exercise 3.11 Model the following business process for assessing credit risks.

When a new credit request is received, the risk is assessed. If the risk is above a threshold, an advanced risk assessment needs to be carried out, *otherwise* a simple risk assessment will suffice. Once the assessment has been completed, the customer is notified with the result of the assessment and *meantime* the disbursement is organized. For simplicity, assume that the result of an assessment is always positive.

Exercise 3.12 Model the following fragment of a business process for insurance claims.

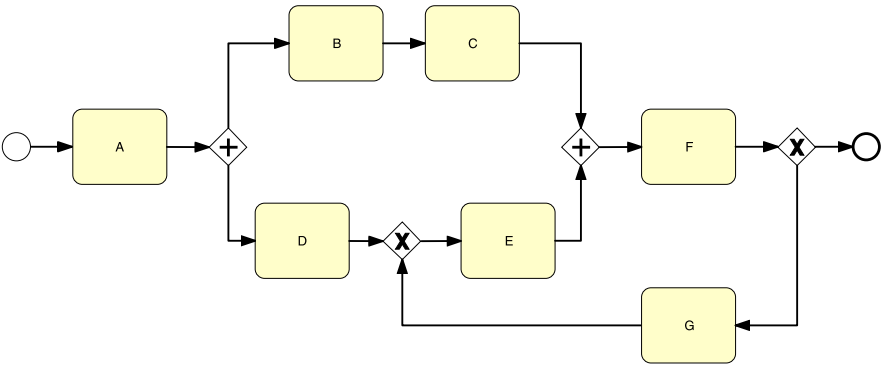
After a claim is registered, it is examined by a claims officer who then writes a settlement recommendation. This recommendation is then checked by a senior claims officer who may mark the claim as “OK” or “Not OK”. If the claim is marked as “Not OK”, it is sent back to the claims officer and the recommendation is repeated. If the claim is “OK”, the claim handling process proceeds.

Exercise 3.13 Model the control flow of the following business process for damage compensation.

If a tenant is evicted because of damages to the premises, a process needs to be started by the tribunal in order to hold a hearing to assess the amount of compensation the tenant owes the owner of the premises. This process starts when a cashier of the tribunal receives a request for compensation from the owner. The cashier then retrieves the file for those particular premises and checks that both the request is acceptable for filing, and compliant with the

description of the premises on file. Setting a hearing date incurs fees to the owner. It may be that the owner has already paid the fees with the request, in which case the cashier allocates a hearing date and the process completes. It may be that additional fees are required, but the owner has already paid also those fees. In this case the cashier generates a receipt for the additional fees and proceeds with allocating the hearing date. Finally, if the owner has not paid the required fees, the cashier produces a fees notice and waits for the owner to pay the fees before reassessing the document compliance.

Exercise 3.14 Can the process model below execute correctly? If not, how can it be fixed without affecting the cycle, i.e. such that "F", "G", and "E" all remain in the cycle?



Exercise 3.15 Write a BPMN model for the process described in Exercise 1.1. Make sure to include artifacts and annotations where appropriate.

Exercise 3.16 Extend the model of Exercise 3.13 by adding the artifacts that are manipulated.

Exercise 3.17 Extend the model of Exercise 3.16 by adding the involved resources. Is there any non-human resource?

Exercise 3.18 Model the following business process. Use gateways and data objects where needed.

In a court each morning the files that have yet to be processed are checked to make sure they are in order for the court hearing that day. If some files are missing a search is initiated, otherwise the files can be physically tracked to the intended location. Once all the files are ready, these are handed to the Associate; meantime the judge's lawlist is distributed to the relevant people. Afterwards, the directions hearings are conducted.

Exercise 3.19 Model the following business process. Use pools/lanes where needed.

The motor claim handling process starts when a customer submits a claim with the relevant documentation. The notification department at the car insurer checks the documents upon

completeness and registers the claim. Next, the Handling department picks up the claim and checks the insurance. Then, an assessment is performed. If the assessment is positive, a Garage is phoned to authorize the repairs and the payment is scheduled (in this order). Otherwise, the claim is rejected. In any case (whether the outcome is positive or negative), a letter is sent to the customer and the process is considered to be complete.

Exercise 3.20 Model the following business process. Use pools/lanes where needed.

When a claim is received, a claims officer first checks if the claimant is insured. If not, the claimant is informed that the claim must be rejected by sending an automatic notification via an SAP system. Otherwise, a senior claims officer evaluates the severity of the claim. Based on the outcome (simple or complex claims), the relevant forms are sent to the claimant, again using the SAP system. Once the forms are returned, they are checked for completeness by the claims officer. If the forms provide all relevant details, the claim is registered in the claims management system, and the process ends. Otherwise, the claimant is informed to update the forms via the SAP system. Upon reception of the updated forms, they are checked again by the claims officer to see if the details have been provided, and so on.

3.8 Further Reading

In this chapter we presented the basics of process modeling through the BPMN language. Other mainstream languages that can be used to model business processes are UML Activity Diagrams (UML ADs), Event-driven Process Chains (EPCs) and Web Services Business Process Execution Language (WS-BPEL). UML ADs are another OMG standard [60]. They are mainly employed in software engineering where they can be used to describe software behavior and linked to other UML diagram types, e.g. class diagrams, to generate software code. UML ADs offer a subset of the modeling elements present in BPMN. For example, constructs like the OR-join are not supported. A good overview of this language and its application to business process modeling is provided in [16].

EPCs were initially developed for the design of the SAP R/3 reference process model [9]. They obtained a widespread adoption by various organizations when they became the core modeling language of the ARIS toolset [12, 82]. Later, they were used by other vendors for the design of SAP-independent reference models such as ITIL and SCOR. The EPC language includes modeling elements corresponding to BPMN activities, AND, XOR and OR gateways, untyped events and data objects. An introduction to EPCs is provided in [50].

WS-BPEL (BPEL for short) version 2.0 [3] is a standard of the Organization for the Advancement of Structured Information Standards (OASIS). A good overview of BPEL is provided in [65]. BPEL is a language for process execution which relies on Web service technology to achieve inter-process communication. A mapping from BPMN to BPEL constructs is available in the BPMN specification [61]. However, this mapping is not complete since BPEL offers a restricted set of constructs compared to BPMN, and is essentially a *block-oriented* language, while BPMN is *graph-oriented*. BPEL is structured in blocks which need to be properly nested and

cannot overlap. A block is made up of a single entry node and a single exit node which matches the type of the entry node and collects all the outgoing branches from the entry node. For example, if the entry node is an AND-split, the exit node must be an AND-join. Moreover, BPEL does not feature a standard notation, since this was deemed to be out of scope by OASIS, though various vendors provide proprietary notations for this language. While BPMN 1.2 aimed to be the conceptual counterpart of BPEL, and mappings were thus available to move from the former to the latter language, BPMN 2.0 can also be used to specify executable processes (see Chap. 9). Thus BPMN 2.0 aims to replace BPEL in this respect.

Other process modeling languages originate from research efforts. Two of them are Workflow nets and Yet Another Workflow Language (YAWL). Workflow nets are an extension of Petri nets to model business processes. Their syntax is purposefully simple and revolves around two elements: places and transitions. The former roughly correspond to BPMN events, while the latter to BPMN activities. A good presentation of Workflow nets is provided in [95].

YAWL is a successor of Workflow nets in that it adds specific constructs to capture the OR-join behavior, multi-instance activities, sub-processes and cancellation regions. YAWL retains the simplicity and intuitiveness of Workflow nets, though it provides a much more expressive language. YAWL and its supporting environment are presented in detail in [92].

A comparison of the above languages in terms of their expressiveness along the control-flow, data and resource perspectives can be found in the Workflow Patterns Initiative website [108]. Over time this initiative has collected a repository of workflow patterns, i.e. recurring process behavior as it has been observed from a thorough analysis of various process modeling languages and supporting tools. Various languages and tools have been compared based on their support for such patterns.

Chapter 4
Advanced Process Modeling

The sciences do not try to explain, they hardly even try to interpret, they mainly make models.
John von Neumann (1903–1957)

In this chapter we will learn how to model complex business processes with BPMN. The constructs presented in this chapter build on top of the knowledge acquired in Chap. 3. In particular, we will expand on activities, events and gateways. We will learn how to use activities to model sub-processes and how to reuse these sub-processes across different processes. We will also extend activities to model more sophisticated forms of rework and repetition. As per events, we will expand on message events, present temporal events and show how race conditions can be modeled among these event types via a new type of gateway. We will also learn how to use events to handle business process exceptions. Finally, we will show how a collaboration diagram can be abstracted into a choreography diagram that only focuses on the interactions between the involved business parties.

4.1 Process Decomposition

When capturing complex business processes, the resulting process model may be too large to be understood at once. Take the order fulfillment process model in Fig. 3.12. While the scenario at hand is still relatively simple, this model already contains 14 activities, six gateways and two events. As we add data objects and message flows, the model gets larger and so harder to understand (see e.g. Fig. 3.16). To improve its readability, we can simplify the process by hiding certain parts within a *sub-process*. A sub-process represents a self-contained, composite activity that can be broken down into smaller units of work. Conversely, an atomic activity, also called *task*, is an activity capturing a unit of work that cannot be further broken down.

In order to use a sub-process, we first need to identify groups of related activities, i.e. those activities which together achieve a particular goal or generate a particular outcome in the process model under analysis. In our order fulfillment example, we can see that the activities "Check raw materials availability" and "Purchase raw

M. Dumas et al., *Fundamentals of Business Process Management*,
DOI 10.1007/978-3-642-33143-5_4, © Springer-Verlag Berlin Heidelberg 2013

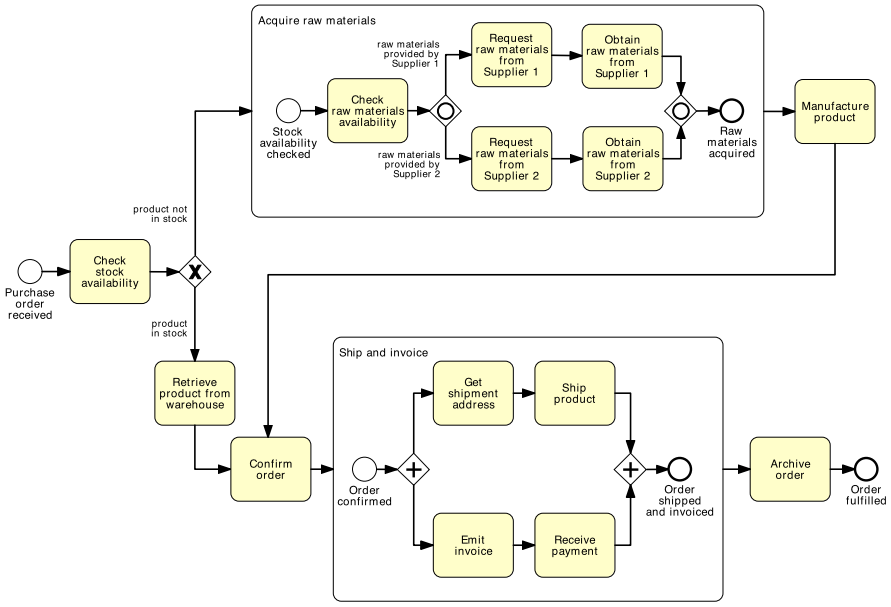


Fig. 4.1 Identifying sub-processes in the order fulfillment process of Fig. 3.12

materials from Supplier 1(2)", lead together to the acquisition of raw materials. Thus these activities, and their connecting gateways, can be encapsulated in a sub-process. In other words, they can be seen as the internal steps of a macro-activity called "Acquire raw materials". Similarly, the two parallel branches for shipping and invoicing the order can be grouped under another sub-process activity called "Ship and invoice". Figure 4.1 illustrates the resulting model, where the above activities have been enclosed in two sub-process activities. We represent such activities with a large rounded box which encloses the internal steps. As we can observe from Fig. 4.1, we also added a start event and an end event inside each sub-process activity, to explicitly indicate when the sub-process starts and completes.

Recall that our initial objective was to simplify a process model. Once we have identified the boundaries of the sub-processes, we can simplify the model by hiding the content of its sub-processes, as shown in Fig. 4.2. This is done by replacing the macro-activity representing the sub-process with a standard-size activity. We indicate that this activity hides a sub-process by marking it with a small square with a plus sign (+) inside (like if we could expand the content of that activity by pressing the plus button). This operation is called collapsing a sub-process. By collapsing a sub-process we reduce the total number of activities (the order fulfillment process has only six activities now), thus improving the model readability. In BPMN, a sub-process which hides its internal steps is called *collapsed sub-process*, as opposed to an *expanded sub-process* which shows its internal steps (as in Fig. 4.1).

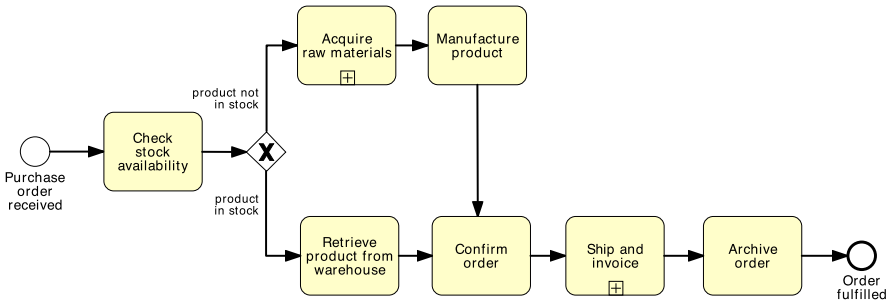


Fig. 4.2 A simplified version of the order fulfillment process after hiding the content of its sub-processes

Exercise 4.1 Identify suitable sub-processes in the process for assessing loan applications modeled in Exercise 3.5.

Hint Use the building blocks that you created throughout Exercises 3.1–3.4.

Collapsing a sub-process does not imply losing its content. The sub-process is still there, just defined at an abstraction level below. In fact, we can nest sub-processes in multiple levels, so as to decompose a process model hierarchically. An example is shown in Fig. 4.3, which models a business process for disbursing home loans. In the first level we identified two sub-processes: one for checking the applicant's liability, the other for signing the loan. In the second level, we factored out the scheduling of the loan disbursement within the process for signing loans into a separate sub-process.

As we go down the hierarchical decomposition of a process model, we can add more details. For example, we may establish a convention that at the top level we only model core business activities, at the second level we add decision points, and so on all the way down to modeling exceptions and details that are only relevant for process automation.

Question When should we decompose a process model into sub-processes?

We should use sub-processes whenever a model becomes too large that is hard to understand. While it is hard to precisely define when a process model is "too large", since understandability is subjective, it has been shown that using more than approximately 30 flow objects (i.e. activities, events, gateways) leads to an increased probability of making mistakes in a process model (e.g. introducing behavioral issues). Thus, we suggest to use as few elements as possible per each process model level, and in particular to decompose a process model if this has more than 30 flow objects.

Reducing the size of a process model, for example by collapsing its sub-processes, is one of the most effective ways of improving a process model's readability. Other structural aspects that affect the readability include the density of the

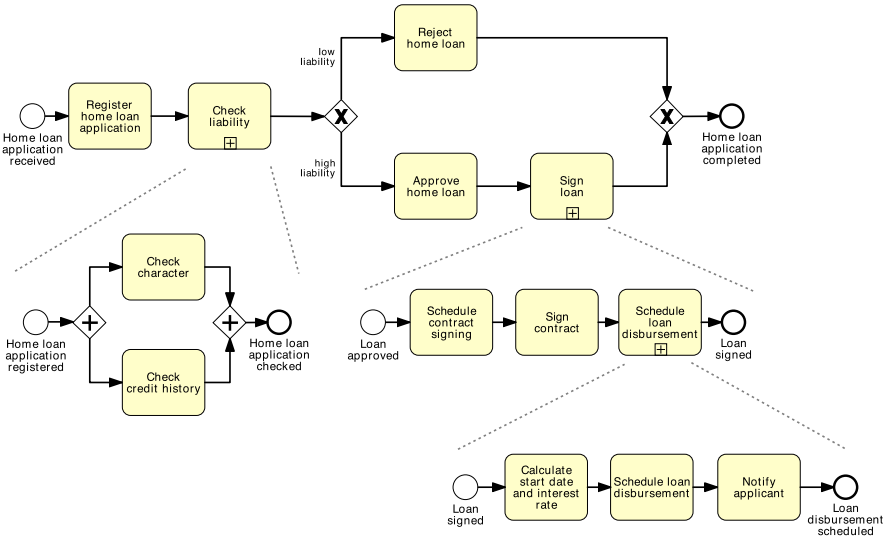


Fig. 4.3 A process model for disbursing home loans, laid down over three hierarchical levels via the use of sub-processes

process model connections, the number of parallel branches, the longest path from a start to an end event, as well as cosmetic aspects such as the layout, the labels style (e.g. always use a verb-noun style), the colors palette, the lines thickness, etc. More information on establishing process modeling guidelines can be found in Chap. 5.

We have shown that we can simplify a process model by first identifying the content of a sub-process, and then hiding this content by collapsing the sub-process activity. Sometimes, we may wish to proceed in the opposite direction, meaning that when modeling a process we already identify activities that can be broken down in smaller steps, but we intentionally under-specify their content. In other words, we do not link the sub-process activity to a process model at a lower level capturing its content (like if by pressing the plus button nothing would happen). The reason for doing this is to tell the reader that some activities are made up of sub-steps, but that disclosing the details of these is not relevant. This could be the case of activity "Ship product" in the order fulfillment example, for which modeling the distinction between its internal steps for packaging and for shipping is not relevant.

4.2 Process Reuse

By default a sub-process is embedded within its parent process model, and as such it can only be invoked from within that process model. Often, when modeling a business process we may need to reuse parts of other process models of the same organization. For example, a loan provider may reuse the sub-process for signing

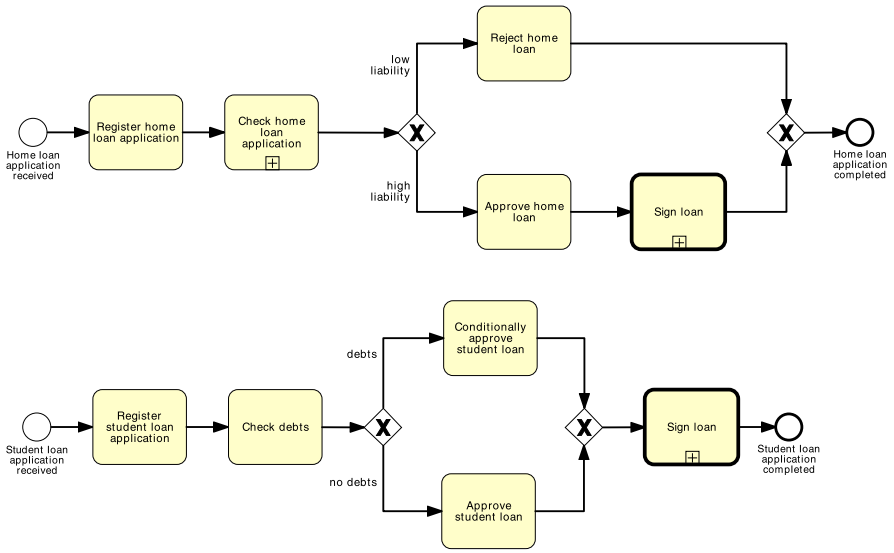


Fig. 4.4 The process model for disbursing student loans invokes the same model for signing loans used by the process for disbursing home loans, via a call activity

loans contained in the home loan disbursement for other types of loan, such as a process for disbursing student loans or motor loans.

In BPMN, we can define the content of a sub-process outside its parent process, by defining the sub-process as a *global* process model. A global process model is a process model that is not embedded within any process model, and as such can be invoked by other process models within the same process model collection. To indicate that the sub-process being invoked is a global process model, we use the collapsed sub-process activity with a thicker border (this activity type is called *call activity* in BPMN). Coming back to the loan disbursement example of Fig. 4.3, we can factor out the sub-process for signing loans and define it as a global process model, so that it can also be invoked by a process model for disbursing student loans (see Fig. 4.4).

Question Embedded or global sub-process?

Our default choice should be to define sub-processes as global process models so as to maximize their reusability within our process model collection. Supporting processes such as payment, invoicing, HR, printing, are good candidates for being defined as global process models, since they are typically shared by various business processes within an organization. Besides reusability, another advantage of using global process models is that any change made to these models will be automatically propagated to all process models that invoke them. In some cases, however, we may want to keep the changes internal to a specific process. For example, an invoicing process used for corporate orders settlement would typically be different

from the invoicing process for private orders. In this case, we should keep two model variants of the invoice sub-process, each embedded within its parent process model: corporate and private order settlement.

Example 4.1 Let us consider the procurement process of a pharmaceutical company.

> A pharmaceutical company has different business units within its manufacturing department, each producing a specific type of medicine. For example, there is a business unit looking after inhaled medications, and another one producing vaccines. The various business units make use of a direct procurement process for ordering chemicals, and of an indirect procurement process for ordering spare parts for their equipment.

The direct procurement process depends on the raw materials that are required to produce a specific type of medicine. For example, vaccines typically include adjuvants that help improve the vaccine's effectiveness, which are not contained in inhaled medications. Similarly, inhaled medications contain a chemical propellant to push the medicine out of the inhaler, which is not required for vaccines. Since this procurement process is specific to each business unit, we need to model it as an embedded sub-process within the manufacturing process model of each unit. On the other hand, the process for ordering spare parts to the equipment for synthesizing chemicals can be shared across all units, since all units make use of the same equipment. Thus, we will model this process with a global process model.

Before concluding our discussion on sub-processes, we need to point to some syntactical rules for using this element. A sub-process is a regular process model. It should start with at least one start event, and complete with at least one end event. If there are multiple start events, the sub-process will be triggered by the first such an event that occurs. If there are multiple end events, the sub-process will return control to its parent process only when each token flowing in this model reaches an end event. Moreover, we cannot cross the boundary of a sub-process with a sequence flow. To pass control to a sub-process, or receive control from a sub-process, we should always use start and end events. On the other hand, message flows can cross the boundaries of a sub-process to indicate messages that emanate from, or are directed to, internal activities or events of the sub-process.

Exercise 4.2 Identify suitable sub-processes in the business process of Exercise 1.7. Among these sub-processes, identify those that are specific to this business process versus those that can potentially be shared with other business processes of the same company.

4.3 More on Rework and Repetition

In the previous chapter we described how to model rework and repetition via the XOR gateways. Expanded sub-processes offer an alternative way to model parts of a process that can be repeated. Let us consider again the process for addressing

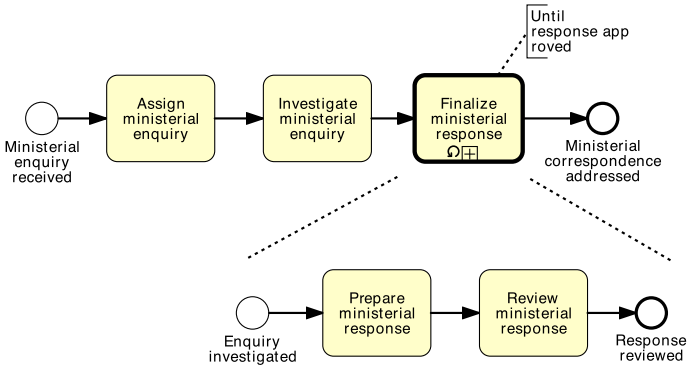


Fig. 4.5 The process model for addressing ministerial correspondence of Fig. 3.13 simplified using a loop activity

ministerial correspondence of Example 3.7. To make this model simpler, we can take the fragment identified by the XOR-join and the XOR-split (which includes the repetition block and the loopback branch) and replace it with a sub-process containing the activities in the repetition block. To identify that this sub-process may be repeated (if the response is not approved), we mark the sub-process activity with a loop symbol, as shown in Fig. 4.5. We can use an annotation to specify the loop condition, e.g. "until response approved".

As for any sub-process, you may decide not to specify the content of a loop sub-process. However, if you do so, do not forget to put a decision activity as the last activity inside the sub-process, otherwise there is no way to determine when to repeat the sub-process.

Question Loop activity or cycle?

The loop activity is a shorthand notation for a structured cycle, i.e. a repetition block delimited by a single entry point to the cycle, and a single exit point from the cycle, like in the example above. Sometimes there might be more than one entry and/or exit point, or the entry/exit point might be inside the repetition block. Consider for example the model in Fig. 4.6. Here the repetition block is made up of activities "Assess application", "Notify rejection" and "Receive customer feedback"; the cycle has an entry point and two exit points, of which one inside the repetition block. When an unstructured cycle has multiple exit points, like in this case, a loop activity cannot be used, unless additional conditions are used to specify the situations in which the cycle can be exited, which will render the model more complex.

Exercise 4.3

1. Identify the entry and exit points that delimit the unstructured cycles in the process models shown in Solution 3.4 and in Exercise 3.9. What are the repetition blocks?

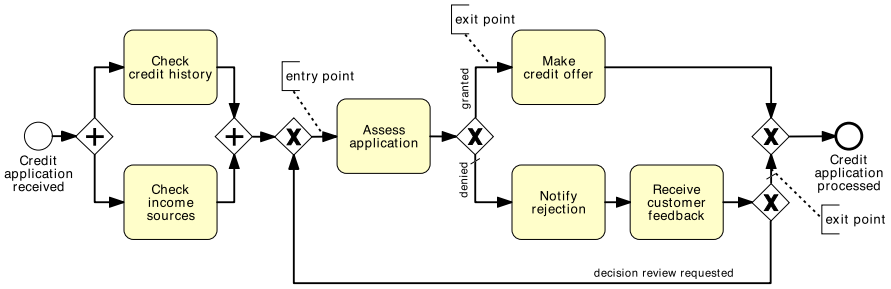


Fig. 4.6 An example of unstructured cycle

2. Model the business process of Solution 3.4 using a loop activity.

4.3.1 Parallel Repetition

The loop activity allows us to capture sequential repetition, meaning that instances of the loop activity are executed one after the other. Sometimes, though, we may need to execute multiple instances of the same activity at the same time, like in the following example.

Example 4.2 In a procurement process, a quote is to be obtained from all preferred suppliers. After all quotes are received, they are evaluated and the best quote is selected. A corresponding purchase order is then placed.

Let us assume five preferred suppliers exist. Then we can use an AND-split to model five tasks in parallel, each to obtain a quote from one supplier, as shown in Fig. 4.7. However, there are several problems with this solution. First, the larger the number of suppliers, the larger the resulting model will be, since we need to use one task per supplier. Second, we need to revise the model every time the number of suppliers changes. In fact, it is often the case in reality that an updated list of suppliers is kept in an organizational database which is queried before contacting the suppliers.

To obviate these problems, BPMN provides a construct called *multi-instance* activity. A multi-instance activity indicates an activity (being it a task or a sub-process) that is executed multiple times concurrently. Such a construct is useful when the same activity needs to be executed for multiple entities or data items, like for example to request quotes from multiple suppliers (as in our example), to check the availability of each line item in an order separately, to send and gather questionnaires for multiple witnesses in the context of an insurance claim, etc.

A multi-instance activity is depicted as an activity marked with three small vertical lines at the bottom. Figure 4.8 shows a revised version of the procurement process model in Fig. 4.7. Not only is this model smaller, but it can also work with a dynamic list of suppliers, which may change on an instance-by-instance basis.

