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Pós-Graduação em Ciência da Computação

"STRATEGY-AWARE BUSINESS PROCESS MANAGEMENT"

Por

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Tese de Doutorado

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When you attain the Way of Strategy
there will not be one thing you cannot see.
— MIYAMOTO MUSASHI (The Book of The Five Rings)

Resumo

Nas últimas duas décadas, a literatura em gestão empresarial tem demonstrado um interesse crescente no tema da incerteza e os meios utilizados pelas organizações para lidar com ela. Há um consenso entre os pesquisadores atualmente de que as organizações precisam estar constantemente mudando e adaptando as suas operações e estratégias para atender a novos requisitos econômicos e de mercado.

A capacidade de uma empresa de mudar rapidamente as suas metas e estratégias e de reconfigurar rapidamente as suas operações é chamada de "flexibilidade estratégica". Essa capacidade tem sido identificada como um fator crítico para o sucesso das organizações de hoje. Contudo, o apoio da tecnologia da informação à flexibilidade estratégica tem sido limitado. Na maioria das organizações, há ainda uma grande lacuna que separa as atividades de planejamento estratégico das atividades de desenvolvimento de sistemas. Isso reduz a agilidade da companhia em responder a novas necessidades do mercado. Um estudo da literatura em gestão mostra que as necessidades atuais de gerentes em ambientes incertos e mutáveis não tem sido satisfeitas pelos sistemas de apoio à gestão disponíveis hoje.

Nesta tese, nós propomos um mecanismo para tornar sistemas da informação "conscientes da estratégia". Essa consciência estratégica é definida como uma funcionalidade que permite a atualização rápida das funções do sistema em resposta a mudanças estratégicas. Essa funcionalidade também aumenta a capacidade de alinhamento estratégico e monitoramento de desempenho da organização. Mais especificamente, nós propomos uma arquitetura de software que permite que os usuários de um sistema se tornem mais conscientes das necessidades estratégicas da companhia durante a realização do seu trabalho. Nosso foco nesse trabalho é na gestão de processos de negócio e o conceito que nós desenvolvemos é chamado de Gestão de Processos de Negócio Consciente de Estratégia (*Strategy-Aware Business Process Management* - SA-BPM). A consciência estratégica é obtida por meio de uma infraestrutura modular que muda o comportamento do sistema de gestão de processos em tempo real. O sistema passa a ser capaz de capturar informações derivadas diretamente dos sistemas de apoio à decisão da organização (ex.: sistema de planejamento estratégico). Por meio desse instrumento, as organizações podem desenvolver a capacidade de realizar mudanças frequentes nas suas estratégias e de tornar essas mudanças operacionais de maneira rápida, contribuindo assim para a sua flexibilidade estratégica.

Palavras-chave: gestão de processos de negócio, alinhamento estratégico, sistemas de apoio à gestão, sistemas sensíveis ao contexto, gestão orientada a resultados, flexibilidade estratégica

Abstract

Over the past two decades, management research has demonstrated a growing interest in the subject of uncertainty and in the means employed by organizations to cope with it. There is a consensus among researchers nowadays that organizations must be constantly changing and adapting their operations and strategies to match new market and economic requirements.

The ability of a firm to rapidly change its goals and strategies and to readily reconfigure its operations is called "strategic flexibility". Such ability is being identified as a critical success factor for contemporary organizations. Nevertheless, information technology support for strategic flexibility has been limited. In most organizations, there is still a large gap that separates strategic planning activities from information systems development activities. This reduces the agility of the company to respond to new market necessities. A study of the management literature demonstrates that current requirements of managers in uncertain and changing environments have not been fulfilled by the management support systems available today.

In this thesis, we propose a mechanism to make information systems "strategy-aware". Such strategy awareness is defined as a feature that allows for the rapid update of a system's functions in response to strategic changes. This feature also improves an organization's capacity for strategic alignment and performance monitoring. More specifically, we propose a software architecture that makes information system's users become aware of the company's strategic necessities while performing their job. Our focus in this work is on business process management and the concept developed by us is called Strategy-Aware Business Process Management (SA-BPM).