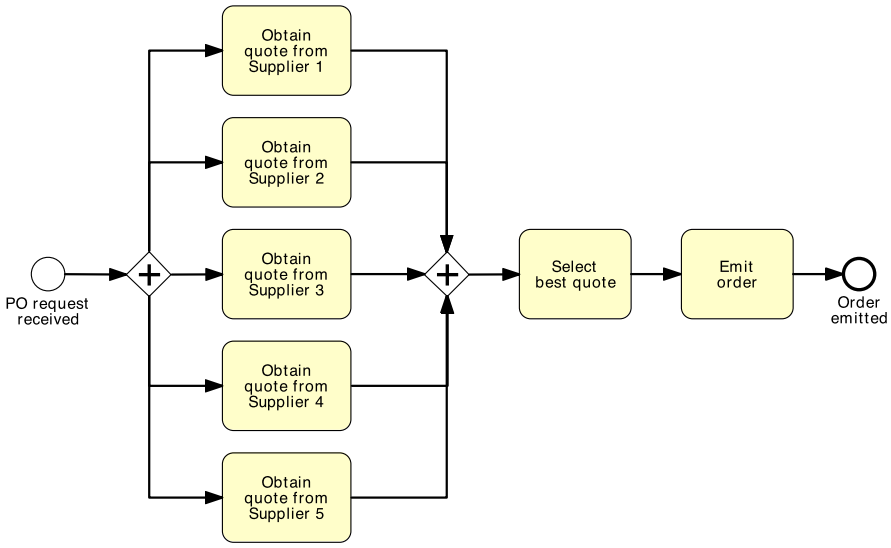


Fig. 4.7 Obtaining quotes from five suppliers

To do so, we added a task to retrieve the list of suppliers, and passed this list to a multi-instance task, which contacts the various suppliers. You would have noticed that in this example we have also marked the data object Suppliers list with the multi-instance symbol. This is used to indicate a *collection* of similar data objects, like a list of order items, or a list of customers. When a collection is used as input to a multi-instance activity, the number of items in the collection determines the number of activity instances to be created. Alternatively, we can specify the number of instances to be created via an annotation on the multi-instance activity (e.g. "15 suppliers", or "as per suppliers database").

Let us come back to our example. Assume the list of suppliers has become quite large over time, say there are 20 suppliers in the database. As per our organizational policies, however, five quotes from five different suppliers are enough to make a decision. Thus, we do not want to wait for all 20 suppliers to reply back to our request for quote. To do so, we can annotate the multi-instance activity with the minimum number of instances that need to complete before passing control to the outgoing arc (e.g. "complete when five quotes obtained", as shown in Fig. 4.8). When the multi-instance activity is triggered, 20 tokens are generated, each marking the progress of one of the 20 instances. Then, as soon as the first five instances complete, all the other instances are canceled (the respective tokens are destroyed) and one token is sent to the output arc to signal completion.

Let us take the order fulfillment example in Fig. 4.2, and expand the content of the sub-process for acquiring raw materials. To make this model more realistic, we can use a multi-instance sub-process in place of the structure delimited by the two OR gateways, assuming that the list of suppliers to be contacted will be determined

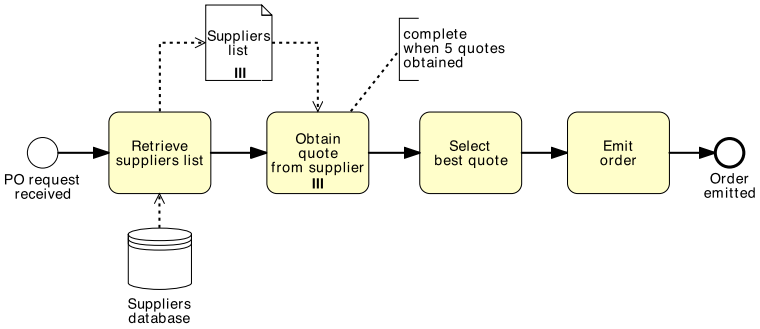


Fig. 4.8 Obtaining quotes from multiple suppliers, whose number is not known a priori

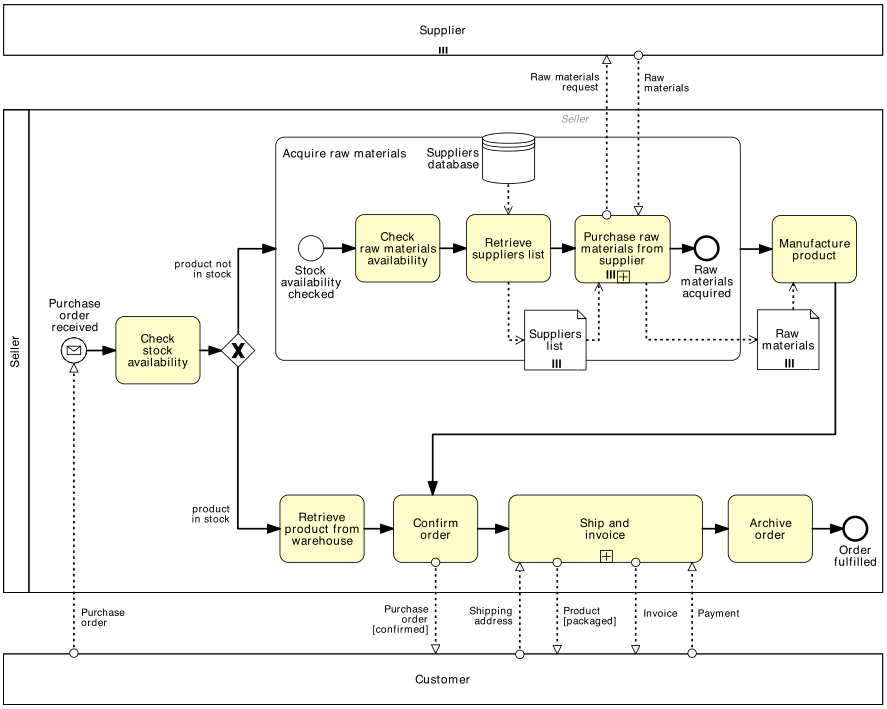


Fig. 4.9 Using a multi-instance pool to represent multiple suppliers

on the fly from a suppliers database (the updated model is shown in Fig. 4.9). By the same principle, we replace the two pools "Supplier 1" and "Supplier 2" with a single pool, namely "Supplier", which we also mark with the multi-instance symbol—a multi-instance pool represents a set of resource classes, or resources, having similar characteristics.

From this figure we note that there are four message flows connected to the sub-process "Ship and invoice", as a result of collapsing the content of this activity. The order in which these messages are exchanged is determined by the activities inside this sub-process that receive and send them. In other words, when it comes to a collapsed sub-process activity, the message semantics for tasks described in Sect. 3.4 is not enforced.

Exercise 4.4 Model the following process fragment.

After a car accident, a statement is sought from two witnesses out of the five that were present, in order to lodge the insurance claim. As soon as the first two statements are received, the claim can be lodged with the insurance company without waiting for the other statements.

4.3.2 Uncontrolled Repetition

Sometimes we may need to model that one or more activities can be repeated a number of times, without a specific order, until a condition is met. For example, let us assume that the customer of our order fulfillment process needs to inquire about the progress of their order. The customer may do so simply by sending an e-mail to the seller. This may be done any time after the customer has submitted the purchase order and as often as the customer desires. Similarly, the customer may attempt to cancel the order or update their personal details before the order has been fulfilled. These activities are *uncontrolled*, in the sense that they may be repeated multiple times with no specific order, or not occur at all, until a condition is met—in our case the order being fulfilled.

To model a set of uncontrolled activities, we can use an *ad-hoc sub-process*. Figure 4.10 shows the example of the customer's process, where the completion condition ("until order is fulfilled") has been specified via an annotation. The ad-hoc sub-process is marked with a tilde symbol at the bottom of the sub-process box.

A partial order may be established among the activities of an ad-hoc sub-process via the sequence flow. However, we cannot represent start and end events in an ad-hoc sub-process.

Exercise 4.5 Model the following process snippet.

A typical army recruitment process starts by shortlisting all candidates' applications. Those shortlisted are then called to sit the following tests: drug and alcohol, eye, color vision, hearing, blood, urine, weight, fingerprinting and doctor examination. The color vision can only be done after the eye test, while the doctor examination can only be done after color vision, hearing, blood, urine and weight have been tested. Moreover, it may be required for some candidates to repeat some of these tests multiple times in order to get a correct assessment, e.g. the blood test may need to be repeated if the candidate has taken too much sugar in the previous 24 hours. The candidates that pass all tests are asked to sit a mental exam and a physical exam, followed by an interview. Only those that also pass these two exams and perform well in the interview can be recruited in the army.

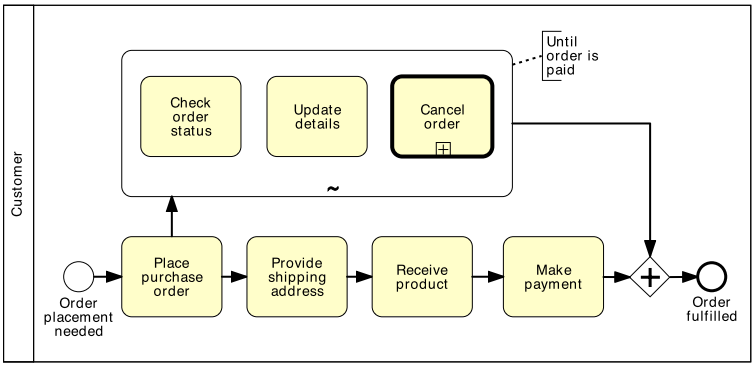


Fig. 4.10 Using an ad-hoc sub-process to model uncontrolled repetition

4.4 Handling Events

As we pointed out in Chap. 3, events are used to model something that happens instantaneously in a process. We saw start events, which signal how process instances start (tokens are created), and end events, which signal when process instances complete (tokens are destroyed). When an event occurs during a process, for example an order confirmation is received after sending an order out to the customer and before proceeding with the shipment, the event is called *intermediate*. A token remains trapped in the incoming sequence flow of an intermediate event until the event occurs. Then the token traverses the event instantaneously, i.e. events cannot retain tokens. An intermediate event is represented as a circle with a double border.

4.4.1 Message Events

In the previous chapter, we showed that we can mark a start event with an empty envelope to specify that new process instances are triggered by the receipt of a message (cf. Fig. 3.16). Besides the start message event, we can also mark an end event and an intermediate event with an envelope to capture the interaction between our process and another party. These types of event are collectively called *message events*. An end message event signals that a process concludes upon sending a message. An intermediate message event signals the receipt of a message, or that a message has just been sent, during the execution of the process. Intermediate and end message events represent an alternative notation to those activities that are solely used to send or receive a message. Take for example activities "Return application to applicant" and "Receive updated applications" in Fig. 4.11a, which is an extract of the loan assessment model of Solution 3.7. It is more meaningful to replace the former activity with an intermediate send message event and the latter activity with an intermediate receive message event, as illustrated in Fig. 4.11b, since these activities

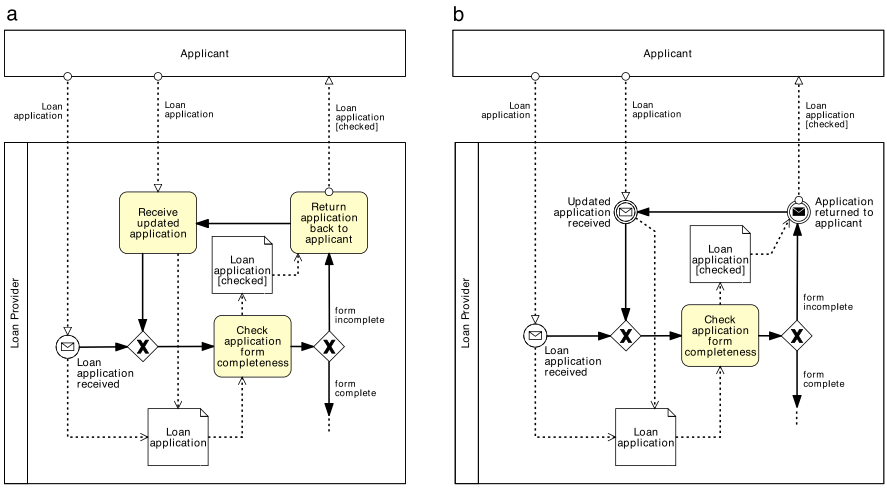


Fig. 4.11 Replacing activities that only send or receive messages (**a**) with message events (**b**)

do not really represent units of work, but rather the mechanical sending or receiving of a message. An intermediate message event that receives a message is depicted as a start message event but with a double border. If the intermediate event signals a message being sent, the envelope is darkened.

Further, if the send activity is immediately followed by an untyped end event, we can replace this with an end message event, since again, this activity is merely used to send a message after which the process concludes. An end message event is depicted as an end event marked with a darkened envelope. Beware that a start message event is not an alternative notation for an untyped start event followed by a receive activity: these two constructs are not interchangeable. In the former case, process instances start upon the receipt of a specific message; in the latter case, process instances may start at any time, after which the first activity requires a message to be performed.

Question Typed or untyped event?

We suggest to specify the type of an event whenever this is known, since it will help the reader better understand the process model.

Exercise 4.6 Is there any other activity in the loan assessment model of Solution 3.7 that can be replaced by a message event?

In BPMN, events come in two flavors based on the filling of their marker. A marker with no fill, like that on the start message event, denotes a *catching event*, i.e. an event that catches a trigger, typically originating from outside the process. A marker with a dark fill like that on the end message event denotes a *throwing*

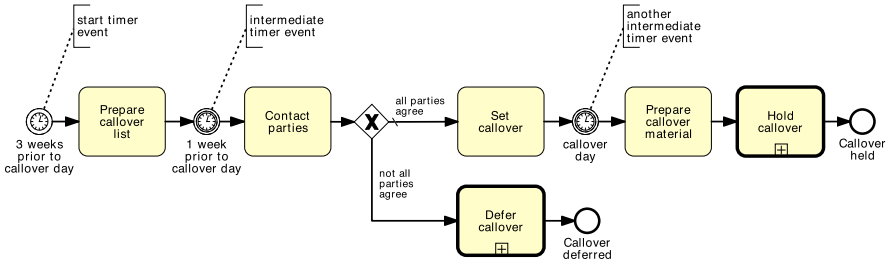


Fig. 4.12 Using timer events to drive the various activities of a business process

event, i.e. an event that throws a trigger from within the process. An intermediate message event has both flavors since it can be used both as a catching event (the message is received from another pool) or as a throwing event (the message is sent to another pool).

4.4.2 Temporal Events

Besides the message event, there are other triggers that can be specified for a start event. One worth of notice is the *timer event*. This event type indicates that process instances start upon the occurrence of a specific temporal event, e.g. every Friday morning, every working day of the month, every morning at 7am.

A timer event may also be used as intermediate event, to model a temporal interval that needs to elapse before the process instance can proceed. To indicate a timer event, we mark the event symbol with a light watch inside the circle. Timer events are catching events only since a timer is a trigger outside the control of the process. In other words, the process does not generate the timer, but rather reacts to this.

Example 4.3 Let us consider the following process at a small claims tribunal.

> In a small claims tribunal, callovers occur once a month, to set down the matter for the upcoming trials. The process for setting up a callover starts three weeks prior to the callover day, with the preparation of the callover list containing information such as contact details of the involved parties and estimated hearing date. One week prior to the callover, the involved parties are contacted to determine if they are all ready to go to trial. If this is the case, the callover is set, otherwise it is deferred to the next available slot. Finally, on the callover day, the callover material is prepared and the callover is held.

This process is driven by three temporal events: it starts three weeks prior to the callover date, continues one week prior to the callover date, and concludes on the day of the callover. To model these temporal events we need one start and two intermediate timer events, as shown in Fig. 4.12. Let us see how this process works from a token semantics point of view. A token capturing a new instance is generated every time it is three weeks prior to the callover date (we assume this date has been scheduled by another process). Once the first activity

"Prepare callover list" has been completed, the token is sent through the incoming arc of the following intermediate timer event, namely "1 week prior to callover day". The event thus becomes *enabled*. The token remains trapped in the incoming arc of this event until the temporal event itself occurs, i.e. only when it is one week prior to the callover day. Once this is the case, the token instantaneously traverses the event symbol and moves to the outgoing arc. This is why events are said to be *instantaneous*, since they cannot retain tokens as opposed to activities, which retain tokens for the duration of their execution (recall that activities consume time).

Exercise 4.7 Model the billing process of an Internet Service Provider (ISP).

> The ISP sends an invoice by email to the customer on the first working day of each month (Day 1). On Day 7, the customer has the full outstanding amount automatically debited from their bank account. If an automatic transaction fails for any reason, the customer is notified on Day 8. On Day 9, the transaction that failed on Day 7 is re-attempted. If it fails again, on Day 10 a late fee is charged to the customer's bank account. At this stage, the automatic payment is no longer attempted. On Day 14, the Internet service is suspended until payment is received. If on Day 30 the payment is still outstanding, the account is closed and a disconnection fee is applied. A debt-recovery procedure is then started.

4.4.3 Racing Events

A typical scenario encountered when modeling processes with events is the one where two external events *race* against one another. The first of the two events that occurs determines the continuation of the process. For example, after an insurance quote has been sent to a client, the client may reply either with an acceptance message, in which case an insurance contract will be made, or with a rejection, in which case the quote will be discarded.

This race between external events is captured by means of the *event-based exclusive* (*XOR*) split. An event-based exclusive split is represented by a gateway marked by an empty pentagon enclosed in a double-line circle. Figure 4.13 features an event-based exclusive split. When the execution of the process arrives at this point (in other words—when a token arrives at this gateway), the execution stops until either the message event or the timer event occurs. Whichever event occurs first will determine which way the execution will proceed. If the timer event occurs first, a shipment status inquiry will be initiated and the execution flow will come back to the event-based exclusive gateway. If the message signaling the freight delivery is received first, the execution flow will proceed along the sequence flow that leads to the AND-join.

The difference between the XOR-split that we saw in Chap. 3 and the event-based XOR-split is that the former models an internal choice that is determined by the outcome of a decision activity, whereas the latter models a choice that is determined

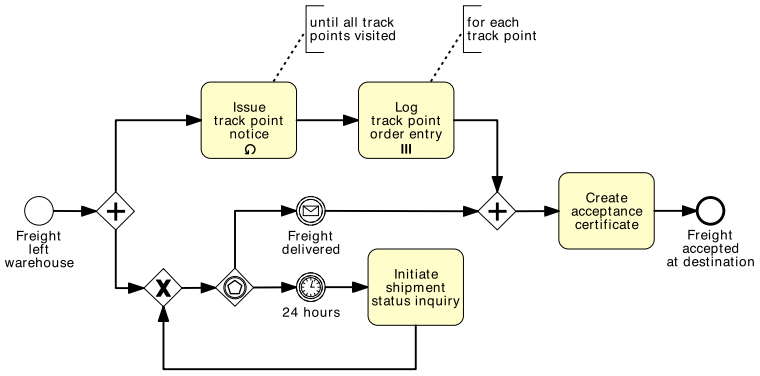


Fig. 4.13 A race condition between an incoming message and a timer

by the process environment.[1] An internal choice is determined by the outcome of a decision activity. Thus, the event-based XOR-split can only be followed by intermediate catching events like a timer or a message event, or by receiving activities. Since the choice is delayed until an event happens, the event-based split is also known as *deferred choice*. There is no event-based XOR-join, so the branches emanating from an event-based split are merged with a normal XOR-join.

Exercise 4.8 Model the following process.

> A restaurant chain submits a purchase order (PO) to replenish its warehouses every Thursday. The restaurant chain's procurement system expects to receive either a "PO Response" or an error message. However, it may also happen that no response is received at all due to system errors or due to delays in handling the PO on the supplier's side. If no response is received by Friday afternoon or if an error message is received, a purchasing officer at the restaurant chain's headquarters should be notified. Otherwise, the PO Response is processed normally.

The event-based split can be used as the counterpart of an internal decision on a collaborating party. For example, a choice made from within the Client pool to send either an acceptance message or a rejection message to an Insurer, needs to be matched by an event-driven decision on the insurer pool to *react* to the choice made by the client. This example is illustrated in Fig. 4.14.

Event-based gateways can be used to avoid behavioral anomalies in the communication between pools. Take for example the collaboration diagram between the auctioning service and the seller in Fig. 4.15. This collaboration may deadlock if the seller is already registered, as this party will wait for the account creation request message which in that case will never arrive. To fix this issue, we need to allow the seller to receive the creation confirmation message straightaway in case the seller is already registered, as shown in Fig. 4.16.

[1] Specifically, the XOR-split of Chap. 3 is called *data-based XOR-split* since the branch to take is based on the evaluation of two or more conditions on data that are produced by a decision activity.

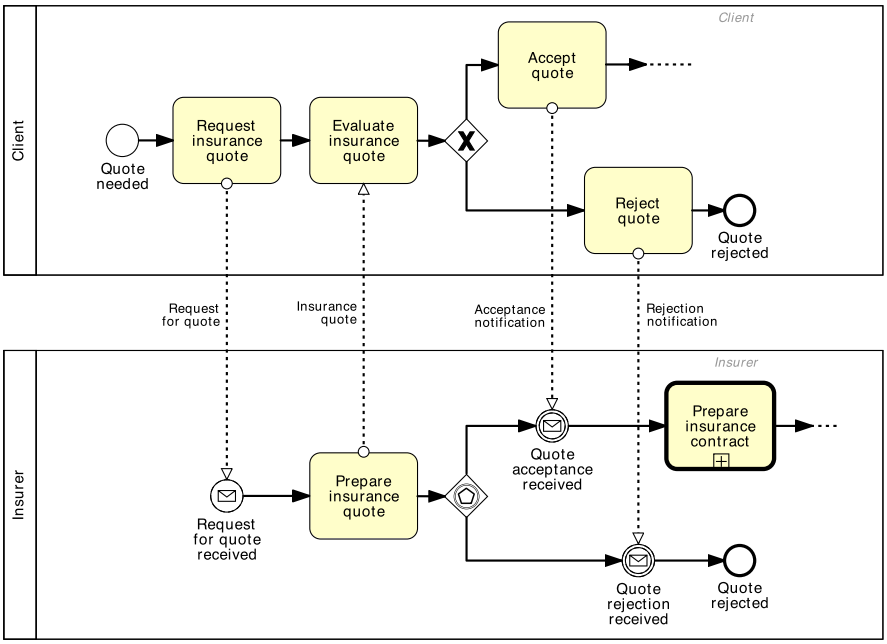


Fig. 4.14 Matching an internal choice in one party with an event-based choice in the other party

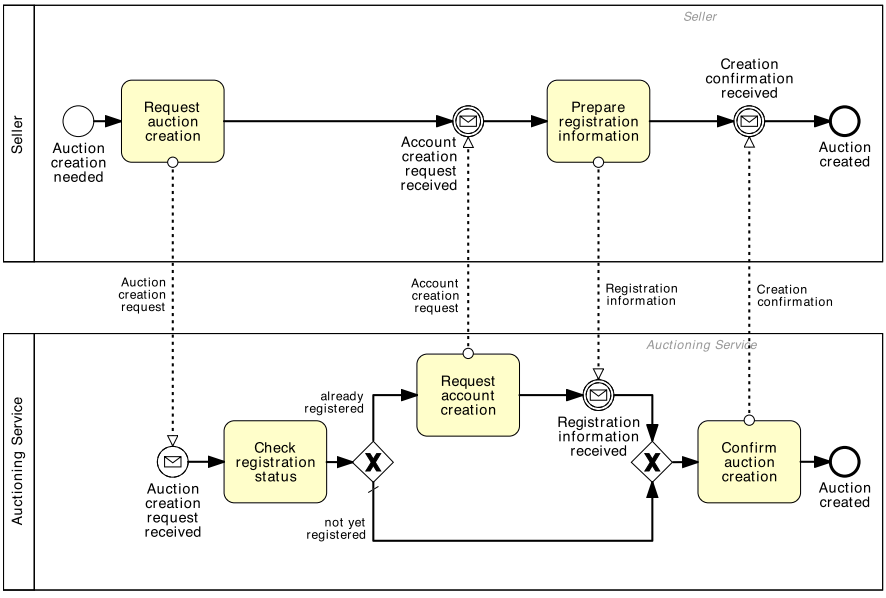


Fig. 4.15 An example of deadlocking collaboration between two pools

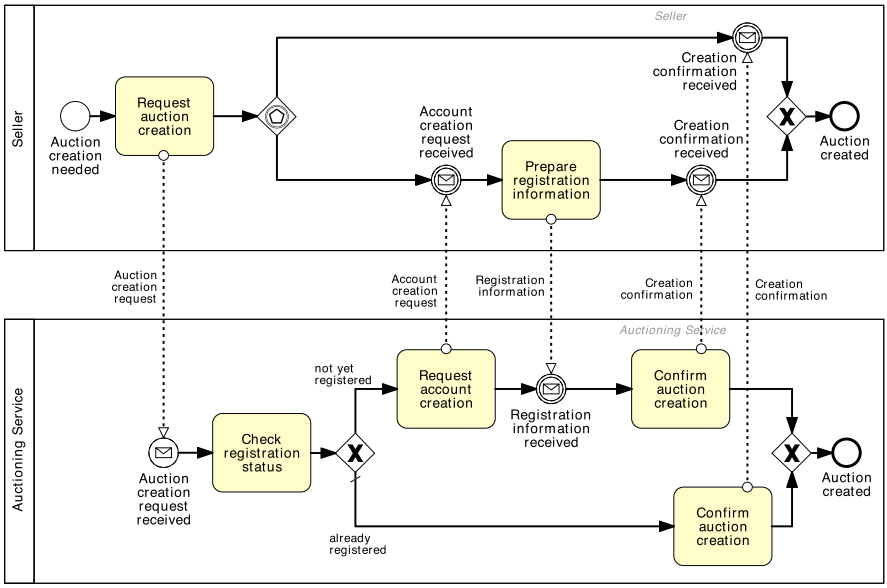


Fig. 4.16 Using an event-based gateway to fix the deadlocking collaboration of Fig. 4.15

When connecting pools with each other via message flows, make sure you check the order of these connections so as to avoid deadlocks. Recall, in particular, that an internal decision in one party needs to be matched by an event-based decision in the other party, and that an activity with an outgoing message flow will send that message upon activity completion, whereas an activity with an incoming message flow will wait for that message to start.

Exercise 4.9 Fix the collaboration diagram in Fig. 4.17.

Acknowledgement This exercise is partly inspired by: *Niels Lohmann: "Correcting Deadlocking Service Choreographies Using a Simulation-Based Graph Edit Distance". LNCS 5240, Springer, 2008.*

4.5 Handling Exceptions

Exceptions are events that deviate a process from its normal course, i.e. from what is commonly known as the "sunny-day" scenario. These "rainy-day" situations happen frequently in reality, and as such they should be modeled when the objective is to identify all possible causes of problems in a given process. Exceptions include *business faults* like an exception due to an out-of-stock or discontinued product, and *technology faults* like a database crash, a network outage or a program logic violation. They deviate the normal process course since they cause the interruption

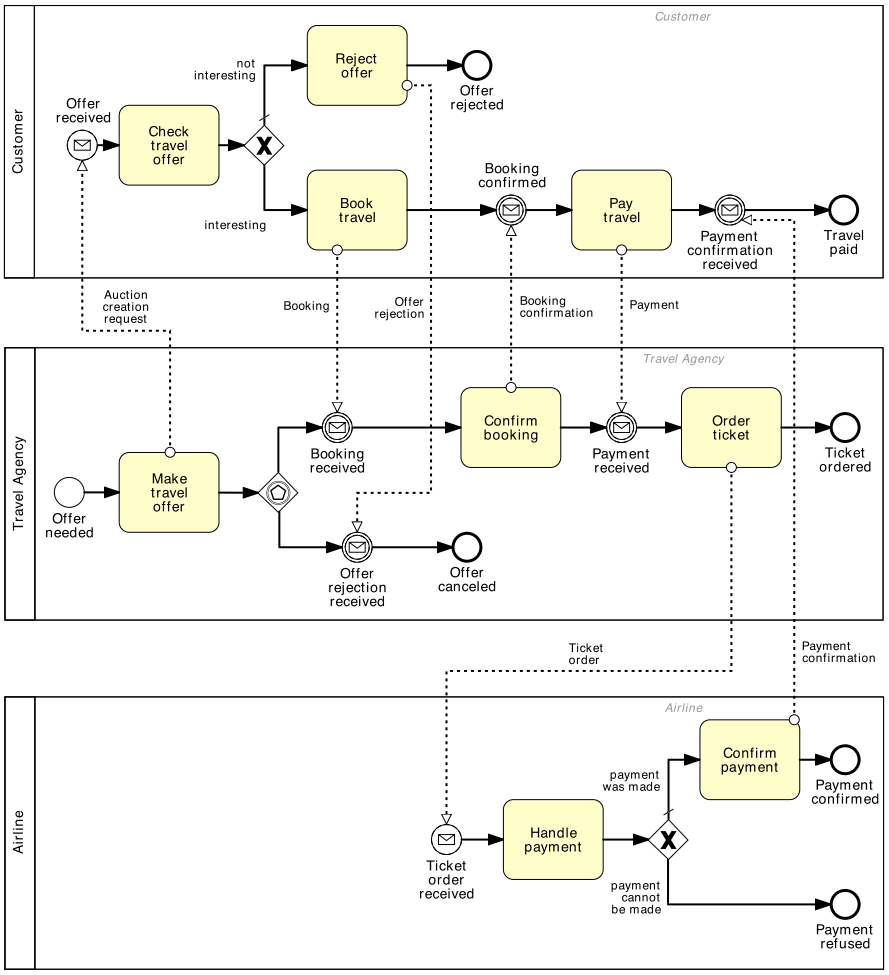


Fig. 4.17 A collaboration diagram between a client, a travel agency and an airline

or abortion of the running process. For example, in case of an out-of-stock product, an order-to-cash process may need to be interrupted to order the product from a supplier, or aborted altogether if the product cannot be supplied within a given timeframe.

4.5.1 Process Abortion

The simplest way of handling an exception is to abort the running process and signal an improper process termination. This can be done by using an *end terminate event*, as shown in Fig. 4.18. An end terminate event (depicted as an end event marked

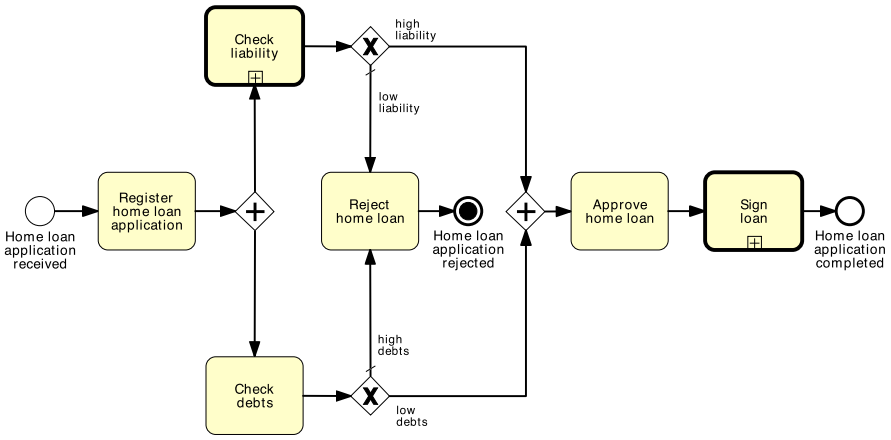


Fig. 4.18 Using a terminate event to signal improper process termination

with a full circle inside), causes the immediate cessation of the process instance at its current level and for any sub-process.

In the example of Fig. 4.18—a variant of the home loan that we already saw in Fig. 4.3—a home loan is rejected and the process is aborted if the applicant has debts and/or low liability. From a token semantics, the terminate event destroys all tokens in the process model and in any sub-process. In our example, this is needed to avoid the process to deadlock at the AND-join, since a token may remain trapped before the AND-join if there is high liability and debts or low liability and no debts.

Observe that if a terminate event is triggered from within a sub-process, it will not cause the abortion of the parent process but only that of the sub-process, i.e. the terminate event is only propagated downwards in a process hierarchy.

Exercise 4.10 Revise the examples presented so far in this chapter, by using the terminate event appropriately.

4.5.2 Internal Exceptions

Instead of aborting the whole process, we can handle an exception by interrupting the specific activity that has caused the exception. Next, we can start a recovery procedure to bring the process back to a consistent state and continue its execution, and if this is not possible, only then, abort the process altogether. BPMN provides the *error event* to capture these types of scenario. An end error event is used to interrupt the enclosing sub-process and throw an exception. This exception is then caught by an intermediate catching error event which is attached to the boundary of the same sub-process. In turn, this *boundary event* triggers the recovery procedure through an outgoing branch which is called *exception flow*.

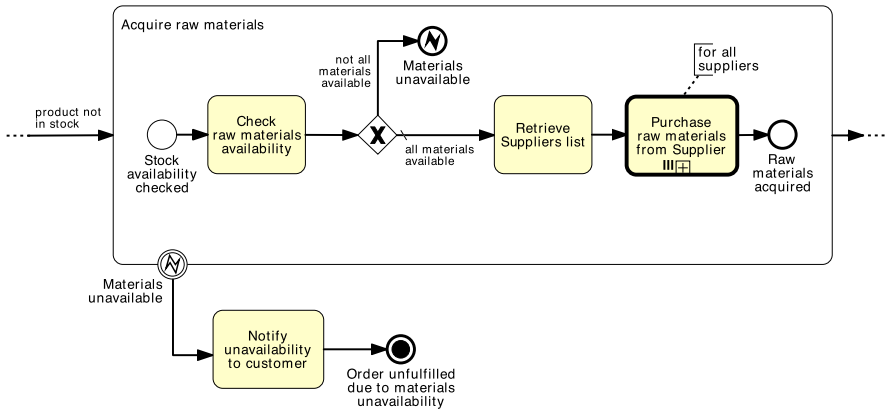


Fig. 4.19 Error events model internal exceptions

The error event is depicted as an event with a lightning marker. Following the BPMN conventions for throwing and catching events, the lightning is empty for the catching intermediate event and full for the end throwing event.

An example of error events is shown in Fig. 4.19 in the context of our order fulfillment process. If there is an out of stock exception, the acquisition of raw materials is interrupted and the recovery procedure is triggered, which in this case simply consists of a task to notify the customer before aborting the process. In terms of token semantics, upon throwing an end error event, all tokens are removed from the enclosing sub-process (causing its interruption), and one token is sent through the exception flow emanating from the boundary error event. There is no restriction on the modeling elements we can put in the exception flow to model the recovery procedure. Typically, we would complete the exception flow with an end terminate event to abort the process, or wire this flow back to the normal sequence flow if the exception has been properly handled.

4.5.3 External Exceptions

An exception may also be caused by an external event occurring during an activity. For example, while checking the stock availability for the product in a purchase order, the Seller may receive an order cancellation from the customer. Upon this request, the Seller should interrupt the stock availability check and handle the order cancellation. Scenarios like the above are called *unsolicited exceptions* since they originate externally to the process. They can be captured by attaching a catching intermediate message event to an activity's boundary, as shown in Fig. 4.20. From a token semantics, when the intermediate message event is triggered, the token is removed from the enclosing activity, consequently causing the activity interruption, and sent through the exception flow emanating from the boundary event, to perform the recovery procedure.

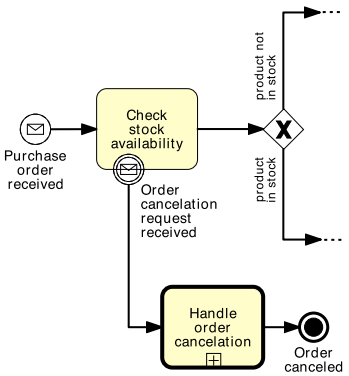


Fig. 4.20 Boundary events catch external events that can occur during an activity

Before using a boundary event we need to identify the *scope* within which the process should be receptive of this event. For example, in the order fulfillment example, order cancellation requests can only be handled during the execution of task "Check stock availability". Thus, the scope for being receptive to this event is made up by this single task. Sometimes the scope should include multiple activities. In these cases, we can encapsulate the interested activities into a sub-process and attach the event to the sub-process's boundary.

Exercise 4.11 Model the following routine for logging into an Internet bank account.

The routine for logging into an Internet bank account starts once the credentials entered from the user have been retrieved. First, the username is validated. If the username is not valid, the routine is interrupted and the invalid username is logged. If the username is valid, the number of password trials is set to zero. Then the password is validated. If this is not valid, the counter for the number of trials is incremented and if lower than three, the user is asked to enter the password again, this time together with a CAPTCHA test to increase the security level. If the number of failed attempts reaches three times, the routine is interrupted and the account is frozen. Moreover, the username and password validation may be interrupted should the validation server not be available. Similarly, the server to test the CAPTCHA may not be available at the time of log in. In these cases, the procedure is interrupted after notifying the user to try again later. At any time during the log in routine, the customer may close the web-page, resulting in the interruption of the routine.

4.5.4 Activity Timeouts

Another type of exception is that provoked by the interruption of an activity which is taking too long to complete. To model that an activity must be completed within a given timeframe (e.g. an approval must be completed within 24 hours), we can attach an intermediate timer event to the boundary of the activity: the timer is activated when the enclosing activity starts, and if it fires before the activity completes, provokes the activity's interruption. In other words, a timer event works as a timeout when attached to an activity's boundary.

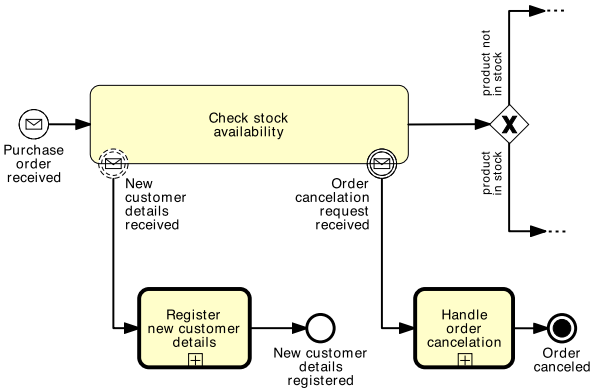


Fig. 4.21 Non-interrupting boundary events catch external events that occur during an activity, and trigger a parallel procedure without interrupting the enclosing activity

Exercise 4.12 Model the following process fragment.

> Once a wholesale order has been confirmed, the supplier transmits this order to the carrier for the preparation of the transportation quote. In order to prepare the quote, the carrier needs to compute the route plan (including all track points that need to be traversed during the travel) and estimate the trailer usage (e.g. whether it is a full track-load, half track-load or a single package). By contract, wholesale orders have to be dispatched within four days from the receipt of the order. This implies that transportation quotes have to be prepared within 48 hours from the receipt of the order to remain within the terms of the contract.

4.5.5 Non-interrupting Events and Complex Exceptions

There are situations where an external event occurring during an activity should just trigger a procedure without interrupting the activity itself. For example, in the order fulfillment process, the customer may send a request to update their details during the stock availability check. The details should be updated in the customer database without interrupting the stock check. In order to denote that the boundary event is *non-interrupting*, we use a dashed double border, as shown in Fig. 4.21.

Exercise 4.13 Extend the process for assessing loan applications of Solution 3.7 as follows.

> An applicant who has decided not to combine their loan with a home insurance plan may change their mind any time before the eligibility assessment has been completed. If a request for adding an insurance plan is received during this period, the loan provider will simply update the loan application with this request.

Non-interrupting events can be used to model more complex exception handling scenarios. Consider again the example in Fig. 4.19 and assume that the customer sends a request to cancel the order during the acquisition of raw materials. We catch this request with a non-interrupting boundary message event, and first determine

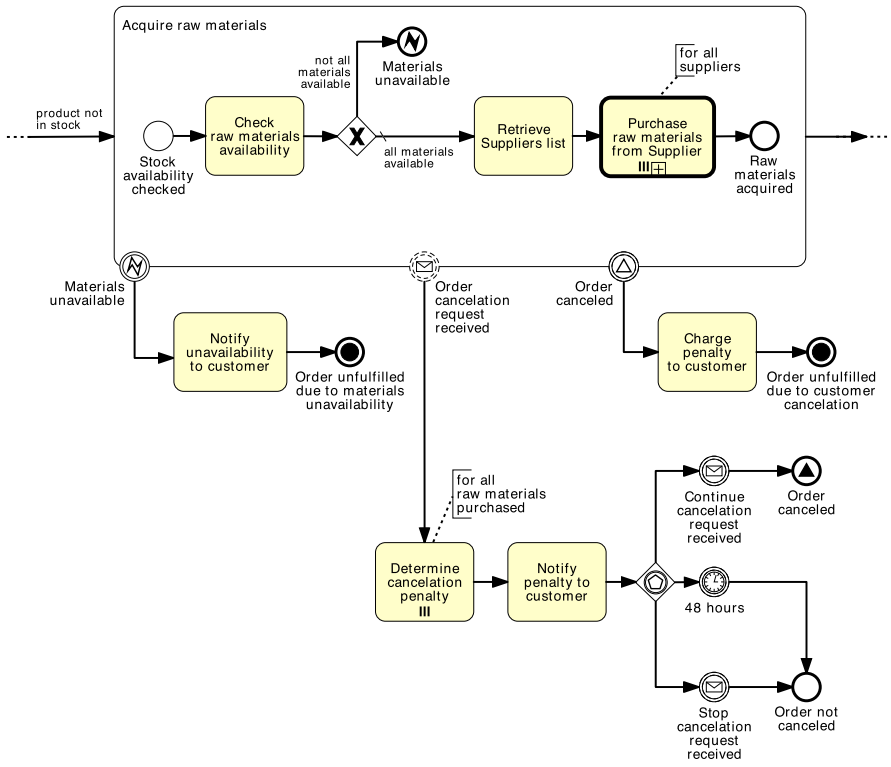


Fig. 4.22 Non-interrupting events can be used in combination with signal events to model complex exception handling scenarios

the penalty that the customer will need to incur based on the raw materials that have already been ordered. We forward this information to the customer who then may decide within 48 hours to either stop the cancellation, in which case nothing is done, or go on with it (see Fig. 4.22). In the latter case, we throw an end *signal event*. This event, depicted with a triangle marker, broadcasts a signal defined by the event's label, which can be caught by all catching signal events bearing the same label. In our case, we throw an "Order canceled" signal and catch this with a matching intermediate signal event on the boundary of the sub-process for acquiring raw materials. This event causes the enclosing sub-process to be interrupted and then triggers a recovery procedure to charge the customer, after which the process is aborted. We observe that in this scenario the activity interruption is triggered from within the process, but outside the activity itself.

Observe that the signal event is different from the message event, since it has a source but no specific target, whilst a message has both a specific source and a specific target. Like messages, signals may also originate from a process modeled in a separate diagram.

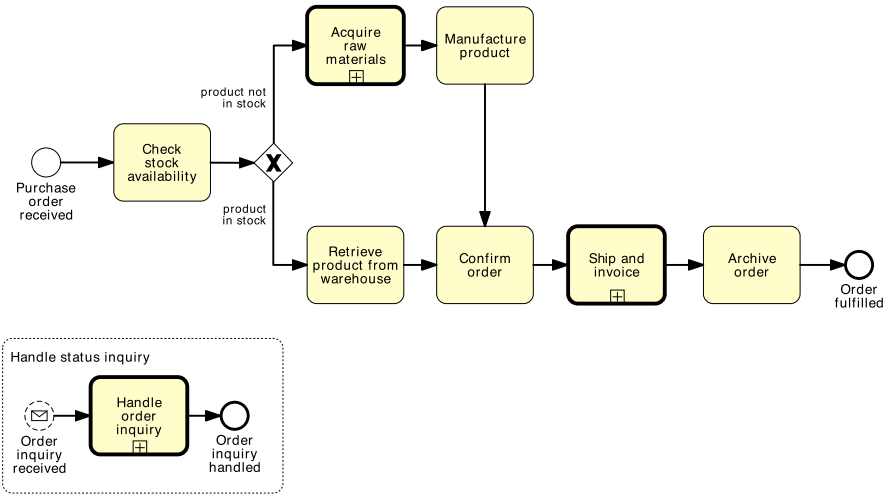


Fig. 4.23 Event sub-processes can be used in place of boundary events, and to catch events thrown from outside the scope of a particular sub-process

4.5.6 Interlude: Event Sub-processes

An alternative notation to boundary events is the *event sub-process*. An event sub-process is started by the event which would otherwise be attached to the boundary of an activity, and encloses the procedure that would be triggered by the boundary event. An important difference with boundary events is that event sub-processes do not need to refer to a specific activity, but can model events that occur during the execution of the whole process. For example, any time during the order fulfillment process the customer may send an inquiry about the order status. To handle this request, which is not specific to a particular activity of this process, we can use an event sub-process as shown in Fig. 4.23.

The event sub-process is depicted within a dotted rectangle with rounded corners which is placed into an expanded sub-process or into the top-level process. Similar to boundary events, an event sub-process may or may not interrupt the enclosing process depending on whether its start event is interrupting or not. If its start event is non-interrupting, this is depicted with a dashed (single) border.

All syntactical rules for a sub-process apply to the event sub-process, except for boundary events, which cannot be defined on event sub-processes. For example, the event sub-process can also be represented as a collapsed sub-process. In this case, the start event is depicted on the top-left corner of the collapsed event sub-process rectangle to indicate how this event sub-process is triggered.

Question Event sub-processes or boundary events?

Event sub-processes are self-contained, meaning that they must conclude with an end event. This has the disadvantage that the procedure captured inside an event

sub-process cannot be wired back to the rest of the sequence flow. The advantage is that an event sub-process can also be defined as a global process model, and thus be reused in other process models of the same organization. Another advantage is that event sub-processes can be defined at the level of an entire process whereas boundary events must refer to a specific activity. Thus, we suggest to use event sub-processes when the event that needs to be handled may occur during the entire process, or when we need to capture a reusable procedure. For all other cases, boundary events are more appropriate since the procedure triggered by these events can be wired back to the rest of the flow.

Exercise 4.14 Model the following business process for reimbursing expenses.

> After an Expense report is received from an employee, the employee is notified of the receipt of the report. Next, a new account must be created if the employee does not already have one. The report is then reviewed for automatic approval. Amounts under €1,000 are automatically approved while amounts equal to or over €1,000 require manual approval. In case of rejection, the employee must receive a Rejection notice by email. In case of approval, the reimbursement is deposited directly to the employee's bank account. At any time during the review, the employee can send a Request for amount rectification. In that case the rectification is registered and the report needs to be reviewed again. Moreover, if the report is not handled within 30 days, the process is stopped and the employee receives a Cancelation notice email so that he can re-submit the expense report from scratch.

4.5.7 Activity Compensation

As part of a recovery procedure, we may need to *undo* one or more steps that have already been completed, due to an exception that occurred in the enclosing sub-process. In fact, the results of these steps, and possibly their side effects, may no longer be desired and for this reason they should be reversed. This operation is called *compensation* and tries to restore the process to a business state close to the one before starting the sub-process that was interrupted.

Let us delve into the sub-process for shipment and invoice handling of the order fulfillment example and assume that also this activity can be interrupted upon the receipt of an order cancellation request (see Fig. 4.24). After communicating the cancellation penalty to the customer, we need to revert the effects of the shipment and of the payment. Specifically, if the shipment has already been made, we need to handle the product return, whereas if the payment has already been made, we need to reimburse the Customer. These compensations can be modeled via a *compensation handler*. A compensation handler is made up of a throwing *compensate event* (an event marked with a rewind symbol), a catching intermediate compensate event and a compensation activity. The throwing compensate event is used inside the recovery procedure of an exception to start the compensation, and can either be an intermediate or an end event (in the latter case, the recovery procedure concludes with the compensation). The catching intermediate compensation event is attached to those activities that need to be compensated—in our example "Ship product" and "Receive payment". These boundary events catch the compensation request and trigger

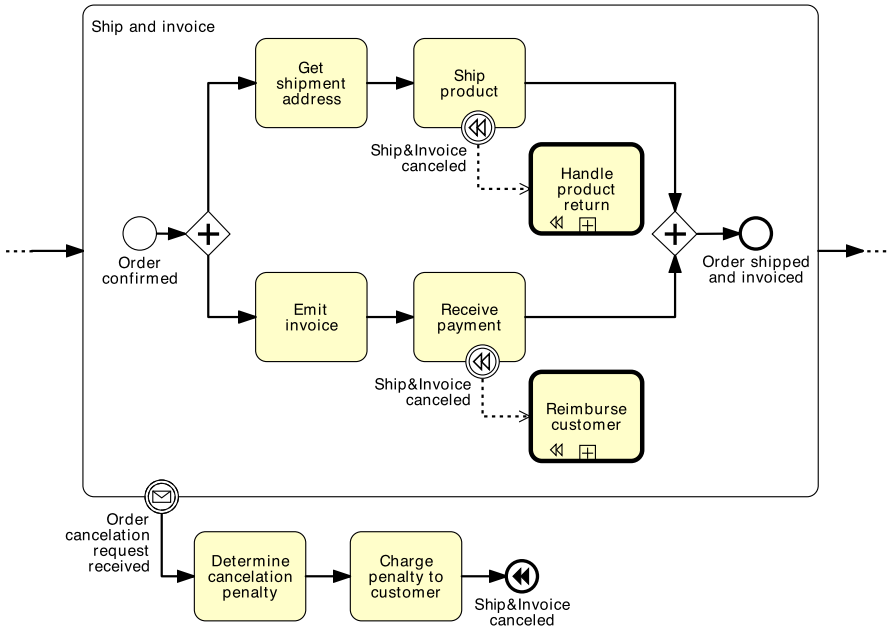


Fig. 4.24 Compensating for the shipment and for the payment

a *compensation activity* specific to the activity to be compensated. For example the compensation activity for "Receive payment" is "Reimburse customer". The boundary event is connected to the compensation activity via a dotted arrow with an open arrowhead, called *compensation association* (whose notation is the same as that of the data association). This activity is marked with the compensate symbol to indicate its purpose, and must not have any outgoing flow: in case the compensation procedure is complex, this activity can be a sub-process.

Compensation is only effective if the attached activity has completed. Once all activities that could be compensated are compensated, the process resumes from after the throwing compensation event, unless this is an end event. If the compensation is for the entire process, we can use an event sub-process with a start compensate event in place of the boundary event.

In this section we have seen various ways to handle exceptions in business process, from simple process abortion to complex exception handling. Before adding exceptions it is important to understand the sunny-day scenario well. So start by modeling that. Then think of all possible situations that can go wrong. For each of these exceptions, identify what type of exception handling mechanism needs to be used. First, determine the cause of the exception: internal or external. Next, decide if aborting the process is enough, or if a recovery procedure needs to be triggered. Finally, evaluate whether the interrupted activity needs to be compensated as part of the recovery procedure.

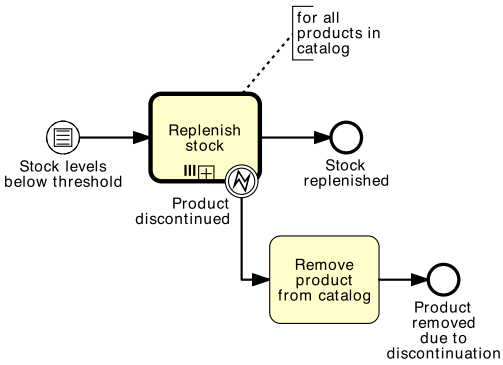


Fig. 4.25 A replenishment order is triggered every time the stock levels drop below a threshold

Exercise 4.15 Modify the model that you created in Exercise 4.14 as follows.

If the report is not handled within 30 days, the process is stopped, the employee receives a cancellation notice email and must re-submit the expense report. However, if the reimbursement for the employee's expenses had already been made, a money recall needs to be made, to get the money back from the employee, before sending the cancellation notice email.

4.6 Processes and Business Rules

A business rule implements an organizational policy or practice. For example, in an online shop, platinum customers have a 20 % discount for each purchase above €250. Business rules can appear in different forms in a process model. We have seen them modeled in a decision activity and in the condition of a flow coming out of an (X)OR-split (see Exercise 3.5 for some examples). A third option is to use a dedicated BPMN event called *conditional event*. A conditional event causes the activation of its outgoing flow when the respective business rule is fulfilled. Conditional events, identified by a lined page marker, can be used as start or intermediate catching events, including after an event-based gateway or attached to an activity's boundary. An example of conditional event is shown in Fig. 4.25.

The difference between an intermediate conditional event and a condition on a flow is that the latter is only tested once, and if it is not satisfied the corresponding flow is not taken (another flow or the default flow will be taken instead). The conditional event, on the other hand, is tested until the associated rule is satisfied. In other words, the token remains trapped before the event until the rule is satisfied.

In the example of Fig. 4.25, observe the use of the error event on the boundary of a multi-instance activity. This event only interrupts the activity instance that refers to the particular product being discontinued, i.e. the instance from which the error event is thrown. All other interrupting boundary events, i.e. message, timer, signal and conditional, interrupt all instances of a multi-instance activity.

Exercise 4.16 Model the following business process snippet.

In a stock exchange, stock price variations are continuously monitored during the day. A day starts when the opening bell rings and concludes when the closing bell rings. Between the two bells, every time the stock price changes by more than 10 %, the entity of the change is first determined. Next, if the change is high, a "high stock price" alert is sent, otherwise a "low stock price" alert is sent.

4.7 Process Choreographies

Sometimes it might be hard to frame a business collaboration between two or more parties, e.g. two organizations, by working directly at the level of the collaboration diagram. First, the collaboration diagram is typically too low-level and if the terms of the interactions between the two parties are not clear yet, it might be confusing to mix communication aspects with internal activities. Second, a party may not be willing to expose their internal activities to other parties (e.g. the logic behind a claim approval should remain private). Thus, it might be opportune to first focus on the interactions that have to occur among all involved parties, and on the order in which these interactions can take place. In BPMN, this information is captured by a *choreography diagram*. A choreography diagram is the process model of the interactions occurring between two or more parties. This high-level view on a collaboration acts as a contract among all involved parties. Once this contract has been crafted, each party can take it and refine it into their private processes, or alternatively, all parties can work together to refine the choreography into a collaboration diagram.