The strategy awareness is achieved through a modular adaptation infrastructure that changes the behavior of the business process management system at run-time. The system becomes able to capture information derived directly from the organization's management support systems (e.g., its strategic planning systems). Through our framework, organizations can develop the capacity to make frequent changes to their strategies and to rapidly make these changes operational, contributing to the improvement of their strategic flexibility.

Keywords: business process management, strategic alignment, management support systems, context-aware information systems, results-oriented management, strategic flexibility

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Chapter 1
Introduction

You will remember the beginning of humankind. Our first parents were quick to get themselves into trouble. They were expelled from the garden of the Eden. I understand that Adam took Eve's hand, and said: "My dear, we are living in a time of transition".

— (Stafford Beer, World in Torment, 1992)

1.1 Overview

The increasingly complexity and uncertainty of today's market environment has been the focus of many debates [38, 40, 81]. Organizations need to be constantly adapting their operations and strategies to match new customer requirements, unforeseen economic conditions, political pressures, and new developments in information technology. Such factors require that companies develop skills, management structures, and information systems that are prepared to change [33, 110].

The ability of a firm to rapidly change its goals and strategies and promptly realign its operations is called *strategic flexibility* [104]. Such ability is being identified by many researchers as a critical success factor for contemporary organizations [38, 112]. However, the contribution of computer science literature to this subject is scant. Although information technology (IT) is seen as an important element of modern enterprise strategies [86], it offers little support to improve a firm's strategic flexibility in uncertain environments.

Business process management (BPM) has shown to be a successful framework for the rapid transmission of business requirements to software systems [32]. Through business process models, a high-level flow of activities can be defined at the managers level. Then, BPM systems (or BPMS) interpret these models and automatically coordinate the company's operations. However, it is difficult to ensure that strategic changes are implemented by business process models [63]. Current BPM tools and methodologies lack features to help managers and employees understand how a business process' activities contribute to the firm's strategy and how they should be changed when strategic changes are necessary.

This work proposes a new approach to business process *design* and *management*, which we call *Strategy-Aware Business Process Management* (SA-BPM). The objective of SA-BPM is to fill a gap in information systems research with respect to the alignment between business processes and business strategies. SA-BPM offers tools and methodologies through which companies can achieve the capacity to rapidly propagate strategic changes to changes in business processes, improving their strategic flexibility. To this end, we propose a modular design through which process models are decomposed into a stable core process model and flexible strategy-specific modules. The core process is adapted at run-time by these modules to fulfill strategic needs. When the strategy changes, the corresponding changes to business processes can be isolated into its specific modules, which are automatically incorporated to the core process.

This thesis defines the concept of SA-BPM, proposes an architecture for its implementation, and a methodology for integrating these concepts with management concepts. Our approach is independent from specific BPMSs or languages, making it compatible with most BPMSs existing today.

This chapter introduces the motivations for this work, defines its objectives, and summarizes its contributions.

1.2 What is a Strategy?

Although the term *strategy* is ubiquitous in our daily lives, it has specific meaning within the business field. To prevent any confusion derived from our intuitive interpretation of the term, which may be different from its business meaning, we shall begin by precisely defining the concept. According to Chandler [20]:

> *Strategy is the determination of the basic long-term goals of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals.*

This definition must be analyzed more in depth: firstly, a strategy always determines *goals* and a process of change in the pursuit of those goals. Thus, there is not a strategy without goals. The nature of these goals may be diverse, depending on the strategic planning methodology adopted by the firm. For example, some organizations may define symbolic, visionary goals such as "By 2020, be the best company in its market segment". Others may prefer goals more specific, such as "Reduce manufacturing costs by 15% in the next 10 months". In either case, the company must determine means to measure the achievement of these goals. Usually, goal achievement is measured by key performance indicators (KPI). In a simplistic view, the final objective is to make the KPIs of the company reach the desired target values.