Figure 4.26 shows the choreography for the order fulfillment collaboration of Fig. 4.9. As we can see, a choreography is indeed a process model: it is started by one or more start events and concluded by one or more end events, activities are connected via sequence flows and gateways are used for branching and merging. The key characteristic is, however, that an activity represents an *interaction* between two parties, rather than a unit of work. An interaction can be one-way (one message is exchanged) or *two-way* (a message is followed by a return message in the opposite direction). Each interaction has an *initiator* or sender (the party sending the message), and a *recipient* or receiver (the party receiving the message, who may reply with a return message). For example, the first activity of Fig. 4.26, "Submit purchase order" takes place between the Customer, who sends the purchase order, and the Seller, who receives it.

A choreography activity is depicted as a box with rounded corners where two bands, one at the top, the other at the bottom of the box, represent the two parties involved in the interaction captured by the activity. A light band is used for the initiator whilst a darkened band is used for the recipient. The position of each band with respect to the box is left to the modeler, so long as the two bands are on opposite sides. An envelope attached to a band via a dashed line represents the message sent by that party. This envelop is darkened if it is the return message of a two-way interaction.

A precedence relation between two interactions can only be established if the initiator of the second interaction is involved in the preceding interaction (either as

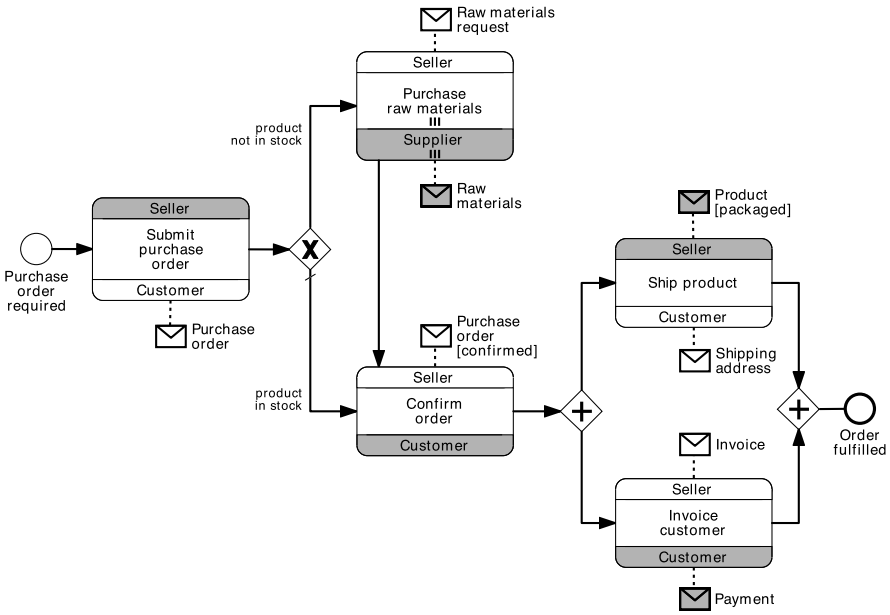


Fig. 4.26 The choreography diagram for the collaboration diagram in Fig. 4.9

a sender or as a receiver), except for the first interaction. In this way the sender of the second interaction 'knows' when this can take place. On the other hand, if there are no order dependencies between two or more interactions, we can link these interactions via an AND-split, as shown in Fig. 4.26. Make sure, however, that the sender of each interaction following the split is involved in the interaction preceding the split.

An (X)OR-split models the outcomes of a an internal decision that is taken by one party. This imposes that the data upon which the decision is taken are made available to that party via an interaction prior to the split. In our example, the data required by the XOR-split are extrapolated from the purchase order, which is sent to the seller in the interaction just before the split. Furthermore, all interactions immediately following the split must be initiated by the party who took the decision. In our example, these are done by the seller. In fact, it makes no sense that a decision taken by one party results in an interaction initiated by another party—the latter would not be able to know the results of the decision at that stage.

The event-based XOR-split is used when the data to make a choice are not exposed through an interaction before the split. Thus, the parties not involved in the decision will only know about this with the receipt of a message. This imposes that the interactions following an event-based split must either have the same sender or the same receiver. For example, we use an event-based split to model a situation where an applicant waits for a confirmation message that may either arrive from a broker or directly from the insurer (the decision of which party to interact with

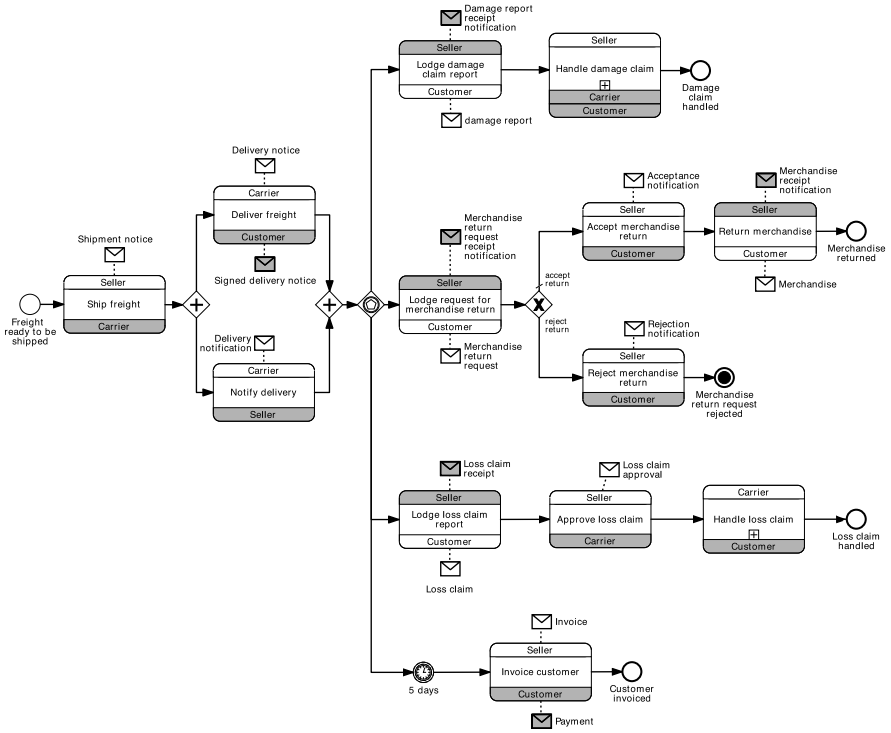


Fig. 4.27 The choreography diagram between a seller, a customer and a carrier

the applicant is taken by the broker together with the insurer). Figure 4.27 shows another example: here a seller waits for one of three possible messages from a customer, representing three different types of complaint. The decision is taken by the customer and the seller is not aware of this until the specific complain is received. The interactions following an event-based split can be constrained by a timer. In this example, if the seller does not receive any message after five days, they will trigger an interaction to invoice the customer. In this case, all parties in the interactions following the split must be involved in the interaction preceding the split in order to be aware of the timer.

Exercise 4.17 The choreography below illustrates the interactions that may occur among a seller, a customer and a carrier after the freight has been delivered by the carrier to the client. Use this diagram as a template to build the corresponding collaboration diagram. Observe the use of the terminate event in this example. In a choreography this event can only be used to denote a negative outcome and not to forcefully terminate the choreography, since the parties not involved in the interaction preceding the terminate event would not know that the terminate event has been reached.

Complex interactions involving more than one business party are modeled via a sub-choreography activity. This activity is represented with the plus symbol (as a sub-process) and may have multiple bands representing all roles involved. For example, the "Handle damage claim" interaction in Fig. 4.27 occurs between the seller, the carrier and the customer. The messages involved in a sub-choreography are only visible when expanding the content of the sub-choreography where also their order becomes apparent.

Artifacts cannot be explicitly expressed in a choreography via data objects or data stores. This is because a choreography does not have a central control mechanism to maintain data.

Exercise 4.18 Model the choreography and collaboration diagrams for the following mortgage application process at BestLoans.

The mortgage application process starts with the receipt of a mortgage application from a client. When an application is sent in by the client to the broker, the broker may either deal with the application themselves, if the amount of the mortgage loan is within the mandate the broker has been given by BestLoans, or forward the application to BestLoans. If the broker deals with the application themselves, this results in either a rejection or an approval letter being sent back to the client. If the broker sends an approval letter, then it forwards the details of this application to BestLoans so that from there on the client can interact directly with BestLoans for the sake of disbursing the loan. In this case, BestLoans registers the application and sends an acknowledgment to the client.

The broker can only handle a given number of clients at a time. If the broker is not able to reply within one week, the client must contact BestLoans directly. In this case, a reduction on the interest rate is applied should the application be approved.

If BestLoans deals with the application directly, its mortgage department checks the credit of the client with the Bureau of Credit Registration. Moreover, if the loan amount is more than 90 % of the total cost of the house being purchased by the client, the mortgage department must request a mortgage insurance offer from the insurance department. After these interactions BestLoans either sends an approval letter or a rejection to the broker, which the broker then forwards to the client (this interaction may also happen directly between the mortgage department and the client if no broker is involved).

After an approval letter has been submitted to the client, the client may either accept or reject the offer by notifying this directly to the mortgage department. If the mortgage department receives an acceptance notification, it writes a deed and sends it to an external notary for signature. The notary sends a copy of the signed deed to the mortgage department. Next, the insurance department starts an insurance contract for the mortgage. Finally, the mortgage department submits a disbursement request to the financial department. When this request has been handled, the financial department notifies the client directly.

Any time during the application process, the client may inquire about the status of their application with the mortgage department or with the broker, depending on which entity is dealing with the client. Moreover, the client may request the cancellation of the application. In this case the mortgage department or the broker computes the application processing fees, which depend on how far the application process is, and communicates these to the client. The client may reply within two days with a cancellation confirmation, in which case the process is canceled, or with a cancellation withdrawal, in which case the process continues. If the process has to be canceled, BestLoans may need to first recall the loan (if the disbursement has been done), then annul the insurance contract (if an insurance contract has been drawn) and finally annul the deed (if a deed has been drawn).

4.8 Recap

This chapter provided us with the means to model complex business processes. We first learned how to structure complex process models in hierarchical levels via sub-process activities. Sub-processes represent activities that can be broken down in a number of internal steps, as compared to tasks, which capture single units of work. An interesting aspect of sub-processes is that they can be collapsed to hide details. We also discussed how to maximize reuse by defining global sub-processes within a process model collection, and invoking them via call activities. A global sub-process is modeled once and shared by different process models in a repository.

We then expanded on the topic of rework and repetition. We illustrated how structured loops can be modeled using a loop activity. Furthermore, we presented the multi-instance activity as a way to model an activity that needs to be executed multiple times without knowing the number of occurrences beforehand. Further, we saw how the concept of multi-instantiation can be related to data collections and extended to pools. We also discussed ad-hoc sub-processes for capturing unstructured repetition.

Next, we expanded on various types of event. We explained the difference between catching and throwing events and distinguished between start, end and intermediate events. We saw how message exchange between pools can be framed by message events, and how timer events can be used to model temporal triggers to the process or delays during the process. We then showed how to capture racing conditions between events external to the process, using an event-based split followed by intermediate catching events.

Afterwards, we showed how to handle exceptions. Exceptions are situations that deviate the process from its normal course, due to technology or business faults. The simplest way to react to an exception is to abort the process via a terminate end event. Exceptions can be handled by using a catching intermediate event on the boundary of an activity. If the event is caught during the activity's execution, the activity is interrupted and a recovery procedure may be launched. Another type of exception is the activity timeout. This occurs when an activity does not complete within a given timeframe. A boundary event can also be configured not to interrupt the attached activity. In this case the event is called non-interrupting. These events are convenient to model procedures that have to be launched in parallel to an activity's execution, when an event occurs. Related to exception handling is the notion of activity compensation. Compensation is required to revert the effects of an activity that has been completed, if these effects are no longer desired due to an exception that has occurred.

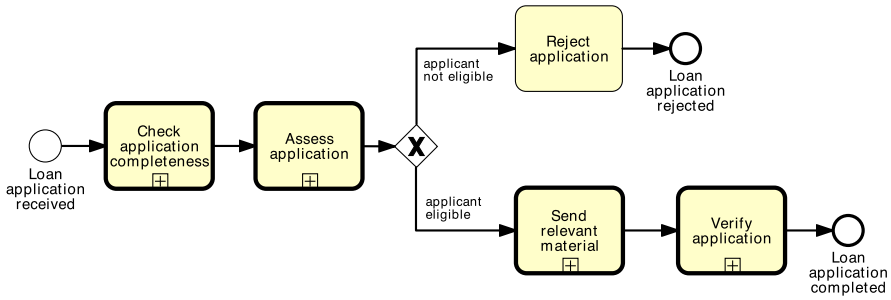
We then saw how business rules can be defined in process models via conditional events. A conditional event, available as a start and catching intermediate event, allows a process instance to start, or progress, only when the corresponding (boolean) business rule evaluates to true.

We concluded this chapter on advanced process modeling by introducing choreography diagrams. A choreography diagram models the interactions that happen between the various business parties partaking in a business process. Each activity in

the choreography captures an interaction between a sender and a receiver. To establish an order dependency between two interactions, the sender of the second activity must be involved in the first one, otherwise this party will not be able to determine when to send the message pertaining to the second interaction. We also discussed the rules for using gateways in a choreography where a decision is made by a specific party based on data or events. Sub-choreographies can be used to model complex interactions involving more than two parties, in a similar vein to sub-processes in a collaboration.

4.9 Solutions to Exercises

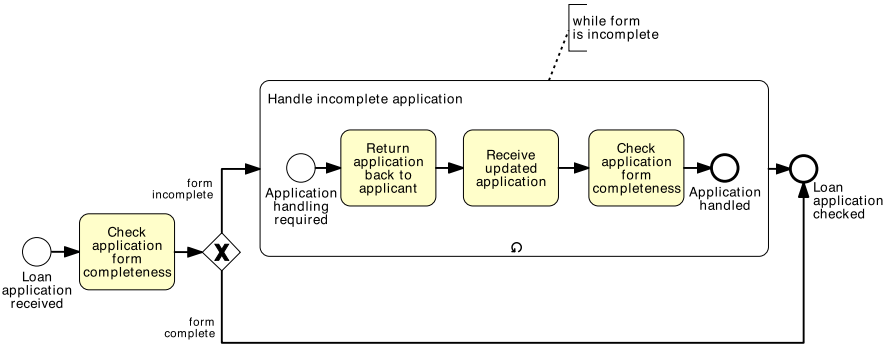
Solution 4.1



Solution 4.2 Possible sub-processes are "Request purchase", "Issue purchase order", "Receive goods" and "Handle invoice". Of these, "Handle invoice" could be shared with other procure-to-pay processes of the same company, e.g. with that described in Example 1.1 for BuildIT. The first three sub-processes are internal to this procure-to-pay process, because they are specific to the enterprise system that supports this process.

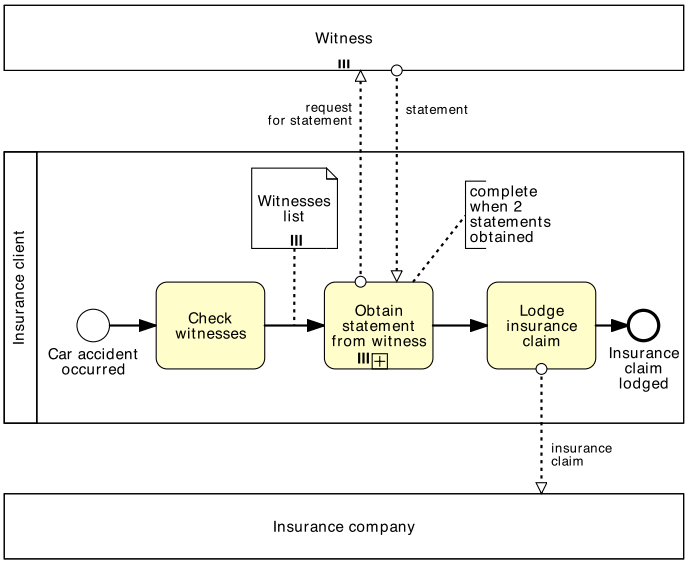
Solution 4.3

1. In Exercise 3.9 the repetition block goes from activity "Record claim" to activity "Review claim rejection". The entry point to the cycle is the input arc of activity "Record claim"; the exit points are arcs "claim to be accepted" and "claim rejection accepted", the former being inside the repetition block.
2. In Solution 3.4 the repetition block is made up of activities "Check application form completeness", "Return application back to applicant" and "Receive updated application". The entry point to the cycle is the outgoing arc of the XOR-split, while the exit point is the arc "form complete" which is inside the repetition block. To model this cycle with a loop activity, we need to repeat activity "Check application form completeness" outside the loop activity, as shown below.

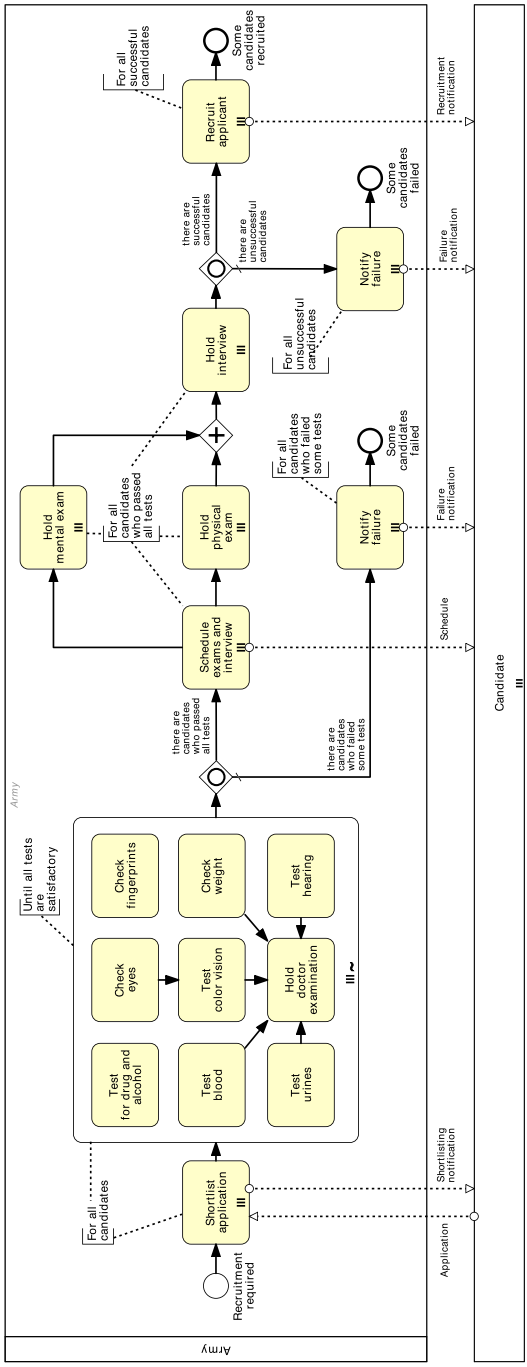


In this case using a loop activity is still advantageous, since we reduce the size of the original model if we collapse the sub-process.

Solution 4.4

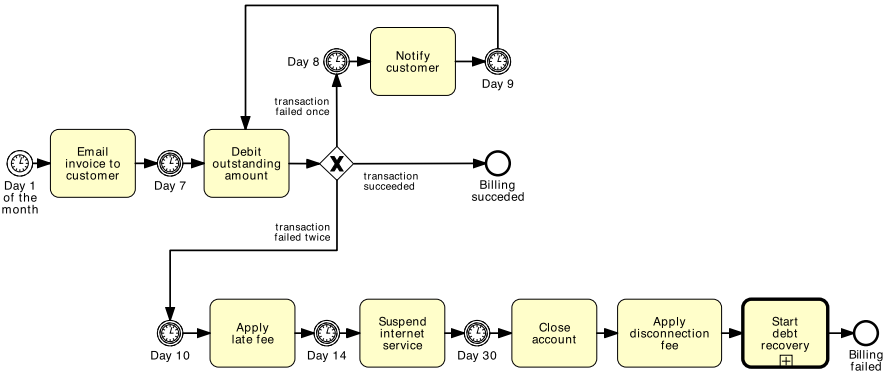


Solution 4.5

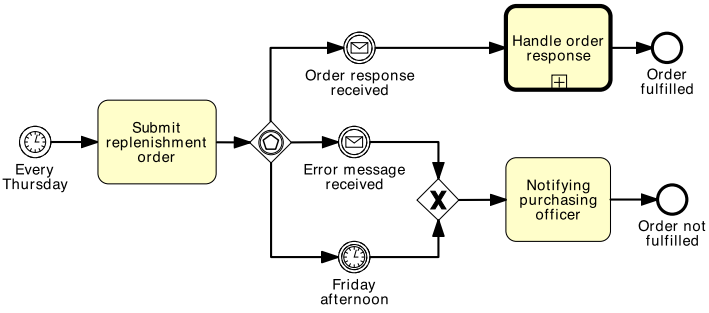

Army
Recruitment required
For all candidates
Shortlist application
Until all tests are satisfactory
Test for drug and alcohol
Test blood
Test urines
Check eyes
Test color vision
Check fingerprints
Check weight
Test hearing
Hold doctor examination
there are candidates who passed all tests
there are candidates who failed some tests
Schedule exams and interview
Hold mental exam
For all candidates who passed all tests
Hold physical exam
For all candidates who failed some tests
Notify failure
Some candidates failed
Hold interview
For all unsuccessful candidates
Notify failure
Some candidates failed
there are successful candidates
there are unsuccessful candidates
For all successful candidates
Recruit applicant
Some candidates recruited
Application
Shortlisting notification
Schedule
Failure notification
Failure notification
Recruitment notification
Candidate

Solution 4.6 Activity "Send acceptance pack" can be replaced by an intermediate send message event; activities "Notify cancelation" and "Notify approval" can each be replaced by an end message event, thus removing the last XOR-join and the untyped end event altogether. Note that activity "Send home insurance quote" cannot be replaced by a message event since it subsumes the preparation of the quote. In fact, a more appropriate label for this activity would be "Prepare home insurance quote". Similarly, we cannot get rid of activity "Reject application" as this activity changes the status of the application before sending the latter out.

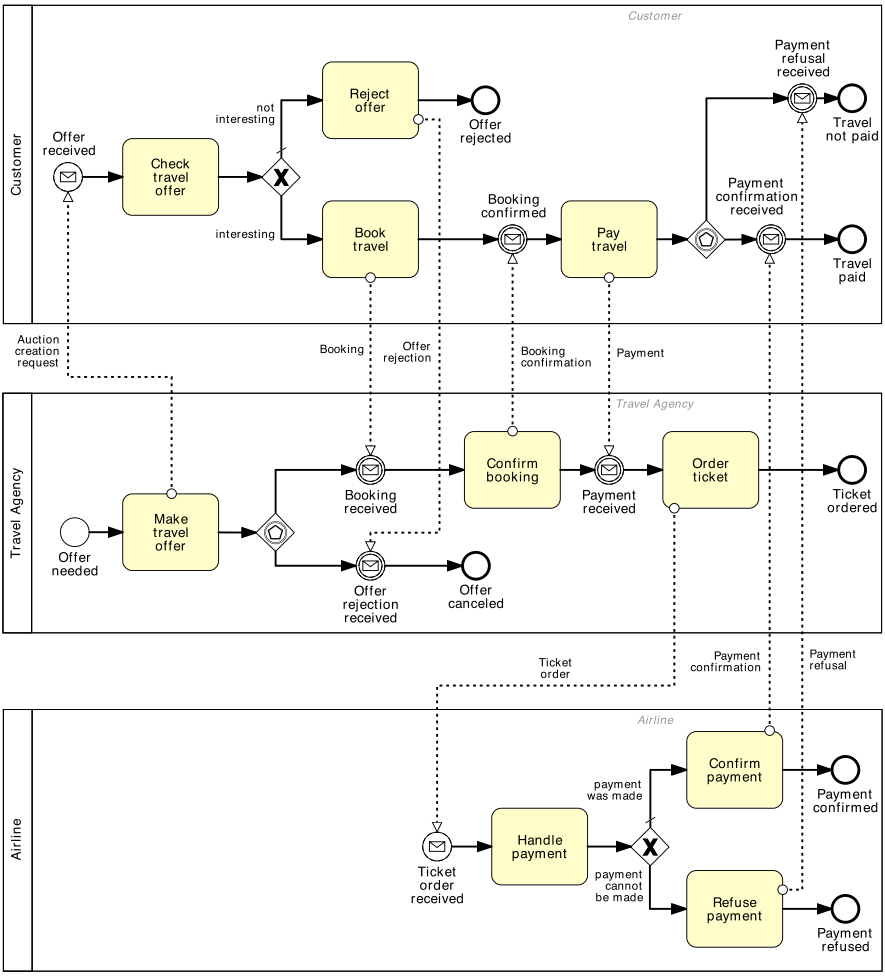
Solution 4.7



Solution 4.8

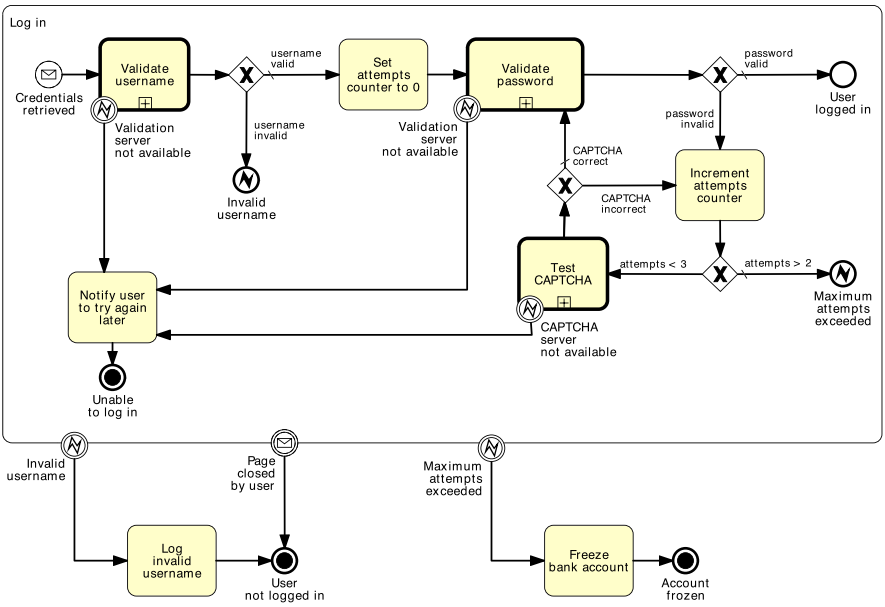


Solution 4.9

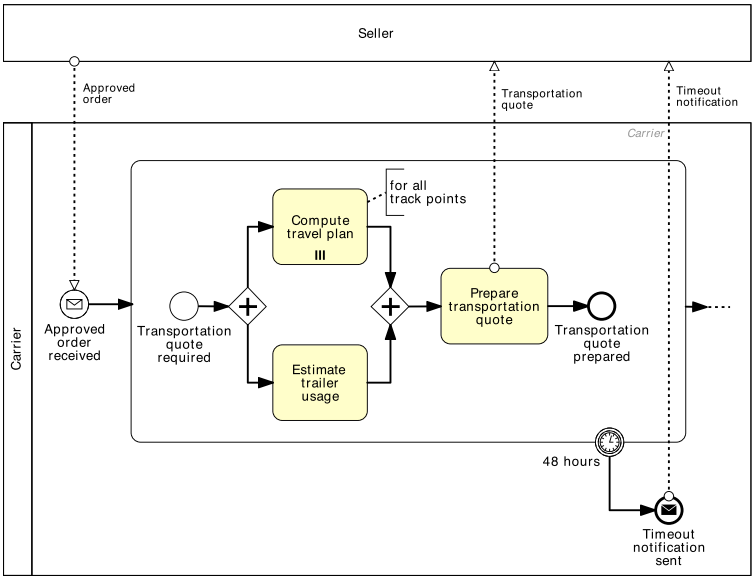


Solution 4.10 The following end events should be terminate events: Fig. 4.12—"callover deferred", Fig. 4.14—"Quote rejected" in the Client and Insurer pools, Fig. 4.18—"Offer rejected" in the Customer pool, "Offer canceled" in the Travel Agency pool and "Payment refused" in the Airline pool.

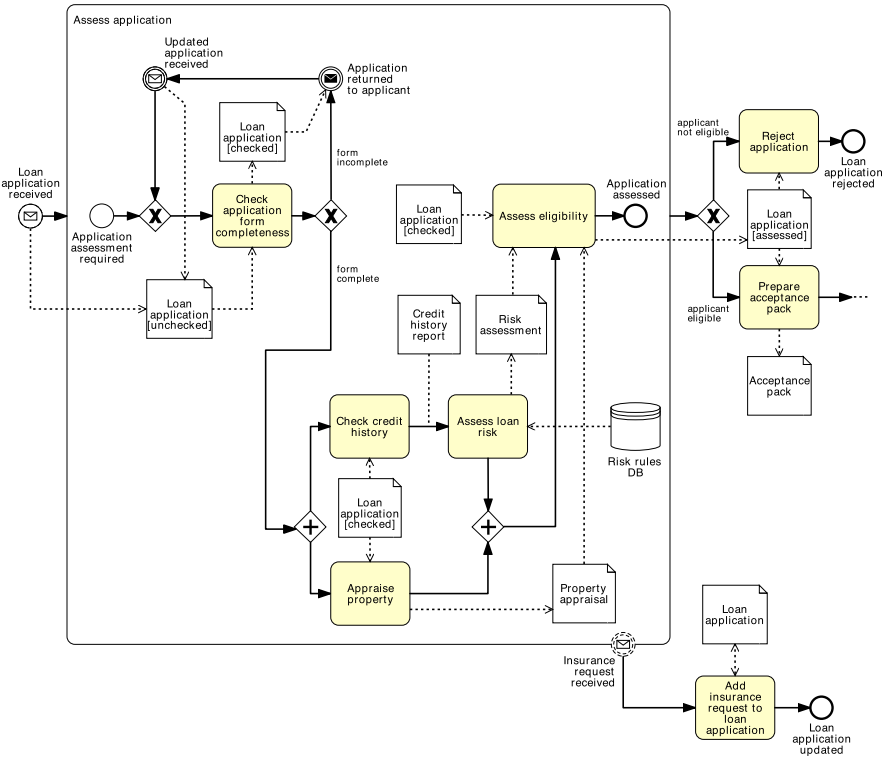
Solution 4.11



Solution 4.12

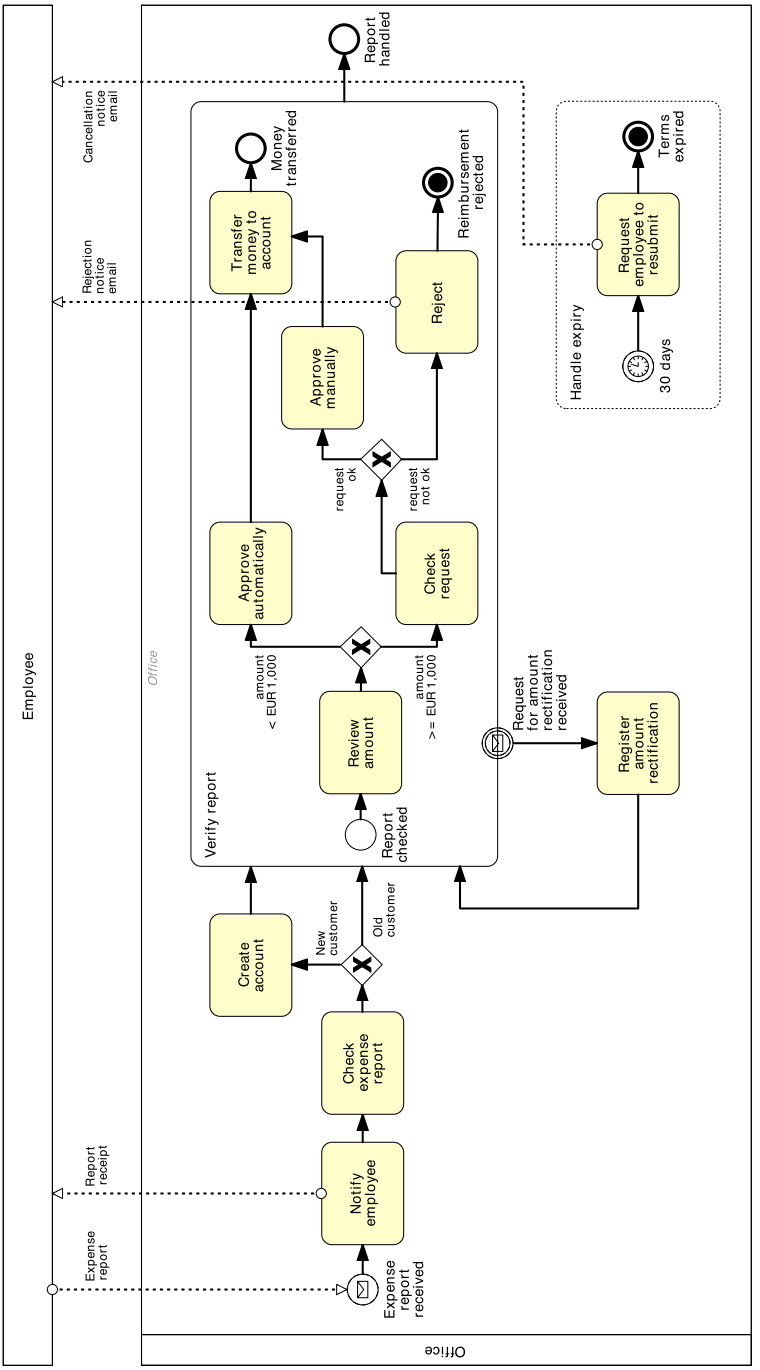


Solution 4.13

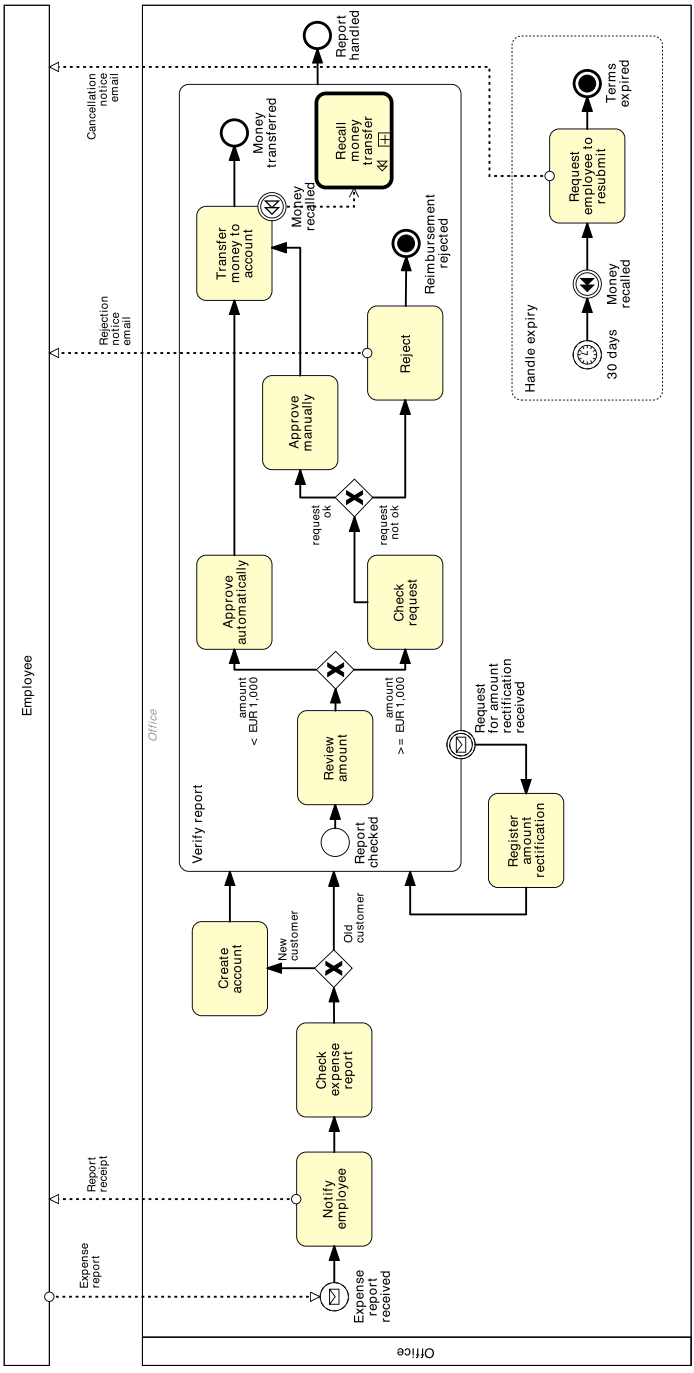


Observe that in the “Assess application” sub-process, the Loan application can have two possible states: “checked” or “unchecked”. In order to use the Loan application in any such state as input of activity “Add insurance request to loan application”, we do not specify any state for this data object in the above model.

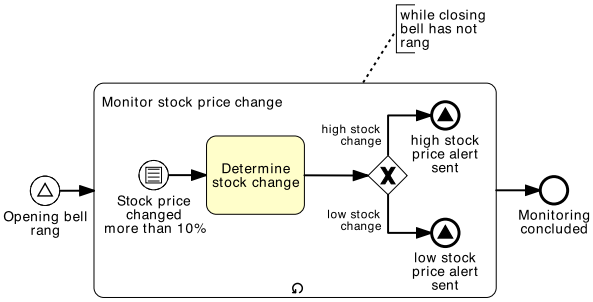
Solution 4.14



Solution 4.15



Solution 4.16



In this solution we did not use a boundary event to stop the sub-process for monitoring stock price changes since this way, the sub-process would only stop because of an exception. Rather, we used the loop condition to allow the sub-process to complete normally, i.e. without being interrupted.

Solution 4.17

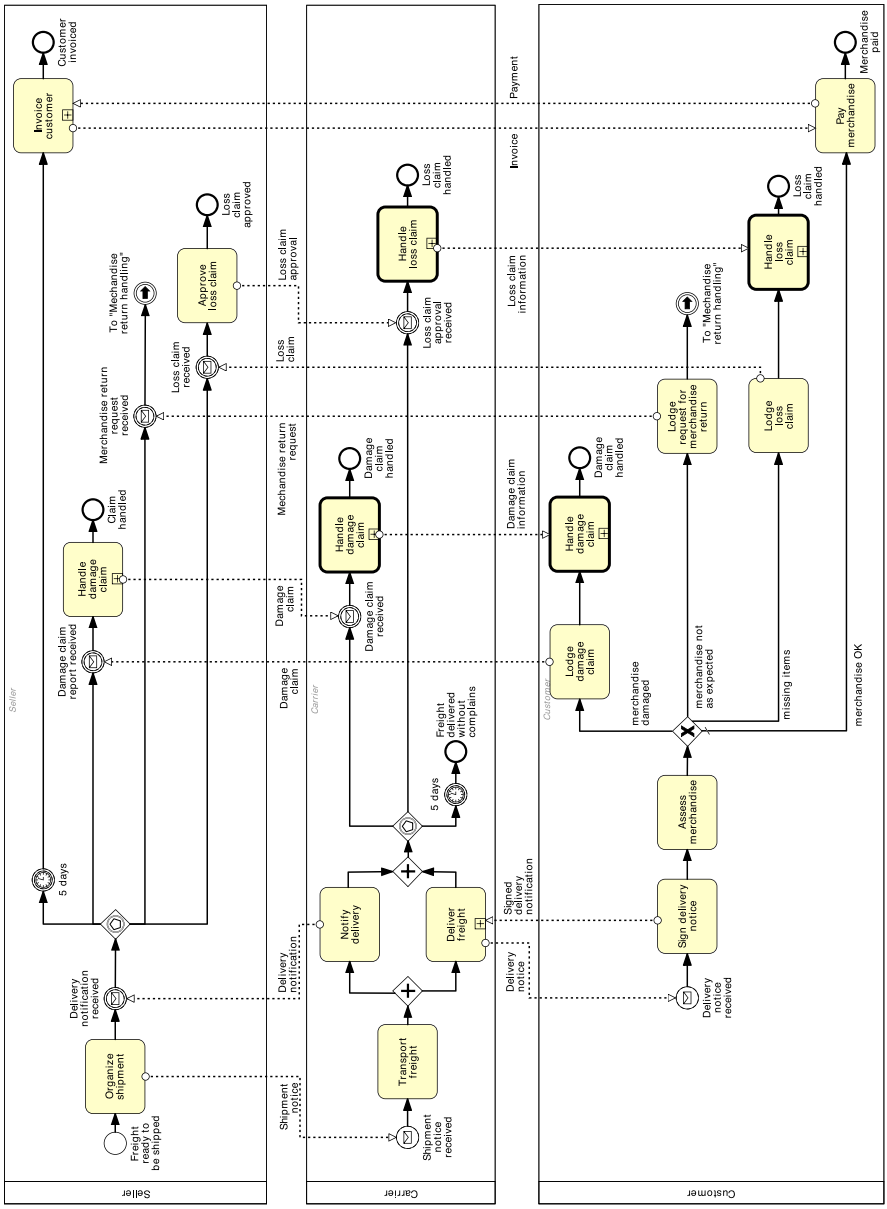


Fig. 4.28 Collaboration diagram—part 1/2 (Freight shipment fragment)

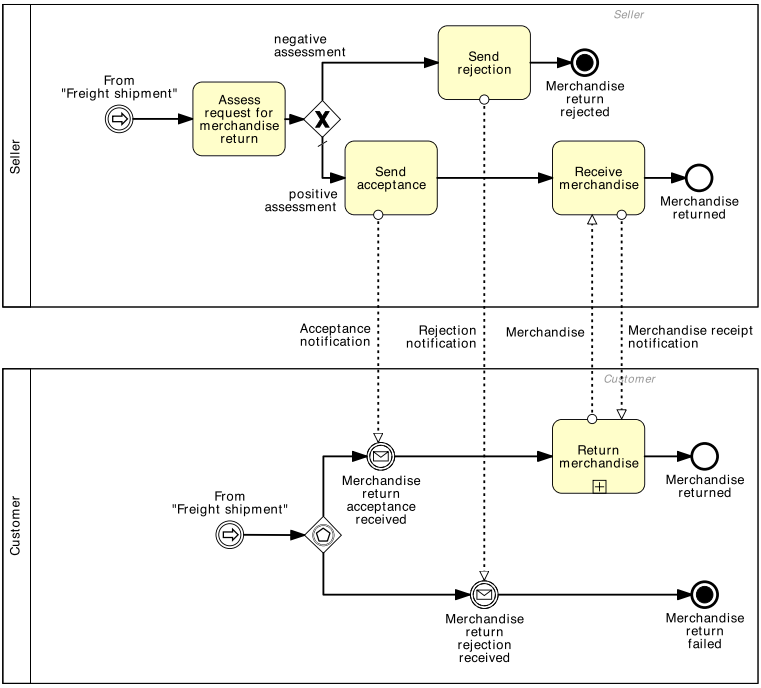


Fig. 4.29 Collaboration diagram—part 2/2 (Merchandise return handling fragment)

In Solution 4.17 we used the *link event* to lay the diagram over two pages, since the model was too large to fit in one page. The link event does not have any semantics: it is purely a notational expedient to break a diagram over multiple pages. An intermediate throwing link event (marked with a full arrow) breaks the process flow and provides a link to the diagram where the flow continues; an intermediate catching link event (marked with an empty arrow) resumes the flow and indicates the diagram where this flow is resumed from.

Solution 4.18

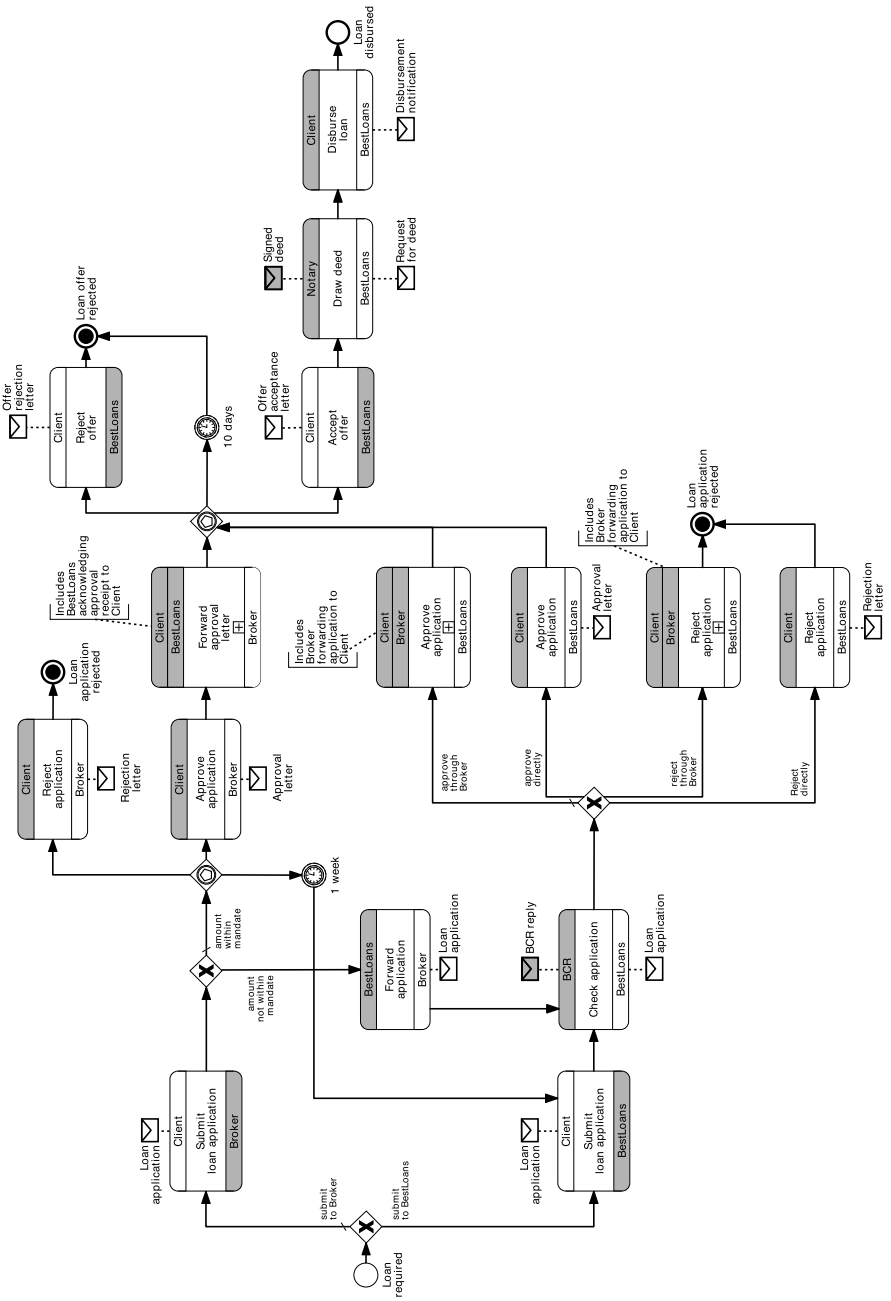


Fig. 4.30 Choreography diagram—part 1/2

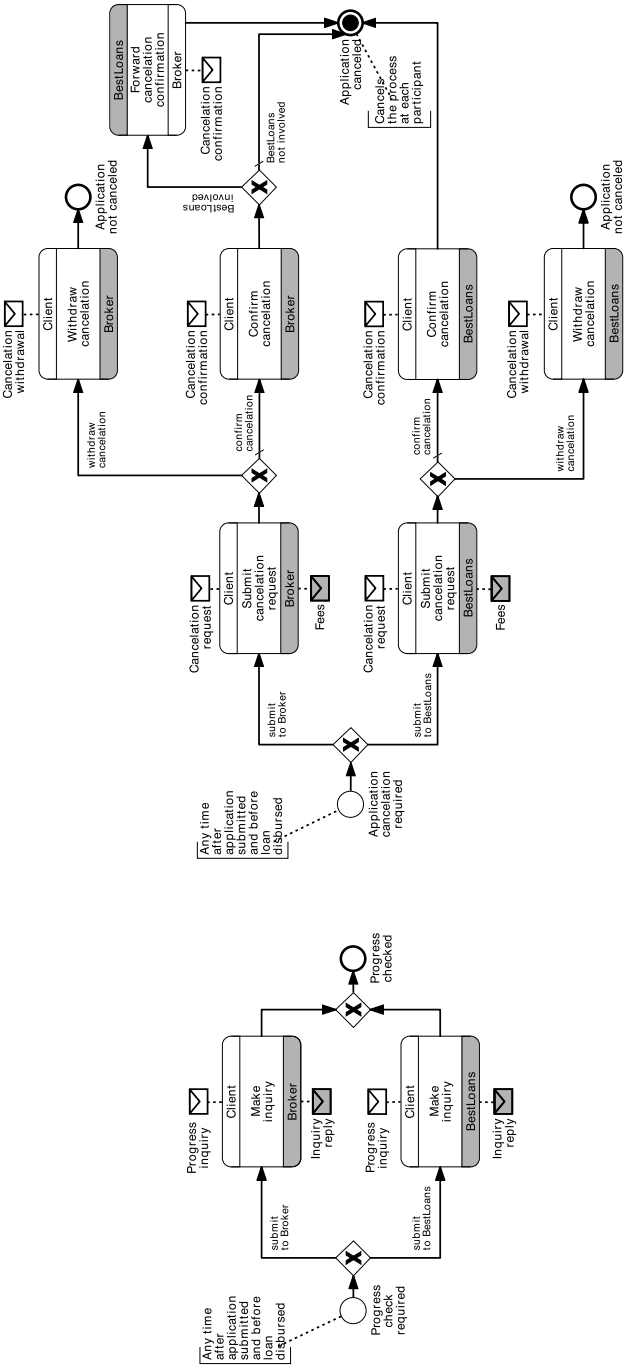


Fig. 4.31 Choreography diagram—part 2/2

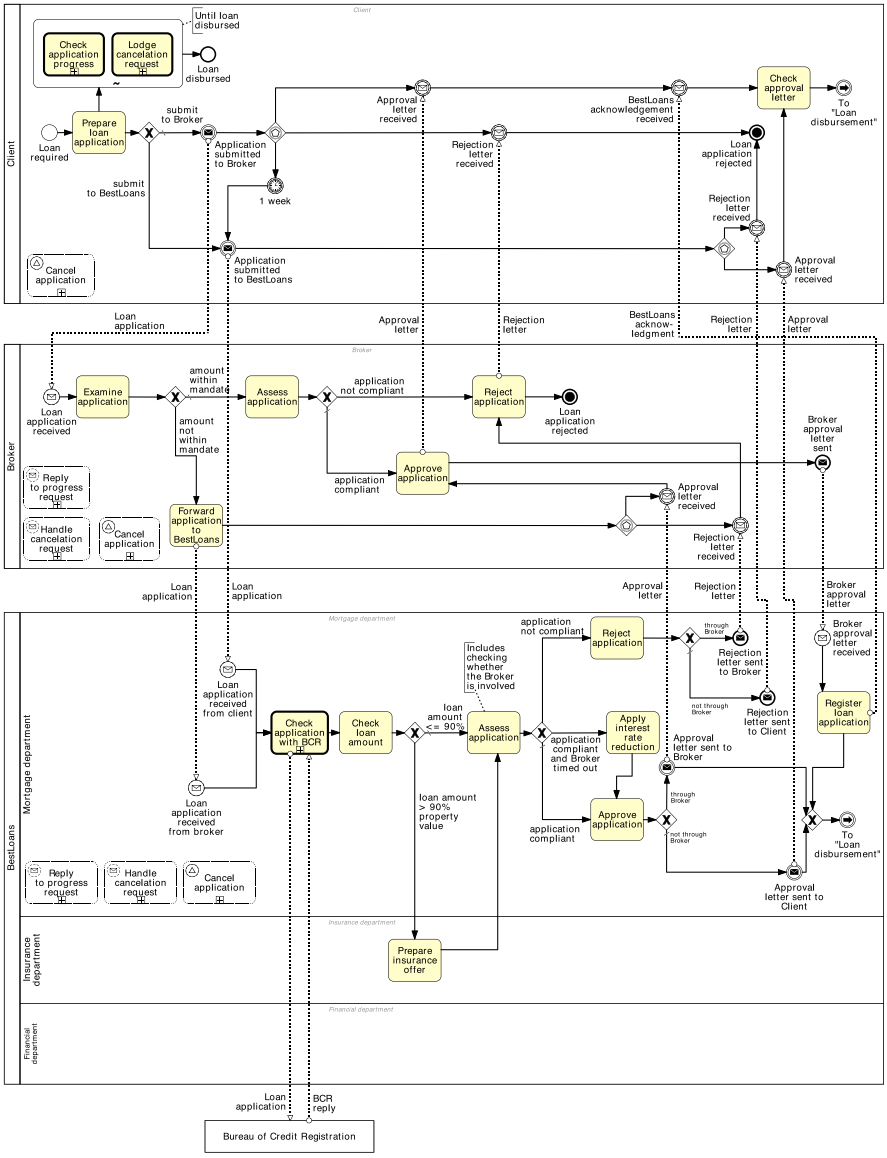


Fig. 4.32 Collaboration diagram—part 1/3 (Loan establishment fragment)

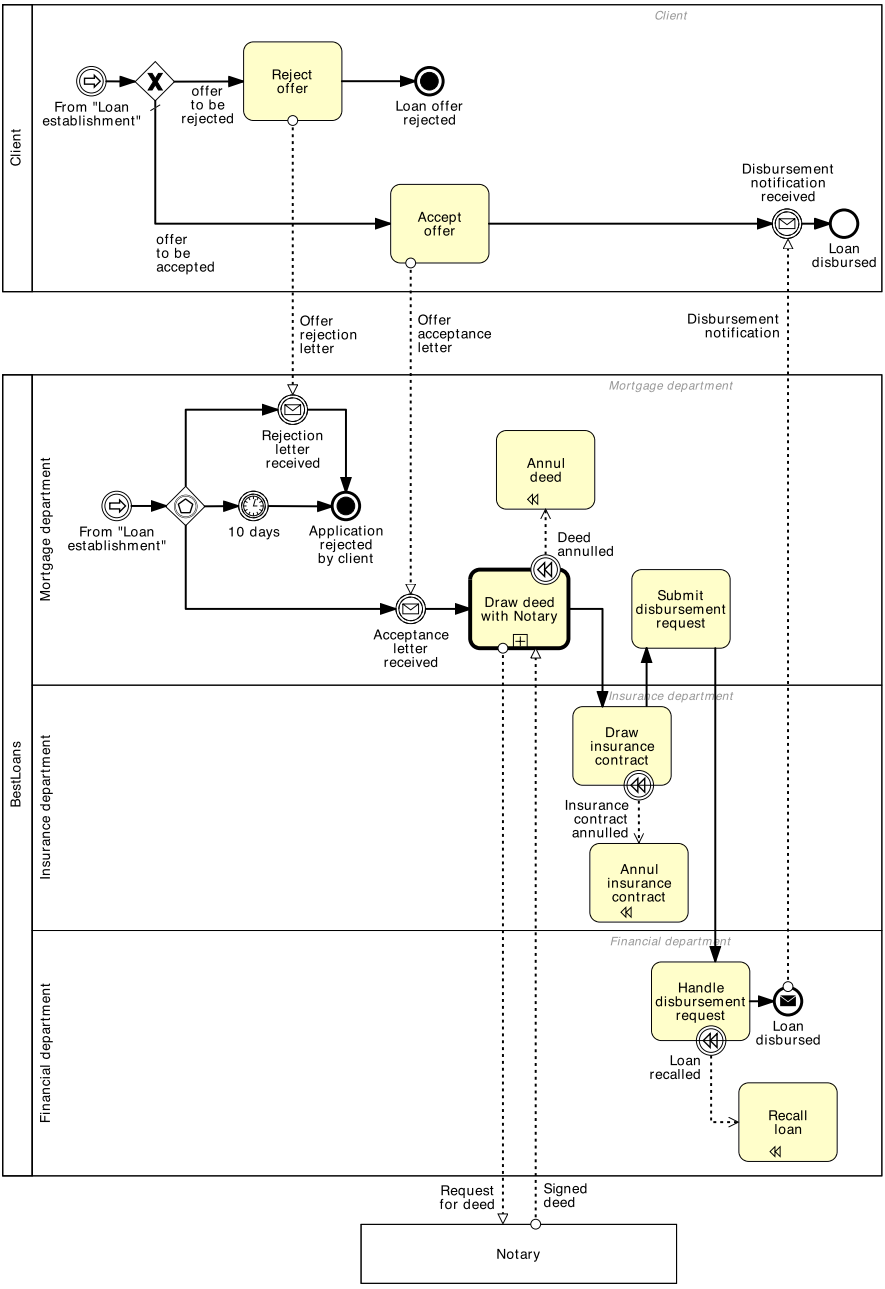


Fig. 4.33 Collaboration diagram—part 2/3 (Loan disbursement fragment)

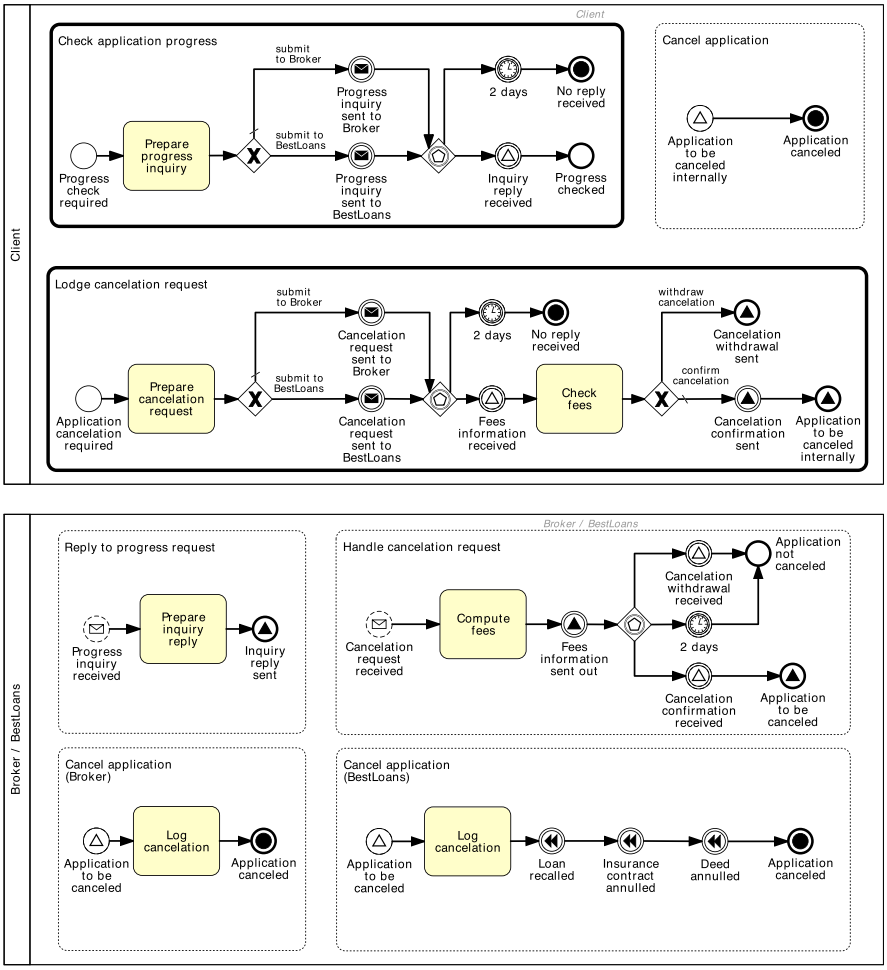


Fig. 4.34 Collaboration diagram—part 3/3 (sub-processes)

4.10 Further Exercises

Exercise 4.19

1. Model the prescription fulfillment process described in Exercise 1.6. Use sub-processes where required, and nest them appropriately.
2. Is there any sub-process that can potentially be shared with other business processes of the same pharmacy, or of other pharmacies?

Exercise 4.20 Model the business process described in Exercise 3.12 using a loop activity.

Exercise 4.21

1. What is the limitation of using a loop activity to model repetition instead of using unstructured cycles?
2. What is the requirement for a sub-process to be used as a loop activity?
3. Model the procure-to-pay process described in Example 1.1.

Hint Use the model in Fig. 1.6 as a starting point for item (3).

Exercise 4.22 Model the following business process.

> Mail from the party is collected on a daily basis by the mail processing unit. Within this unit, the mail clerk sorts the unopened mail into the various business areas. The mail is then distributed. When the mail is received by the registry, it is opened and sorted into groups for distribution, and thus registered in a mail register. Afterwards, the assistant registry manager within the registry performs a quality check. If the mail is not compliant, a list of requisitions explaining the reasons for rejection is compiled and sent back to the party. Otherwise, the matter details are captured and provided to the cashier, who takes the applicable fees attached to the mail. At this point, the assistant registry manager puts the receipt and copied documents into an envelope and posts it to the party. Meantime, the cashier captures the party details and prints the physical court file.

Exercise 4.23 Model the following process for selecting Nobel prize laureates for chemistry.

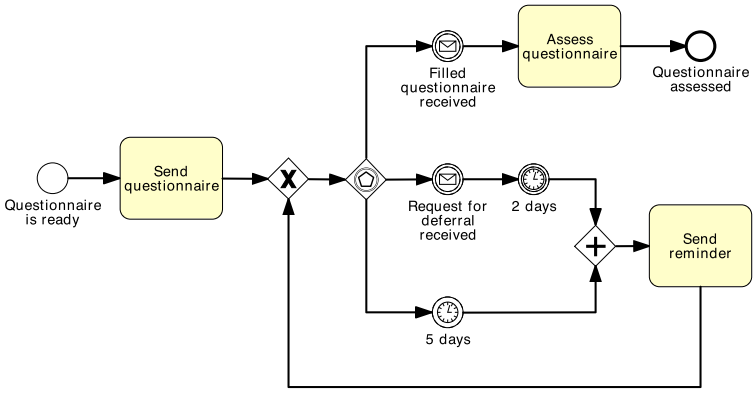
> September: nomination forms are sent out. The Nobel committee sends out confidential forms to around 3,000 people—selected professors at universities around the world, Nobel laureates in physics and chemistry, and members of the Royal Swedish Academy of Sciences, among others.
> February: deadline for submission. The completed nomination forms must reach the Nobel Committee no later than 31 January of the following year. The committee screens the nominations and selects the preliminary candidates. About 250–350 names are nominated as several nominators often submit the same name.
> March–May: consultation with experts. The Nobel committee sends the list of the preliminary candidates to specially appointed experts for their assessment of the work of the candidates.
> June–August: writing of the report. The Nobel committee puts together the report with recommendations to be submitted to the Academy. The report is signed by all members of the committee.
> September: committee submits recommendations. The Nobel committee submits its report with recommendations on the final candidates to the members of the Academy. The report is discussed at two meetings of the chemistry section of the Academy.
> October: Nobel laureates are chosen. In early October, the Academy selects the Nobel laureates in chemistry through a majority vote. The decision is final and without appeal. The names of the Nobel laureates are then announced.
> December: Nobel laureates receive their prize. The Nobel prize award ceremony takes place on 10 December in Stockholm, where the Nobel laureates receive their Nobel prize, which consists of a Nobel medal and diploma, and a document confirming the prize amount.

Acknowledgement This exercise is taken from "Nomination and Selection of Chemistry Laureates", Nobelprize.org. 29 Feb 2012 (http://www.nobelprize.org/nobel_prizes/chemistry/nomination).

Exercise 4.24

1. What is the difference between throwing and catching events?
2. What is the meaning of an event attached to an activity's boundary and what events can be attached to an activity's boundary?
3. What is the difference between the untyped end event and the terminate end event.

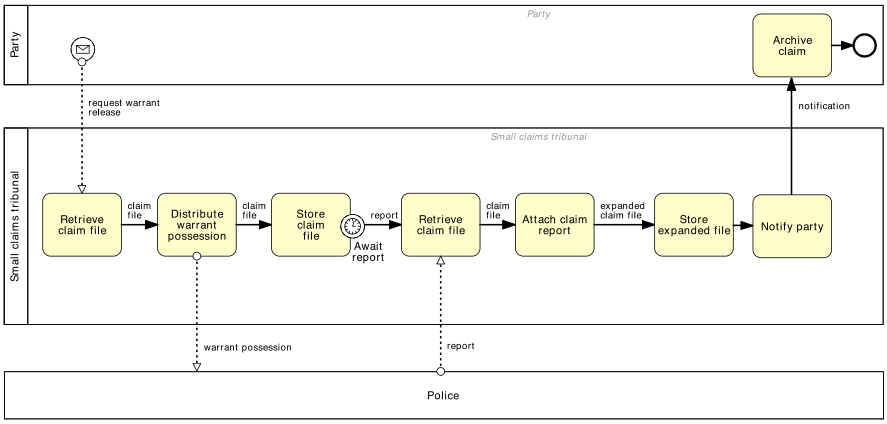
Exercise 4.25 What is wrong with the following model?



Exercise 4.26 Extend the billing process model seen in Exercise 4.7 as follows.

Any time after the first transaction has failed, the customer may pay the invoice directly to the ISP. If so, the billing process is interrupted and the payment is registered. This direct payment must also cover the late fees, based on the number of days passed since Day 7 (the last day to avoid incurring late fees). If the direct payment does not include late fees, the ISP sends a notification to the customer that the fees will be charged in the next invoice, before concluding the process.

Exercise 4.27 What is wrong with the following model?



Exercise 4.28 Model the following business process at a supplier.

After a supplier notifies a retailer of the approval of a purchase order, the supplier can either receive an order confirmation, an order change or an order cancellation from the retailer. It may happen that no response is received at all. If no response is received after 48 hours, or if an order cancellation is received, the supplier will cancel the order. If an order confirmation is received within 48 hours, the supplier will process the order normally. If an order change is received within 48 hours, the supplier will update the order and ask again the retailer for confirmation. The retailer is allowed to change an order at most three times. Afterwards, the supplier will automatically cancel the order.

Exercise 4.29 Revise the model in Exercise 3.9 by using the terminate event.

Exercise 4.30 Model the following business process.

When a claim is received, it is first registered. After registration, the claim is classified leading to two possible outcomes: simple or complex. If the claim is simple, the insurance policy is checked. For complex claims, both the policy and the damage are checked independently. A possible outcome of the policy check is that the claim is invalid. In this case, any processing is canceled and a letter is sent to the customer. In the case of a complex claim, this implies that the damage checking is canceled if it has not been completed yet. After the check(s), an assessment is performed which may lead to two possible outcomes: positive or negative. If the assessment is positive, the garage is phoned to authorize the repairs and the payment is scheduled (in this order). In any case (whether the outcome is positive or negative), a letter is sent to the customer and the process ends. At any moment after the registration and before the end of the process, the customer may call to modify the details of the claim. If a modification occurs before the payment is scheduled, the claim is classified again (simple or complex) and the process is repeated. If a request to modify the claim is received after the payment is scheduled, the request is rejected.

Exercise 4.31 Model the following business process.

An order handling process starts when an order is received. The order is first registered. If the current date is not a working day, the process waits until the following working day before proceeding. Otherwise, an availability check is performed and a purchase order response is sent back to the customer. If any item is not available, any processing related to the order must be stopped. Thereafter, the client needs to be notified that the purchase order cannot be further processed. Anytime during the process, the customer may send a purchase order cancel request. When such a request is received, the purchase order handling process is interrupted and the cancellation is processed. The customer may also send a "Customer address change request" during the order handling process. When such a request is received, it is just registered, without further action.

Exercise 4.32

1. What is the difference between a collaboration and a choreography diagram? What are the respective modeling objectives?
2. Model the choreography diagram for the collaboration diagram that you modeled in Exercise 3.7.

Exercise 4.33 Model the choreography and collaboration diagrams for the following business process for electronic land development applications.

The Smart Electronic Development Assessment System (Smart eDA) is a Queensland Government initiative aimed to provide an intuitive service for preparing, lodging and assessing land development applications. The land development business process starts with the receipt of a land development application from an applicant. Upon the receipt of a land development application, the assessment manager interacts with the cadastre to retrieve geographical information on the designated development area. This information is used to get an initial validation of the development proposal from the city council. If the plan is valid, the assessment manager sends the applicant a quote of the costs that will incur to process the application. These costs depend on the type of development plan (for residential or commercial purposes), and on the permit/license that will be required for the plan to be approved. If the applicant accepts the quote, the assessment can start.

The assessment consists of a detailed analysis of the development plan. First, the assessment manager interacts with the Department of Main Roads (DMR) to check for conflicts with planned road development works. If there are conflicts, the application cannot proceed and must be rejected. In this case, the applicant is notified by the assessment manager. The applicant may wish to modify the development plan and re-submit it for assessment. In this case, the process is resumed from where it was interrupted.

If the development plan includes modifications to the natural environment, the assessment manager needs to request a land alteration permit to the Department of Natural Resources and Water (NRW). If the plan is for commercial purposes, additional fees will be applied to obtain this permit. Once the permit is granted, this is sent by NRW directly to the applicant. Likewise, if the designated development area is regulated by special environment protection laws, the assessment manager needs to request an environmental license to the Environmental Protection Agency (EPA). Similarly, once the license is granted, this is sent by EPA directly to the applicant. Once the required permit and/or license have been obtained, the assessment manager notifies the Applicant of the final approval.

At any time during this process, the applicant can track the progress of their application by interacting directly with the assessment manager.

Assessment manager, cadastre, DMR, NRW and EPA are all Queensland Government entities. In particular, NRW and EPA are part of the Department of Environment and Resource Management within the Queensland Government.

Exercise 4.34 Model the choreography and collaboration diagrams for the following business process for ordering maintenance activities at Sparks.

The ordering business process starts with the receipt of a request for work order from a customer. Upon the receipt of this request, the ordering department of Sparks estimates the expected usage of supplies, parts and labor and prepares a quote with the estimated total cost for the maintenance activity. If the customer's vehicle is insured, the ordering department interacts with the insurance department to retrieve the details of the customer's insurance plan so that these can be attached to the quote. The ordering department then sends the quote to the customer, who can either accept or reject the quote by notifying the ordering department within five days. If the customer accepts the quote, the ordering department contacts the warehouse department to check if the required parts are in stock before scheduling an appointment with the customer. If some parts are not in stock, the ordering department orders the required parts by interacting with a certified reseller and waits for an order confirmation from the reseller, to be received within three days. If it is not received, the order department orders the parts again from a second reseller. If no reply is received from the second reseller too, the order department notifies the customer that the parts are not available and the process terminates. If the required parts are in stock or have been ordered, the ordering department interacts with an external garage to book a suitably equipped service bay and a suitably qualified mechanic to perform the work. A confirmation of the appointment is then sent by the garage to the order department which forwards the confirmation to the customer. The customer has one week to pay Sparks, otherwise the ordering department cancels the work order by sending a cancellation notice to both the service bay and the mechanic that have been booked for this order. If the customer pays in time, the work order is performed.

Exercise 4.35 Model the choreography and collaboration diagrams for the following business process at MetalWorks. Keep in mind that the purpose of this BPMN diagram is to serve as a means of communication between the business stakeholders and the IT team who has to build a software system to automate this process.

A build-to-order (BTO) process, also known as make-to-order process, is an "order-to-cash" process where the products to be sold are manufactured on the basis of a confirmed purchase order. In other words, the manufacturer does not maintain any ready-to-ship products in their stock. Instead, the products are manufactured on demand when the customer orders them. This approach is used in the context of customized products, such as metallurgical products, where customers often submit orders for products with very specific requirements.

We consider a BTO process at a company called MetalWorks. The process starts when MetalWorks receives a purchase order (PO) from one of its customers. This PO is called the "customer PO". The customer PO may contain one or multiple line items. Each line item refers to a different product.

Upon receiving a customer PO, a sales officer checks the PO to determine if all the line items in the order can be produced within the timeframes indicated in the PO. As a result of this check, the sales officer may either confirm the customer PO or ask the customer to revise the terms of the PO (for example: change the delivery date to a later date). In some extreme cases, the sales officer may reject the PO, but this happens very rarely. If the customer is asked to revise the PO, the BTO process will be put in "stand-by" until the customer submits a revised PO. The sales officer will then check the revised PO and either accept it, reject it, or ask again the customer to make further changes.

Once a PO is confirmed, the sales officer creates one "work order" for each line item in the customer PO. In other words, one customer PO gives place to multiple work orders (one per line item). The work order is a document that allows employees at MetalWorks to keep track of the manufacturing of a product requested by a customer.

In order to manufacture a product, multiple raw materials are typically required. Some of these raw materials are maintained in stock in the warehouse of MetalWorks, but others need to be sourced from one or multiple suppliers. Accordingly, each work order is examined by a production engineer. The production engineer determines which raw materials are required in order to fulfill the work order. The production engineer annotates the work order with a list of required raw materials. Each raw material listed in the work order is later checked by a procurement officer. The procurement officer determines whether the required raw material is available in stock, or it has to be ordered. If the material has to be ordered, the procurement officer selects a suitable supplier for the raw material and sends a PO to the selected supplier. This "PO for a raw material" is called a "material PO", and it is different from the customer PO. A material PO is a PO sent by MetalWorks to one of its suppliers, whereas a customer PO is a PO received by MetalWorks from one of its customers.
Once all materials required to fulfill a work order are available, the production can start. The responsibility for the production of a work order is assigned to the same production engineer who previously examined the work order. The production engineer is responsible for scheduling the production. Once the product has been manufactured, it is checked by a quality inspector. Sometimes, the quality inspector finds a defect in the product and reports it to the production engineer. The production engineer then decides whether: (i) the product should undergo a minor fix; or (ii) the product should be discarded and manufactured again. Once the production has completed, the product is shipped to the customer. There is no need to wait until all the line items requested in a customer PO are ready before shipping them. As soon as a product is ready, it can be shipped to the corresponding customer.
At any point in time (before the shipment of the product), the customer may send a "cancel order" message for a given PO. When this happens, the sales officer determines if the order can still be canceled, and if so, whether or not the customer should pay a penalty. If the order can be canceled without penalty, all the work related to that order is stopped and the customer is notified that the cancellation has been successful. If the customer needs to pay a penalty, the sales officer first asks the customer if they accept to pay the cancellation penalty. If the customer accepts to pay the cancellation penalty, the order is canceled and all work related to the order is stopped. Otherwise, the work related to the order continues.

4.11 Further Reading

In this chapter we showed how sub-processes can be used to reduce the complexity of a process model by reducing the overall process model *size*. Size is a metric strongly related to the understandability of a process model. Intuitively, the smaller the size, the more understandable will the model be. There are other metrics that can be measured from a process model to assess its understandability, for instance the *degree of structuredness*, the *diameter*, and the *coefficient of connectivity*. A comprehensive discussion on process model metrics is available in [50]. The advantages of modularizing process models into sub-processes and automatic techniques are covered in [75], while the correlation between number of flow objects and error probability in process models is studied in [54, 55].

BPMN 2.0 provides various other event types besides the main ones presented in this chapter. For example, the *link event* can be used to modularize a process sequentially (useful when a process model does not fit on a single paper and has to be divided over multiple papers). An example of link event is shown in Figs. 4.28 and 4.29. The *multiple event* can be used to catch one of a set of events or throw a set of

events. Moreover, BPMN 2.0 provides a further diagram type besides collaborations and choreographies. This diagram type is called *conversation diagram*, and focuses on the messages exchanged by two or more process parties, abstracting from the precise order in which the messages occur. All these constructs are described in detail in the BPMN 2.0 specification by OMG [61]. There are also various books that present BPMN 2.0 by example, among others [2, 87, 107].

This chapter concludes our coverage of the BPMN 2.0 language. For further information on this language, we point to the BPMN web-site: www.bpmn.org, where the official specification can be downloaded from. This site also provides a link to a handy BPMN poster, a quick reference guide on all BPMN elements and includes a comprehensive list of books on the subject, as well as tool implementations that support this standard.

Chapter 5
Process Discovery

All truths are easy to understand once they are discovered;
the point is to discover them.
Galileo Galilei (1564–1642)

The previous chapters showed how to create a BPMN model. This chapter goes further by showing how to create models that are both correct and complete. To this end, one needs to thoroughly understand the operation of a business process, and one needs to possess the technical skills to represent it in an appropriate BPMN model. These two types of skill are hardly ever unified in the same person. Hence, multiple stakeholders with different and complementary skills are typically involved in the construction of a process model.

This chapter presents the challenges faced by the stakeholders involved in the lead-up to a process model. Then, we discuss methods to facilitate effective communication and information gathering in this setting. Given the information gathered in this way, we show step by step how to construct a process and what criteria should be verified before a process model is accepted as an authoritative representation of a business process.

5.1 The Setting of Process Discovery

Process discovery is defined as the act of gathering information about an existing process and organizing it in terms of an as-is process model. This definition emphasizes gathering and organizing information. Accordingly, process discovery is a much broader activity than modeling a process. Clearly, modeling is a part of this activity. The problem is though that modeling can only start once enough information has been put together. Indeed, gathering information often proves to be cumbersome and time-consuming in practice. Therefore, we need to first define a setting in which information can be gathered effectively. In order to address these issues, we can describe four phases of process discovery:

1. Defining the setting: This phase is dedicated to assembling a team in a company that will be responsible for working on the process.

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2. Gathering information: This phase is concerned with building an understanding of the process. Different discovery methods can be used to acquire information on a process.
3. Conducting the modeling task: This phase deals with organizing the creation of the process model. The modeling method gives guidance for mapping out the process in a systematic way.
4. Assuring process model quality: This phase aims to guarantee that the resulting process models meet different quality criteria. This phase is important for establishing trust in the process model.

Typically, one or several *process analysts* are responsible for driving the modeling and analysis of a business process. Often, the process analyst is not familiar with all details of the business process. The definition of the setting of process discovery is critical since it helps the process analyst to secure the commitment of various domain experts for providing information on the process. These domain experts have to cover the relevant perspectives on the process. Therefore, different *domain experts* should be involved. A domain expert is any individual who has intimate knowledge about how a process or activity is performed. Typically, the domain expert is a process participant, but it can also be a process owner or a manager who works closely with the process participants who perform the process. Also suppliers and customers of the process can be considered as domain experts. The involved domain experts should jointly have insight into all activities of the process. It is the task of the process owner to secure the commitment and involvement of these persons. In the following, we will focus on the relationship between process analyst and domain expert in order to illustrate three challenges of process discovery.

5.1.1 Process Analyst Versus Domain Expert

One fundamental problem of process discovery relates to the question of who is going to model the business process. This problem is illustrated by the following exercise.

Exercise 5.1 Consider the following two tasks, and explain their difference:

- The task of modeling the process of signing a rental contract in your city.
- The task of modeling the process of getting a license plate for your car in Liechtenstein as a foreign resident.

The point of this exercise is to emphasize a potential difference in knowledge about processes. If you have already acquired some knowledge of mapping processes with BPMN by the help of this book, you will be able to create an initial process model for the rental process. The reason is that you not only have modeling

Table 5.1 Typical profile of process analyst and domain expert

Aspect	Process Analyst	Domain Expert
Modeling Skills	strong	limited
Process Knowledge	limited	strong

knowledge but also some knowledge about the domain of renting a flat in your city. The case is likely to be different for getting a license plate for a car in Liechtenstein as a foreign resident. There are only few foreign residents living in Liechtenstein, our colleague Jan vom Brocke being one of them. Most other people would not know how this process works. If we are supposed to model a process that we do not know, we have to gather an extensive amount of information about it in order to understand how it works. That is exactly the situation we are typically facing in practice: a process needs to be modeled, we have the required modeling skills, but we have only limited knowledge of the corresponding domain.

In order to describe the typical modeling situation in a plastic way, we distinguish between the role of a *process analyst* and the role of a *domain expert*. In a real modeling project, we have one or a few process analysts and several domain experts. Process analysts and domain experts have complementary roles in the act of process discovery as well as different strengths as shown in Table 5.1. The process analyst is the one who has profound knowledge of business process modeling techniques. A process analyst is familiar with languages like BPMN and skilled in organizing information in terms of a process diagram. However, process analysts have typically a limited understanding of the concrete process that is supposed to be modeled. For this reason, they depend upon the information being provided by domain experts. Domain experts have detailed knowledge of the operation of the considered business process. They have a clear understanding of what happens within the boundaries of the process, which participants are involved, which input is required, and which output is generated. On the downside, the domain expert is typically not familiar with languages like BPMN. In some companies, domain experts even refuse to discuss process models and diagrams, because they feel more comfortable by sticking to natural language for explaining what is happening in the process. As a consequence, domain experts often rely on a process analyst for organizing their process knowledge in terms of a process model.

At this stage, it has to be emphasized that the difference in modeling skills of process analysts and domain experts only results from different exposure to practical modeling and modeling training. Many companies use training programs for improving the modeling skills of domain experts. Such training is a prerequisite for modeling initiatives where process participants are expected to model processes on their own. On the other hand, there are consulting companies that specialize in a particular domain. It is an advantage when process analysts of consultancies can be assigned to modeling projects who are experts in modeling and have at least a certain level of domain expertise.

5.1.2 Three Process Discovery Challenges

The fact that modeling knowledge and domain knowledge is often available in different persons in a modeling project has strong implications. It gives rise to three essential challenges of process discovery, namely fragmented process knowledge, thinking in cases, and lack of familiarity with process modeling languages.

Exercise 5.2 An online book retailer faces a problem with its order process in terms of processing time. In order to identify the root cause of the problem, the company decides that every team involved with the order process should model its part of the process. Why could this approach be problematic?

The first challenge of process discovery relates to *fragmented process knowledge*. Business processes define a set of logically related activities. These activities are typically assigned to specialized participants. This has the consequence that a process analyst needs to gather information about a process not only by talking with a single domain expert, but with several domain experts who are responsible for the different tasks of the process. Typically, domain experts have an abstract understanding of the overall process and a very detailed understanding of their own task. This makes it often difficult to puzzle the different views together. In particular, one domain expert might have a different idea about which output has to be expected from an upstream activity than the domain expert actually working on it. Potential conflicts in the provided information have to be resolved. It is also often the case that the rules of the process are not explicitly defined in detail. In those situations, domain experts may operate with diverging assumptions, which are often not exactly consistent. Fragmented process knowledge is one of the reasons why process discovery requires several iterations. Having received input from all relevant domain experts, the process analyst has to make proposals for resolving inconsistencies, which again requires feedback and eventually approval of the domain experts.

The second challenge of process discovery stems from the fact that domain experts typically *think of processes on a case level*. Domain experts will find it easy to describe the activities they conducted for one specific case, but they might have problems responding to general questions about how a process works in the general way. Process analysts often get answers like "you cannot really generalize, every case is different" to such a question. It is indeed the task of the process analyst to organize and abstract from the pieces of information provided by the domain expert in such a way that a systematically defined process model can emerge. Therefore, it is required to ask specific questions about what happens if some task is completed, what if certain conditions do or do not hold, and what if certain deadlines are not met. In this way, the process analyst can reverse engineer the conditions that govern the routing decisions of a business process.

The third challenge of process discovery is a result of the fact that domain experts are typically *not familiar with business process modeling languages*. This observation already gave rise to the distinction of domain experts and process analysts. In this context, the problem is not only that domain experts are often not trained to

create process models themselves, but also that they are not trained to read process models that others have created. This lack of training can encumber the act of seeking feedback to a draft of a process model. In this situation it is typically not appropriate to show the model to the domain expert and ask for corrections. Even if domain experts understand the activity labels well, they would often not understand the sophisticated parts of control flow captured in the model. Therefore, the process analyst has to explain the content of the process model in detail, for example by translating the formal notation of the process model to a natural-language description with the same meaning. Domain experts will feel at ease in responding to these natural-language explanations, pointing out aspects that need modification or further clarification according to their understanding of the process.

5.1.3 Profile of a Process Analyst

The skills of a process analyst play an important role in process discovery. Expert process analysts can be described based on a set of general dispositions, their actual behavior in a process analysis project, and in terms of the process resulting from their efforts.

Exercise 5.3 You are the manager of a consulting company, and you need to hire a person for the newly signed process analysis project with an online book retailer. Consider the following two profiles, who would you hire as a process analyst?

- Mike Miller has ten years of work experience with an online retailer. He has worked in different teams involved with the order process of the online retailer.
- Sara Smith has five years of experience working as a process analyst in the banking sector. She is familiar with two different process modeling tools.

Research on expertise in the general area of system analysis and design has found that there are certain personal traits that are likely to be observed for expert process analysts. Apparently, there seems to exist a set of certain personal dispositions that help in becoming an expert in process analysis. One of the ways to describe personality is the so-called *Five Factor Model* developed in psychological research. In essence, this model contains the dimensions openness (appreciating art, emotion, and adventure), conscientiousness (tendency to self-discipline, achievement and planning), extraversion (being positive, energetic, and seeking company), agreeableness (being compassionate and cooperative), and neuroticism (being anxious, depressed and vulnerable). These factors have also been studied regarding their connection with expert analysts. These experts appear to be strong both in terms of conscientiousness and extraversion. Indeed, process discovery projects require a conscientious planning and coordination of interviews with various domain experts in a limited period of time. Furthermore, process discovery projects are sometimes subject to enterprise-internal politics in situations where the agenda of different process stakeholders is not thoroughly clear or where stakeholders might fear losing

their position. In such an environment, it is valuable to have an energetic and extraverted process analyst involved who is able to create a positive atmosphere for working on the project.

Process discovery in general belongs to the category of ill-defined problems. This means in the beginning of a process discovery project, it is not exactly clear who of the domain experts have to be contacted, which documentation can be utilized, and which agenda the different stakeholders might have in mind. The way how expert analysts navigate through a project is strongly influenced by experiences with former projects. Therefore, there is a strong difference between the way how novices and expert analysts conduct problem understanding and problem solving. In terms of problem understanding, it has been observed that expert analysts approach a project in terms of what are the things that need to be achieved. Novices lack this clear goal orientation, and try to approach things in a bottom-up way. This means, they often start by investigating material that is easily accessible and talk to persons that readily respond. Experts work in a different way. They have an explicit set of triggers and heuristics available from experiences with prior projects. They tend to pay specific attention to the following aspects:

- Getting the right people on board. If you need to talk to a given process participant, make sure their immediate supervisor and the one above them is on board and that the process participant knows that their hierarchy backs their involvement in the process discovery effort.
- Having a set of working hypotheses on how the process is structured at different levels of details. In order to progress with the project, it is important to have a short and precise set of working hypotheses, which they step-by-step challenge. Prepare a extensive set of questions and assumptions to be discussed in workshops or interviews.
- Identifying patterns in the information provided by domain experts. These can be utilized for constructing parts of a process model. Such pieces of information typically refer to specific control structure. For instance, statements about certain activities being alternative, exclusive, or subject to certain conditions often point to the usage of XOR-gateways. In a similar way, statements about activities being independent of another, or sometimes being in one or another order, often suggest concurrency. For their knowledge of such patterns, it is often easy for expert analysts to sketch out processes.
- Paying attention to model aesthetics. Models have to look nice to be engaging to a wide audience. This does not only help to have a resulting model that is easy to understand by stakeholders, but also valuable throughout the process of creating the model. Experts also use the right level of abstraction. For example, you should not show a super-detailed model to an executive-level manager. The importance of layout is apparent from the fact that expert analysts often take half of the time while creating a model for repositioning its elements in a meaningful way.

5.2 Discovery Methods

As we have now a rough idea of the tasks that a process analyst has and which capabilities and limitations he has to keep in mind when interacting with domain experts, we turn to different techniques for gathering information about a process. In general, we distinguish three classes of discovery techniques, namely evidence-based discovery, interview-based discovery, and workshop-based discovery. There are strengths and limitations, which we will discuss subsequently.

Exercise 5.4 Imagine you would be assigned the task of modeling the process of how a book order is processed by your favorite online book retailer. How can you systematically gather the required pieces of information about this process?

5.2.1 Evidence-Based Discovery

Various pieces of evidence are typically available for studying how an existing process works. Here, we discuss three methods: document analysis, observation, and automatic process discovery.

Document analysis exploits the fact that there is usually documentation material available that can be related to an existing process. However, there are some potential issues with document analysis. First, most of the documentation that is available about the operations of a company is not readily organized in a process-oriented way. Think of an organization chart, for instance. It defines the departments and positions, it is helpful to identify a potential set of process stakeholders. Such material can help to structure phases of a process. For example, in case of our online book retailer, it might reveal that the sales department, the logistics department and the finance department are likely to be involved with the book order. Second, the level of granularity of the material might not be appropriate. While an organization chart draws rather an abstract picture of a company, there are often many documents that summarize parts of a process on a too fine-granular level. Many companies document detailed work instructions for tasks and work profiles for positions. These are typically too detailed for modeling processes. Third, many of the documents are only partially trustworthy. For a process discovery project, it is important to identify how a process works in reality. Many documents do not necessarily show reality. Some of them are outdated and some state how things should work idealistically, and not how people conduct them in reality. The advantage of document analysis is that a process analyst can use them to get familiar with certain parts of a process and its environment, and also to formulate hypotheses. This is helpful before talking to domain experts. On the downside, a process analyst has to keep in mind that documents do not necessarily reflect the reality of the process.

If we use *observation* as a method of discovery, we directly follow the processing of individual cases in order to get an understanding of how a process works. The process analyst can either play the active role of a customer of a process or the

passive role of an observer. As part of the *active customer role*, the process analyst triggers the execution of a process and records the steps that are executed and the set of choices that are offered. For instance, in the case of the online book retailer, the analyst can create a new book order and keep track of which activities are performed at the side of the retailer. This provides a good understanding of the boundaries of the process and its essential milestones. However, the analyst will only see those parts of the process that require interaction with the customer. All backoffice processing remains a black box. The role of a *passive observer* is more appropriate for understanding the entire process, but it also requires access to the people and sights where the process is being worked on. Usually, such access requires the approval of the managers and supervisors of the corresponding teams. Furthermore, there might be a potential issue with people acting differently, because they are aware of being observed. People usually change their behavior under observation in such a way that they work faster and more diligently. This is important to be kept in mind when execution times have to be estimated. However, discovery based on observation has the advantage that it reveals how a process is conducted in reality today, which is in contrast to document analysis that typically captures the past.

A third option of *automatic process discovery* emerges from the extensive operational support of business processes provided by various information systems. Automatic process discovery makes use of event logs that are stored by these information systems. Such event data have to be recorded in such a way that each event can be exactly related to three things: an individual case of the process, a specific activity of the process, and a precise point in time. If these three pieces of information are available in the event logs, then automatic process discovery techniques can be used to reconstruct the process model, for example for the online book retailer. Since this approach shares some characteristics with data mining, where meaningful information is extracted from fine-granular data, these techniques of automatic process discovery are subsumed to the research area of process mining. The advantage of automatic process discovery is that event logs capture the execution of a process very accurately including information about execution times. A limitation is though that some log information can be misleading. This may be the case if a system crashes such that logs are not stored correctly. These failure types relating to a flawed storage of event logs are summarized with the term noise. Furthermore, the models resulting from process mining may not be directly understandable. Process behavior can be very complex, such that the generated models are hardly readable. In such a case, the logs have to be filtered or clustered for getting models that help understanding the process.

5.2.2 Interview-Based Discovery

Interview-based discovery refers to methods that build on interviewing domain experts about how a process is executed. With these methods, we have to explicitly take into account the challenges of process discovery, namely the fact that process

knowledge is scattered across different domain experts, that domain experts typically think in terms of individual cases, and that domain experts are often not familiar with business process modeling languages. This has implications for how the interviews can be scheduled, and which phases and iterations are required.

Exercise 5.5 Consider that the order process of your favorite online book retailer has ten major activities that are conducted by different persons. How much time do you need approximately for creating a process model that is validated and approved by the process owner? Make appropriate assumptions.

We have mentioned that process knowledge is typically fragmented due to specialization and division of labor. For this reason, interviews have to be conducted with various domain experts involved in the process. As the process analyst might not yet understand the details of the involvement of different domain experts, it might be required to discover the process step by step. There are two strategies available for scheduling interviews: starting backwards from the products and results of the process and starting at the beginning by proceeding forward. Conducting interviews in a forward way permits to follow the flow of processing in the order of how it unfolds. This is particularly helpful for understanding which decisions are taken at a given stage. However, following the processing in a backward way has also advantages. People working in a process require certain input to be available for conducting their work, and this perspective makes it easy to consider what has to be achieved before a specific activity can be conducted. Both perspectives, the downstream and the upstream perspective are important when interviewing domain experts. With each interview partner, it must be clarified which input is expected from prior upstream activities, which decisions are taken, and in which format the results of an activity are forwarded to which subsequent party.

The discovery challenges emphasize that the expertise of the process analyst is required for abstracting information on how individual cases are executed in order to construct meaningful process models. Typically, the process analyst gathers information about the process in interviews and later organizes the material offline before constructing an initial process model. As a consequence, interviewing a domain expert is often conducted in different iterations. After an initial interview, the process analysts creates a draft process model, which is then discussed with the domain expert in terms of correctness and completeness. Here, it is important to ask what happens if something goes wrong or how unexpected cases are handled. This feedback interview usually triggers another round of rework. In some cases, the second feedback round leads to an approval of the process model. In other cases, a third feedback round is required for checking the reworked process model again. Often, domain experts feel more comfortable with free-form interviews where they can discuss the process at a level of detail that they find appropriate. Structured interviews, in contrast, can create a feeling of running through a checklist, with the effect that domain experts hold back important information that they are not explicitly asked for.

It is a strength of interview-based discovery that the interview situation provides a rich and detailed picture of the process and the people working in it. It has the

potential to reveal inconsistent perceptions that different domain experts may have on how a process operates. It also helps the process analyst to understand the process in detail. However, it is a labor-intensive discovery method. Several iterations are required for arriving at a point where domain experts feel comfortable with how a process is described in a process model.

One recurrent pitfall of interviews is that when asked how a given process or activity is performed, the interviewee tends to describe the normal way of processing. Thus, exceptions tend to be left aside. In other words, the interview ends up covering only the "sunny-day" scenario. One way to prevent this pitfall is to reserve time during the interview to focus on the "rainy-day" scenarios. Questions that can be used to spark discussion on the rainy-day scenario are: "How did you handle your most difficult customer?", "What was the most difficult case you have worked on?". This technique allows one to uncover variations or exceptions in the process that, while not necessarily frequent, have a sufficient impact on the process to be worth documenting.

5.2.3 Workshop-Based Discovery

Workshop-based discovery also offers the opportunity to get a rich set of information on the business process. Although this is not always the case, the setting can be organized in such a way that the contributions to the discussion are immediately used to model the process. In contrast to interviews, it not only involves more participants, but also a bigger set of roles. Additional roles are required for facilitating the discussion and for operating the process modeling tool. The *facilitator* takes care of organizing the verbal contributions of the participants. The *tool operator* is responsible for directly entering the discussion results into the modeling tool. Several *domain experts* also participate, as much as the *process owner* and the *process analyst*. The involvement to this extensive set of persons requires diligent preparation and scheduling. Furthermore, the process will not be sketched out in detail in only one session. It can be expected that three to five half-day sessions are required.

At the start of a process discovery effort, when there is not yet information available for modeling the process, it can be beneficial to take a more lightweight and participative approach to organizing the workshops. One technique to engage the workshop participants in the discovery effort is by asking workshop participants to build a map of the process using sticky notes. The facilitator starts with a pad of sticky notes. Each sticky note is meant to represent a task or event. The group starts to discuss how the process typically starts. The facilitator then writes the name of the (supposedly) first task or event into a sticky note and posts it on the wall. Then the facilitator asks what can happen next. The participants start mentioning one or more possible tasks. The facilitator writes these activities in new sticky notes and starts posting these on the wall, organizing them for example from left to right or top to bottom to capture the order of the activities. At this stage no lines are drawn between the tasks and no gateways are discovered. The purpose of this exercise is to build

Table 5.2 Relative strengths and limitations of process discovery methods

Aspect	Evidence	Interview	Workshop
Objectivity	high	medium-high	medium-high
Richness	medium	high	high
Time Consumption	low-medium	medium	medium
Immediacy of Feedback	low	high	high

a map of activities and their temporal ordering. Sometimes, participants disagree on whether something is one task or two tasks. If the disagreement cannot be resolved, the two tasks can be written as two sticky notes and these two related sticky notes are pasted next to each other. The facilitator also needs to pay attention to the fact that the tasks being posted should be at the same level of detail. When people start mentioning small micro-steps, like "putting the document on a fax machine" the facilitator should try to lift the level of abstraction. In the end, this exercise leads to a rough map that the process analyst can take as input for constructing an initial model.

Exercise 5.6 Consider the following two companies. Company A is young, founded three years ago, and has grown rapidly to a current toll of 100 employees. Company B is owned by the state and operates in a domain with extensive health and security regulations. How might these different characteristics influence a workshop-based discovery approach?

Workshop-based process discovery requires an organized facilitation and an atmosphere of openness. In terms of facilitation, the facilitator has to ensure that the parole is balanced between the different participants. This means on the one hand restricting the speech time of talkative participants. On the other hand, more introverted participants should be encouraged to express their perspective. An atmosphere of openness is helpful for having everybody participate. This aspect is influenced by the culture of the company. In organizations with a strongly emphasized hierarchy, it might be difficult for domain experts to express their view openly if their supervisor is present. If creativity and independent thinking is appreciated in the company, the participants are likely to feel at ease with discussing issues. It is the responsibility of the facilitator to stimulate a constructive workshop interaction in both cases. In this case, workshops have the potential to resolve inconsistencies directly with all involved parties.

5.2.4 Strengths and Limitations

The different methods of process discovery have strengths and limitations. These can be discussed in terms of objectivity, richness, time consumption, and immediacy of feedback (see Table 5.2).

- Objectivity: Evidence-based discovery methods typically provide the best level of objectivity. Existing documents, existing logs and observation provide an unbiased account of how a process works. Interview-based and workshop-based discovery both have to rely on the descriptions and interpretations of domain experts who are involved with the process. This bears the risk that those persons may have perceptions and ideas of how the process operates, which may be partially not correct. Even worse, the process analyst is also at risk that domain experts might opportunistically hide relevant information about the process. This can be the case if the process discovery project happens in a political environment where groups of process stakeholders have to fear loss of power, loss of influence, or loss of position.
- Richness: While interview-based and workshop-based discovery methods show some limitations in terms of objectivity, they are typically strong in providing rich insights into the process. Domain experts involved in interviews and workshops are a good source to clarify reasons and objectives for why a process is set up as it is. Evidence-based methods might show issues that need to be discussed and raise questions, but they often do not provide an answer. Talking to domain experts also offers a view into the history of the process and the surrounding organization. This is important for understanding which stakeholders have which agenda. Evidence-based discovery methods sometimes provide insight into strategic considerations about a process when they are documented in white papers, but they hardly allow conclusions about the personal agendas of the different stakeholders.
- Time consumption: Discovery methods differ in the amount of time they require. While documentation of a company and a particular process can be easily made available to a process analyst, it is much more time-consuming to conduct interviews and workshops. While interview-based discovery suffers from several feedback iterations, it is difficult to schedule workshops with various domain experts on short notice. Automatic process discovery often involves a significant amount of time for extracting, reformatting, and filtering of event logs. Passive observation also requires coordination and approval time. Therefore, it is a good idea to start with document analysis, since documentation can often be made accessible on short notice.
- Immediacy of feedback: Those methods that directly build on the conversation and interaction with domain experts are best for getting immediate feedback. Workshop-based discovery is best in this regard since inconsistent perceptions about the operation of a process can be directly resolved by the involved parties. Interviews offer the opportunity for asking questions whenever process-related aspects are unclear. However, not all issues can be directly resolved with a single domain expert. Evidence-based discovery methods raise various questions about how a process works. These questions can often only be answered by talking to domain experts.

Since each discovery method has strengths and limitations, it is recommended to utilize a mixture of them in a discovery project. The process analyst typically starts with documentation that is readily available. It is essential to organize the project in such a way that the information can be gathered from the relevant domain experts

in an efficient and effective way. Interviews and workshops have to be scheduled during the usual work time of domain experts. Therefore, they have to be motivated to participate and involved in such a way that it is the least time-consuming for them. Once issues arise about specific details of a process, it might be required to turn back to evidence-based discovery methods.

Exercise 5.7 In what situations is it simply not possible to use one or more of the described discovery methods?

5.3 Process Modeling Method

Modeling a process in the discovery phase is a complex task. Therefore, it is good to follow a predefined procedure in order to approach this task in a systematic way. One way to do so is to work in five stages, as follows:

1. Identify the process boundaries
2. Identify activities and events
3. Identify resources and their handovers
4. Identify the control flow
5. Identify additional elements

5.3.1 Identify the Process Boundaries

The identification of the process boundaries is essential for understanding the scope of the process. Part of this work might have been done already with the definition of a process architecture. Technically, this means we need to identify the events that trigger our processes and those that identify the possible process outcomes. For example, let us consider again the order fulfillment process that we modeled in Chap. 3. We observe that this process is triggered by the receipt of a purchase order from the customer, and completes with the fulfillment of the order as an outcome. These two events mark the boundaries of this process. Accordingly, we use a start message event and an end event in BPMN to represent them. If our process would have had negative outcomes, we would have modeled these via terminate end events.

5.3.2 Identify Activities and Events

The goal of the second step is to identify the main activities of the process. The advantage of starting with the activities is that domain experts will clearly be able to state what they are doing even if they are not aware of working as part of an overarching business process. Also documents might explicitly mention activities,

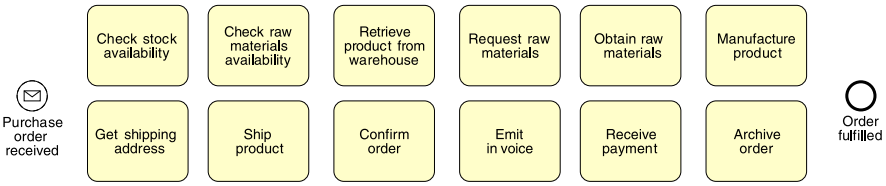

Fig. 5.1 The main activities and events of the order fulfillment process

for instance a set of work instructions. In the case of the order fulfillment process, this stage may lead to a set of activities for which the order and routing conditions are not yet defined. In this step, we also need to identify the events that occur during the process, which we will model with intermediate events. Figure 5.1 lists the 12 activities of our example.[1] Note that this initial set of activities and events may undergo revisions, e.g. more activities may be added as we add more details into our model. If the process is too complex, we suggest to focus on the main activities and events only at this stage, and add the others at a later stage when a deeper understanding of these elements and their relations has been gained.

5.3.3 Identify Resources and Their Handovers

Once we have defined the set of main activities and events, we can turn to the question of *who* is responsible for them. This information provides the basis for the definition of pools and lanes, and the assignment of activities and events to one of these pools and lanes. At this stage, the order of the activities is not defined yet. Therefore, it is a good step to first identify those points in the process where work is handed over from one resource to another, e.g. from one department to the other. These handover points are important since a participant being assigned a new task to perform, usually has to make assumptions about what has been completed before. Making these assumptions explicit is an essential step in process discovery. Figure 5.2 shows the set of activities and events of the order fulfillment process now being assigned to pools and lanes. The sequence flows indicate handover points. The handover points also help to identify parts of the process which can be studied in isolation from the rest. These parts can be refined into sub-processes with the help of the involved stakeholders. For example, in the order fulfillment process the acquisition of raw materials (cf. Fig. 4.19) could be handled in isolation from the rest of the process, since this part involves the suppliers and personnel from the warehouse & distribution department.

[1] For simplicity, we only consider one supplier in this example, so for instance there is only one activity "Request raw materials" instead of "Request raw materials from Supplier 1" and "Request raw materials from Supplier 2".

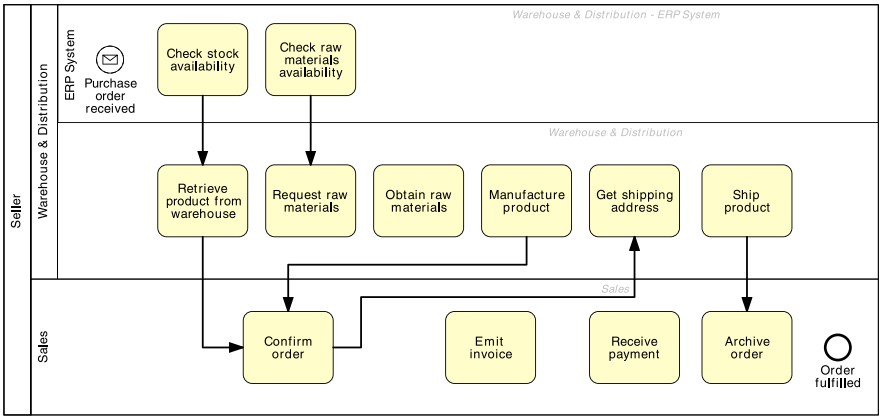

Fig. 5.2 The activities and events of the order fulfillment process assigned to pools and lanes

5.3.4 Identify the Control Flow

The handover points define an initial structure for the control flow. In essence, control flow relates to the questions of *when* and *why* activities and events are executed. Technically, we need to identify order dependencies, decision points, concurrent execution of activities and events and potential reword and repetition. Decision points require the addition of (X)OR-splits, and relevant conditions on the alternative sequence flows. Rework and repetition can be modeled with loop structures. Concurrent activities that can be executed independently from each other are linked to AND gateways. Event-based splits are used to react to decisions taken outside the process. If we have modeled more than one business party in the previous step via the use of multiple pools in this step we also need to capture the exchange of information between the various pools via message flows. Figure 5.3 shows how order constraints are captured by control-flow arcs in the order fulfillment process. Here we can see that the handovers that we identified in the previous step have now been refined in more elaborate dependencies.

Exercise 5.8 What is the relationship between the type of a gateway and the conditions of the subsequent arcs?

5.3.5 Identify Additional Elements

Finally, we can extend the model by capturing the involved artifacts and exception handlers. For the artifacts, this means adding data objects, data stores and their relations to activities and events via data associations. For the exception handlers, this means using boundary events, exception flows and compensation handlers. As we mentioned in Chaps. 3 and 4, the addition of data elements and exceptions, depends

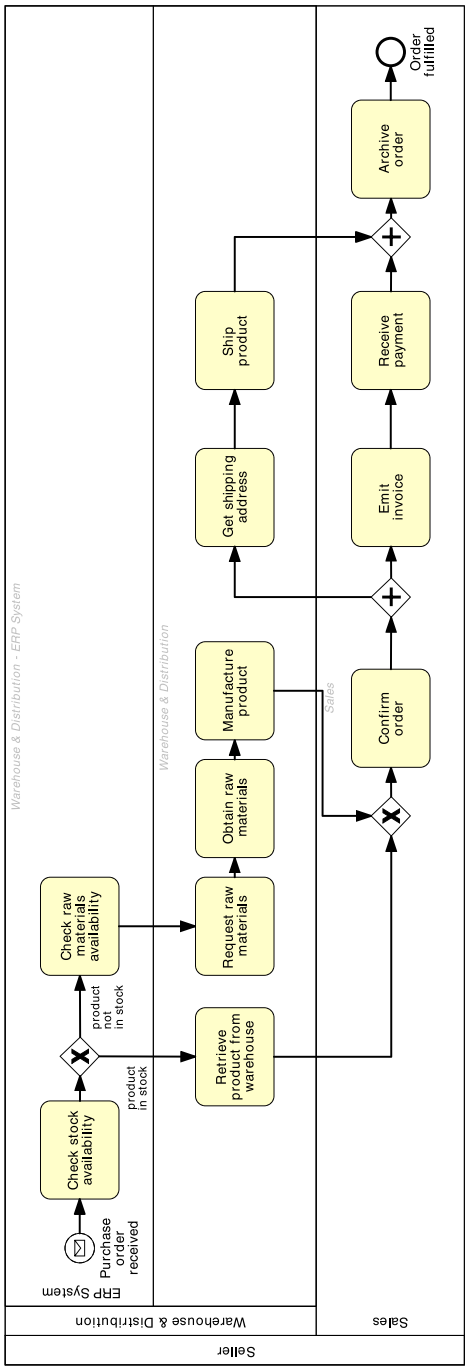

Fig. 5.3 The control flow of the order fulfillment process

on the particular modeling purpose. For example, if the process is meant to be automated, it is desirable to explicitly capture data and exception aspects. In this step we may also add further annotations to help support specific application scenarios, for instance, if the model is used for risk analysis or for process cost estimation we may need to add risk and cost information. In general, which elements to be added depends upon the particular application scenario.

In this section we illustrated a method for constructing a business process model via a number of incremental steps. In a scenario where multiple business parties are involved, an alternative option is to start with a choreography diagram first, and then incrementally refine this diagram into a collaboration diagram. In this case, we use the choreography diagram to identify the resources first, and model each of them via a pool. Next, inside each pool we model those events and activities that handle handover of information between parties (i.e. send and receive activities, message and signal events); we can derive these elements from the activities of the choreography diagram. We can then continue with Step 2 of the above method by adding the other internal activities. Next, in Step 3 we model the inner resources within each party using lanes, and then continue with the rest of the method as normal.

5.4 Process Model Quality Assurance

Process discovery involves at least a process analyst and various domain experts. Since gathering information and organizing it in a process model is often done in a sequential way, and not simultaneously, there is a need for various steps of quality assurance. Here, we focus on syntactic, semantic and pragmatic quality. Figure 5.4 shows that verification is used to achieve syntactic quality, validation provides semantic quality, and certification ensures pragmatic quality. Modeling guidelines and conventions help to ensure a good quality right from the start.

5.4.1 Syntactic Quality and Verification

Process models constructed in process discovery projects typically have to adhere to syntactical rules and guidelines. *Syntactic quality* relates to the goal of producing a process model that conforms to these rules. First of all, this means that the content of the model should comply with the syntax as defined by the process modeling language in use. For instance, in BPMN it is not allowed to draw a sequence flow across the boundaries of pools. BPMN defines an extensive set of syntax rules. Following these rules helps to make sure that a process model can always be interpreted. Beyond that, many companies define *guidelines* in order to guarantee consistency and comparability of process models, which we will discuss below.

Verification essentially addresses formal properties of a model that can be checked without knowing the real-world process. In the context of process model

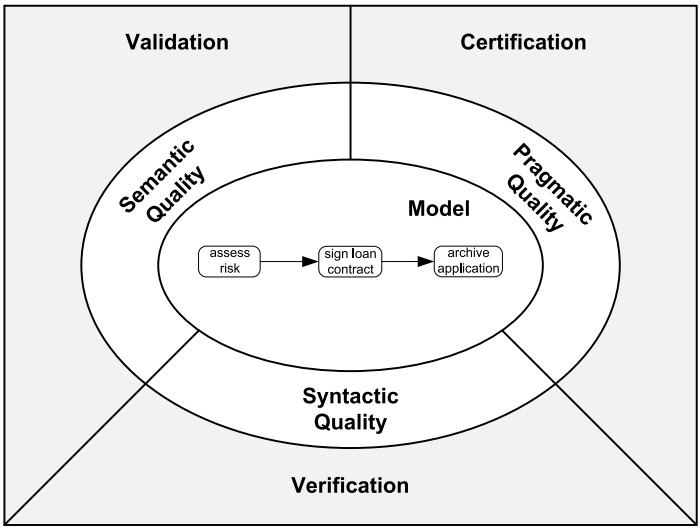

Fig. 5.4 Quality aspects and quality assurance activities

verification, structural and behavioral correctness can be distinguished. *Structural correctness* relates to the types of element that are used in the model and how they are connected. For instance, an activity should always have an incoming and an outgoing arc and every element should be on a path from a start event to an end event of the process model. Such properties can often be checked quite easily by inspecting the graph-based structure of the process model. *Behavioral correctness* relates to potential sequences of execution as defined by the process model. It is a general assumption that a case should never be able to reach a deadlock or a livelock. This is the case when the *soundness* property holds (see Chap. 3). Common sound and unsound process fragments are depicted in Fig. 5.5. Verification properties such as soundness can be checked after a process model is created. Alternatively, a process modeling tool can enforce that a model is correct by design. This can be achieved by allowing only edit operations on the model that preserve structural and behavioral correctness.

Exercise 5.9 Have a look at Fig. 5.5. Explain what exactly is going wrong in the unsound process model fragments.

5.4.2 Semantic Quality and Validation

Semantic quality relates to the goal of producing models that make true statements about the considered domain, either for existing as-is processes or future to-be processes. The particular challenge of a semantic quality assessment is that the process

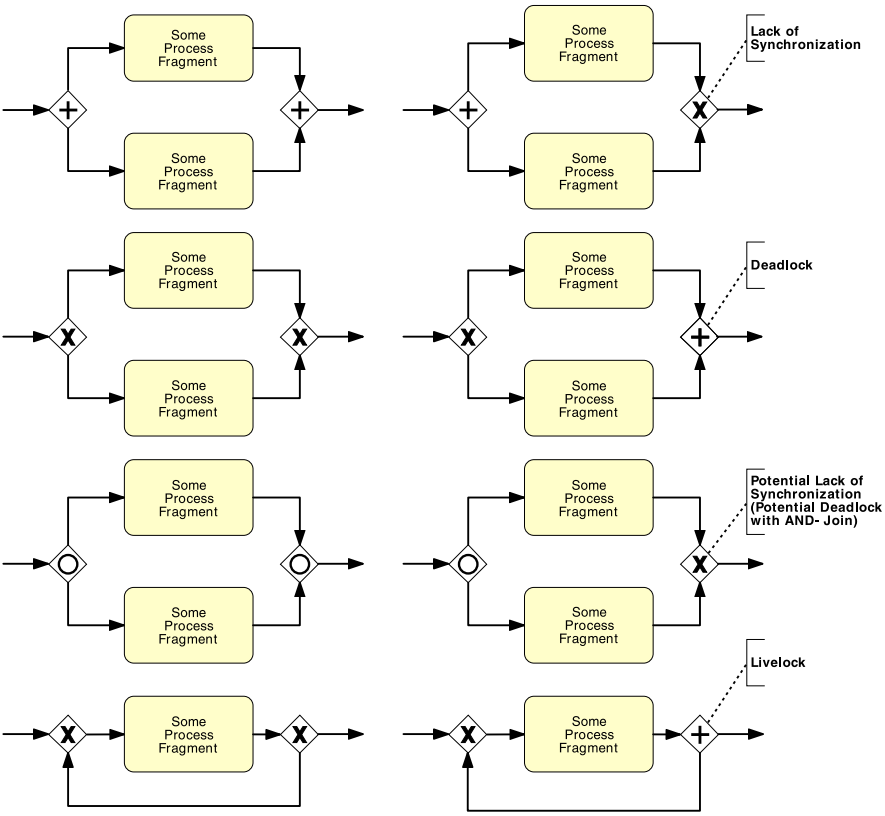

Fig. 5.5 Common sound and unsound process fragments

model has to be compared with the real-world domain of a particular business process. This means there is no set of formal rules that can be used to easily check semantic quality. Whether the process model at the center of Fig. 5.4 is of good semantic quality can only be assessed by talking to people involved in the process and by consulting documentation.

Validation deals with checking the semantic quality of a model by comparing it with the real-world business process. There are two essential aspects of semantic quality: validity and completeness indexCompleteness. *Validity* means that all statements included in the model are correct and relevant to the problem. Validity can be assessed by explaining domain experts how the processing is captured in the model. The domain expert is expected to point out any difference between what the model states and what is possible in reality. *Completeness* means that the model contains all relevant statements on a process that would be correct. Completeness is more difficult to assess. Here, the process analyst has to ask about various alternative processing options at different stages of the process. For example, the model in Fig. 5.3 is still missing all data elements and exception handlers. It is the job of

the process analyst to judge the relevance of these additional elements. This judgment has to be done against the background of the modeling objective, which the process analyst should be familiar with. Let us consider an example to understand the difference between validity and completeness. If the process model for loan assessments expresses that any financial officer may carry out the task of checking the credit history of a particular applicant while in practice this requires a specific authorization, the model has an issue with semantic quality (invalid statement). If the task of checking the credit history is omitted then it has a semantic problem due to incompleteness. Validation can be supported by techniques like simulation or interviews. Alternatively, there are tools that provide truthfulness by design. This is, for instance, achieved by building a process model from the logs of an information system, as we will see in Chap. 10. In practice, process models often require the *approval* from the process owner. This approval is a special validation step, since it again refers to the correctness and completeness of the process model. Beyond that, the approval of the process owner establishes the normative character of the process model at hand. As a consequence, the process model can now be archived, published or used as an input for process redesign.

5.4.3 Pragmatic Quality and Certification

Pragmatic quality relates to the goal of building a process model of good usability. The particular challenge of pragmatic quality assessment is to prognosticate the actual usage of a process model beforehand. Accordingly, this aspect very much focuses on how people interact with a model. Whether the process model at the center of Fig. 5.4 is of good pragmatic quality can, for instance, be checked by testing how well a user understands the content of the model.

Certification is the activity of checking the pragmatic quality of a process model by investigating its usage. There are several aspects of usability including understandability, maintainability, and learning. *Understandability* relates to the fact how easy it is to read a specific process model. *Maintainability* points to the ease of applying changes to a process model. *Learning* relates to the degree of how good a process model reveals how a business process works in reality. There are several characteristics of a model that influence usability including its size, its structural complexity, and its graphical layout. Certification can be conducted using user interviews or user experiments. Alternatively, there are rules that strive to provide usability by design. This can be achieved, for instance, by following design rules on the structure of the process model. There are two essential checks for understanding, maintainability and learning. The first one relates to the consistency between visual structure and logical structure. Figure 5.6 and Fig. 5.7 show the same fragment of the order fulfillment process model. The second model is a rework of the first one in terms of layout. Here, the element positions have been changed with the aim to improve the consistency between visual structure and logical structure. The second check is concerned with meaningful labels. It is important that activities and other

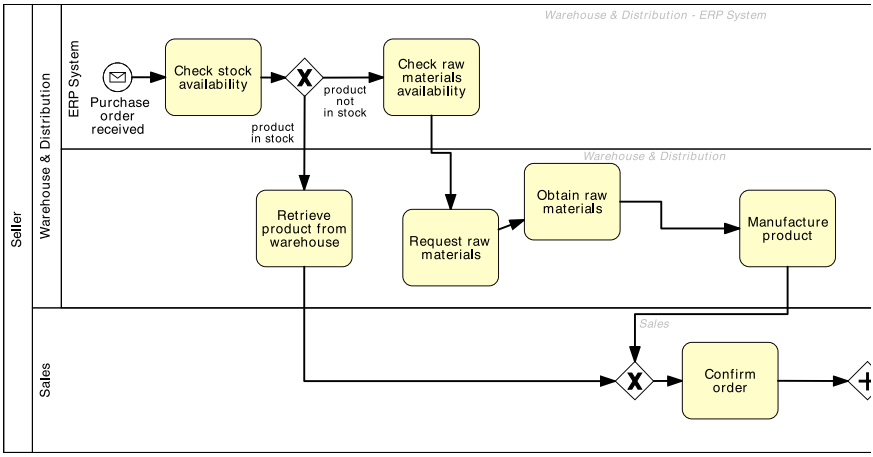

Fig. 5.6 Extract of the order fulfillment process model with bad layout

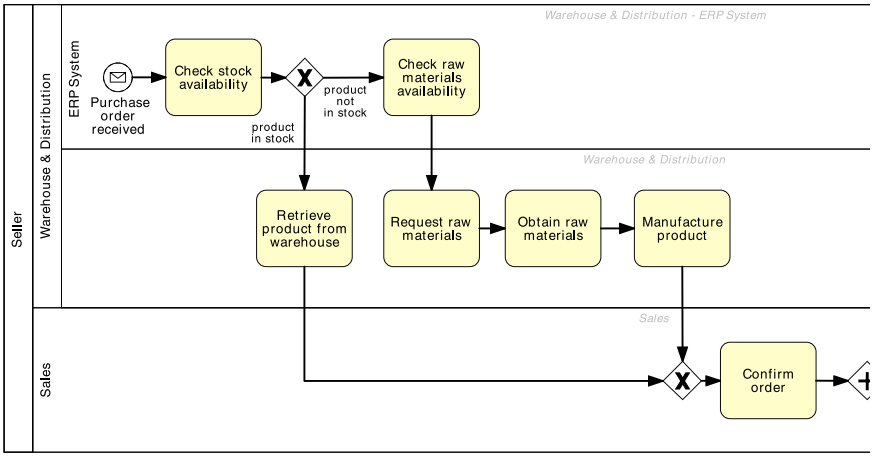

Fig. 5.7 Extract of the order fulfillment process model with good layout

elements have labels that follow specific naming conventions, as those presented in Sect. 3.1.

5.4.4 Modeling Guidelines and Conventions

Modeling guidelines and *conventions* are an important tool for safeguarding model consistency and integrity for bigger modeling initiatives with several people involved. The goals of such guidelines and conventions are to increase readability

and comparability in order to facilitate efficient model analysis. A guideline document typically covers naming conventions for processes, tasks and events, modeling conventions for layout and usage of tasks, events, lanes and pools, and a restriction of the set of elements. *Naming conventions* usually recommend or enforce the verb-object style for labeling of activities and suitable styles for other elements as discussed in Sect. 3.1. Too technical and too generic verbs should be avoided. *Modeling conventions* define element usage and layout. Layout for BPMN models is typically defined with a horizontal orientation. Usage of pools may be enforced for each model along with corresponding message flow. The detail of how start and end events are captured can be specified as well. All the conventions often come along with rules how to capitalize or what to reference in the elements names, e.g. using a glossary. Finally, *restrictions* can be defined in order to simplify the set of elements of BPMN. Such restrictions are recommended to increase understanding of models also by non-expert users.

One set of guidelines that has recently been proposed are the so-called Seven Process Modeling Guidelines (*7PMG*). This set was developed as an amalgamation of the insights that were derived from available research. Specifically, the analysis of large sets of process models by various researchers have identified many syntactical errors as well as complex structures that inhibited their interpretation. The guidelines that are part of 7PMG are helpful in guiding users towards mitigating such problems. The guidelines are as follows:

G1: Use as few elements in the model as possible. The size of a process model has undesirable effects on the understanding of process model and the likelihood of syntactical errors. Studies have shown that larger models tend to be more difficult to understand and have a higher error rate.

G2: Minimize the routing paths per element. For each element in a process model, it is possible to determine the number of incoming and outgoing arcs. This summed figure gives an idea of the routing paths through such an element. A high number makes it harder to understand the model. Also, the number of syntactical errors in a model seems strongly correlated to the use of model elements with high numbers of routing paths.

G3: Use one start and one end event. Empirical studies have established that the number of start and end events is positively connected with an increase in error probability. Models satisfying this requirement are easier to understand and allow for all kinds of formal analysis.

G4: Model as structured as possible. A process model is structured if each split gateway matches a respective join gateway of the same type. Block-structured models can be seen as formulas with balanced brackets, i.e., every opening bracket has a corresponding closing bracket of the same type . Unstructured models are not only more likely to include errors, people also tend to understand them less easily. Nonetheless, as discussed in Chap. 4.3, it is sometimes not possible or not desirable to turn an unstructured process model fragment (e.g. an unstructured cycle) into a structured one. This is why this guideline states “as structured as possible”.

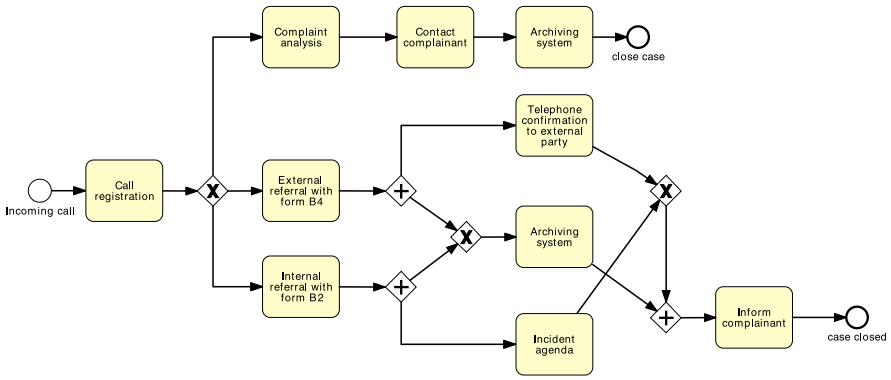

Fig. 5.8 A complaint handling process as found in practice

G5: Avoid OR-gateways. Models that have only AND-gateways and XOR-gateways are less error-prone. This empirical finding is apparently related to the fact that the combinations of choices represented by an OR-split are more difficult to grasp than behavior captured by other gateways.

G6: Use verb-object activity labels. A wide exploration of labeling styles that are used in actual process models, discloses the existence of a number of popular styles. From these, people consider the verb-object style, like "Inform complainant", as significantly less ambiguous and more useful than action-noun labels (e.g. "Complaint analysis") or labels that follow neither of these styles (e.g. "Incident agenda").

G7: Decompose a model with more than 30 elements. This guideline relates to G1 that is motivated by a positive correlation between size and errors. For models with a more than 30 elements the error probability tends to climb sharply. Therefore, large models should be split up into smaller models. For example, large sub-components with a single entry and a single exit can be replaced by one activity that points to the original sub-component as a sub-process.

The need for guidelines like 7PMG is emphasized by the structure of process models we have seen in practice. Figure 5.8 shows a simplified version of a complaint handling process model of one of our industry partners. A complaint is triggered by a phone call by a complaining customer. It is decided whether the complaint can be handled or whether it has to be referred to an internal or external party. An external referral leads to a telephone confirmation to the external party. An internal referral is added to the incident agenda. If no referral is needed, a complaint analysis is conducted and the complainant is contacted. In either case, the complaint is archived and the case is closed.

Exercise 5.10 Consider the process model of Fig. 5.8. Explain which 7PMG guidelines point to potential for improvement. Remodel the process based on your observations.

The 7PMG are but one of the available sets of modeling guidelines. Moreover, it is a tentative set in the sense that research in the area of process model quality is rapidly developing. Many of its guidelines are already applied in practice and have been discussed as state-of-the-art at previous places in this book. For example, in Sect. 3.1 the beneficial verb-object labeling convention was already mentioned. Also, the threshold to start decomposing process models as in guideline G7 was discussed in Sect. 4.1. What is special about the 7PMG is that these guidelines have a strong empirical basis and, as such, transcend the knowledge of individual modelers. As insights develop further, it seems both likely and favorable that the set will be updated and expanded.

5.5 Recap

This chapter described how to proceed in the different phases of process discovery. In essence, we defined four stages of process discovery, namely defining the setting of process discovery, applying different discovery methods for gathering information about the process, stepwise modeling the process, and finally addressing different aspects of quality assurance.

The definition of the setting of process discovery has to take into account the different characteristics and complementary skills of process analysts and domain experts. While process analysts are skilled in analyzing and modeling processes, they often lack detailed domain knowledge. In contrast, domain experts have typically limited modeling skills, but detailed understanding of the part of the process they are involved with. This implies three challenges of process discovery. First, different domain experts have an understanding of only a part of the process. Different partial views have to be integrated in process discovery. Second, domain experts tend to think in cases and not on the general process level. The process analyst has to abstract from these cases. Third, domain experts often have difficulties in understanding process models. Therefore, the process analyst has to guide the domain expert in reading the model for getting feedback.

Different methods of process discovery can be used ranging from evidence-based methods to interviews and workshops. Evidence-based methods typically provide the most objective insight into the execution of the process. However, the immediacy of feedback is low and the richness of the insight can be mediocre. Interviews can be biased towards the perspective or opinion of the interview partner, but reveal rich details of the process. The interview situation offers the chance of direct feedback and clarification. Workshops can help to immediately resolve inconsistent perspectives of different domain experts. On the downside, it is difficult to have all required domain experts synchronously joining. It is recommended to utilize a mixture of the methods that reflects the specifics of the discovery project.

We then defined a process modeling method including six steps. First, the boundaries of the process have to be defined in terms of start and end events. Second, the essential activities of the process have to be identified. Subsequently, we need to determine the handovers between different persons and departments. Once that aspect

is clarified, we can sketch out the details of the control flow. Then, routing conditions and intermediate events have to be added. Finally, additional perspectives and annotations can be included.

In the last sections of this chapter, we discussed different measures of quality assurance. First, we emphasized verification as a tool for assuring syntactical correctness. Then, we discussed how validation helps to establish semantic quality. Finally, we presented different aspects of pragmatic quality and described how they can be certified.

5.6 Solutions to Exercises

Solution 5.1 In case you are supposed to map the process of signing a rental contract in your city, it is likely that you have some experience with this process, either from renting a flat yourself, or from stories from your friends, or from you or your friends giving a flat for rent. Assuming you have already studied the chapters on process modeling, you have both domain expertise and process modeling expertise. This is an uncommon situation. Most often, you face situations like mapping the process of getting a license plate for your car in Liechtenstein as a foreign resident. This is a process for which you would unlikely have domain knowledge. Process discovery typically brings you as a process analyst into an environment that you do not know in detail beforehand. Process discovery is concerned with understanding the process under consideration and also the domain surrounding it.

Solution 5.2 An advantage of having teams modeling processes themselves is first that a lot of process models can be created in a short span of time. It is critical though that these teams possess the required skills in process modeling. According to the third challenge of process discovery, domain experts typically do not have process modeling skills and feel uncomfortable with the modeling task. Furthermore, domain experts often think in cases (second challenge) and lack the process perspective to generalize. Finally, there is the risk that the results from such a modeling initiative might be fragmented and difficult to integrate. It is typically the responsibility of the process analyst to integrate the fragmented perspectives.

Solution 5.3 Domain knowledge can be very helpful for analyzing processes. It helps to ask the right questions and to build analogies from prior experience. On the other hand, the skills of an experienced process analyst should not be underestimated. These skills are domain-independent and relate to how a process discovery project can be organized. Experienced process analysts are typically very skilled in scoping and driving a project into the right direction. They possess problem-solving skills for handling various critical situations of a process discovery project. There is clearly a trade-off between the two sets of skills. It should be ensured that a certain level of process analysis experience is available. If that is not the case for the applying domain expert, the process analyst might be preferred.

Solution 5.4 As a customer, we would have to rely mostly on evidence-based process discovery. We can place exemplary orders and study the different processing options for them. In relation to these placed orders, we could also contact the customer help desk and inquire details of the process that we cannot directly observe. If we were assigned to a process discovery project by the process owner, we would get access to the domain experts within the company. In this case, we could also use interviews and workshop-based discovery methods.

Solution 5.5 This process contains ten major activities that are executed by different persons. We can assume that there will be a kickoff meeting with the process owner and some important domain experts on day one. One day might be required to study available documentation. An interview with one domain expert can take from two to three hours, such that we would be able to meet two persons per day, and document the interview results at night time. Let us assume that we meet some persons only once while we seek feedback from important domain experts in two additional interviews. Then, there would be a final approval from the process owner. This adds up to one day for the kickoff, one for document study, five days for the first iteration interviews, and further five days if we assume that we meet five experts three times. Then, we need one day for preparing the meeting for final approval with the process owner, which would be on the following day. If there are no delays and scheduling problems, this yields $2 + 5 + 5 + 2 = 14$ work days as a minimum.

Solution 5.6 Before starting with process discovery, it is important to understand the culture and the sentiment of an organization. There are companies that preach and practice an open culture in which all employee are encouraged to utter their ideas and their criticism. Such organizations can benefit a lot from workshops as participants are likely to present their ideas freely. In strictly hierarchical organizations, it is necessary to take special care that every participant gets an equal share of parole in a workshop and that ideas and critique are not hold back. It might be the case that the young dynamic company has a more open culture than the company with extensive health and security regulations. This has to be taken into account when organizing a workshop.

Solution 5.7 There are various circumstances that may restrict the application of different discovery methods. Direct observation may not be possible if the process partially runs in a remote or dangerous environment. For instance, the discovery of a process of an oil-producing company for pumping oil from an oil rig to a ship might belong to this category. Then, there might be cases where documentation does not exist, for example when a startup company, which has gone through a period of rapid growth wants to structure its purchasing process. Lack of input may also be a problem for automatic process discovery based on event log data. If the process under consideration is not yet supported by information systems, then there are no data available for conducting automatic process discovery. In general, interviews are always possible. It might still be a problem though to gain commitment of domain experts for an interview. This is typically the case when the process discovery

project is subject to company-internal politics and hidden agendas. Workshop-based discovery can be critical in companies with strong hierarchy which have a culture of suppressing creative thinking of their staff.

Solution 5.8 The type of the gateway has to be consistent with the conditions of the subsequent arcs. If there is an XOR-split, then the conditions on the arcs have to be mutually exclusive. If there is an OR-split, then the conditions can be non-exclusive. If an AND-split is used, there should be no conditions on the arcs.

Solution 5.9 Four unsound fragments are shown with the following problems:

- The lack of synchronization relates to an AND-split followed by an XOR-join. In this case, the two tokens created from the AND-split are not synchronized XOR-join, potentially leading to the duplicate execution of activities downstream.
- A deadlock occurs, for instance, if an XOR-split is followed by an AND-join. As the XOR-split creates a token only on one of its outgoing arcs, the AND-join requiring a token on each of its incoming arcs gets stuck waiting for a second token to arrive.
- In case there is an OR-split followed by an XOR-join, we potentially get a lack of synchronization. This depends upon the conditions of the OR-split. If only one token is generated from it, the process can proceed correctly. If multiple tokens are generated, there is a lack of synchronization. In the same vein, there is a potential deadlock if the OR-split is followed by an AND-join.
- A livelock can occur in an inappropriate loop structure. Here, there is an XOR-join used as an entry to a loop, but the loop exit is modeled with an AND-split. This has the consequence that it is never possible to leave the loop. Each time the AND-split is reached, it creates one token exiting the loop, but also another token that stays within the loop.

Solution 5.10 The process model reveals several problems. Several elements with the same name are shown twice (end event and archiving activity), therefore G1 is violated. Also the control structure is very complicated, violating G4 asking for a

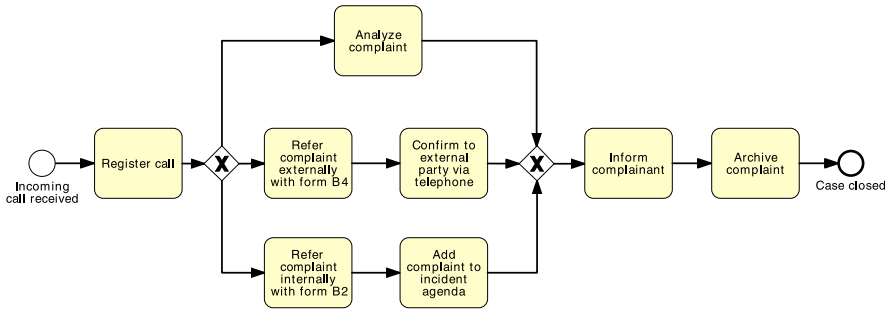

Fig. 5.9 The complaint handling process reworked