Next, Chandler's definition mentions *courses of action*. This is an important aspect of strategies. A collection of goals does not make a strategy. It is also necessary to determine the actions that will be taken by the organization to pursue those goals. These actions usually specify some process of *change* that should be conducted by the company. Examples are "reduce the complexity of the manufacturing plant", "increase the cooperation with universities", and "give promotional discounts regularly". In most cases, these changes are implemented through new projects, acquisitions, training, or new business processes. Usually, the organization determines budget limits for each action, groups of actions, or for each department.

Finally, the *allocation of resources* means not only that the company will define and allocate a budget for the execution of the strategy, but that it will also determine roles and responsibilities for the people involved.

It would be a perfect world if a strategy, once designed, could be executed exactly as initially defined. The reality is, however, that things change in unexpected manners. Projects may fail, financial resources may need to be tightened, new products and competitors may enter the market, and customers may change their preferences. All these factors impose threats to the plans of an organization. It is likely that strategic changes will be necessary. New goals and courses of action may replace old ones and the organization must adapt its policies and operations to deal with new market necessities. It is at this scenario that the work in this thesis is focused.

1.3 Motivation

In this section, we describe the problem that motivated the development of this thesis.

1.3.1 The Need for Flexibility

Over the last two decades, academics and practitioners have been recognizing that the environment of organizations in the global market is becoming more and more unpredictable each day [27, 110]. This occurs either because of political and economic instabilities that affect the company or due to the intrinsic volatility of the market in which a firm is inserted. The rapid-paced advances in information technology (IT) have also a significant contribution in setting up an environment which is constantly changing [8, 86]. In this context, an organization needs to develop capabilities that assure the continuous review of the firm's position and that enable the rapid redesign of strategies to meet new customer needs [18, 104, 110].

Business management literature shows that, when the environment is uncertain, only companies that develop the capacity to adapt are able to survive [38]. To achieve this capacity, they need to build an infrastructure that is flexible [110]. For example, have individuals in the company that can perform multiple functions, manufacturing machines that can produce different families of products, and distribution channels that can be adapted to different levels of demand [38, 100]. If the necessity to change is detected, these flexible resources can be reconfigured to implement new strategies and new business models [110].

As IT becomes an essential part of organizations, the capacity to reconfigure information systems in a timely fashion is of fundamental importance. When companies need to adapt their strategies and to delineate new courses of action, they also need their information systems to be updated accordingly. The challenge is to develop the capacity to implement these changes on time and to ensure that they are effective.

Enterprise Resource Planning (ERP) systems are systems that promise a high level of integration between BPM, strategic planning, and decision support tools [13]. An example of these systems is SAP's R/3. In fact, ERPs offer reference process models which implement tasks that are common to most organizations. These reference models are connected to strategic planning only through specific strategic planning methodologies (such as Balanced Scorecards [56]). According to La Rosa [96], ERP systems do not offer guidance or tools to customize these reference models to specific situations. Brignall and Ballantine [13] also affirm that the specific methodologies for strategy management adopted by these tools are not adequate for all companies in all situations. Conflicts that exist between the different tools offered by these packages have not been sufficiently investigated [13]. Thus, the integration provided by ERP systems is limited and not flexible enough to incorporate change.

Several works in the BPM research field aim at making BPMSs more flexible [81]. The objective is to allow that business process models are adapted at run-time to handle situations that were not foreseen by their designers. Such flexibility allows individuals to improve their daily work in the organization. This, however, does not assure that changes in the strategy will be incorporated by employees. If the organization lacks effective channels for disseminating strategic changes, employees will simply continue working in the manner they are used to do. Even worse, they may deal with unexpected situations in a manner that is diverse from the intentions of managers. Existing work in flexible BPMSs do not take into consideration the quality or fit between employees' decisions and strategic goals.

1.3.2 Problem Statement

Strategic flexibility requires that companies identify problems quickly, plan strategic changes for reacting to them, and rapidly implement these changes in its operations. There are several barriers for a company to reach such level of strategic flexibility:

- *unclear linkages between business processes and strategic goals*, which makes achieving and maintaining the alignment between processes and strategies more difficult;
- *the difficulty in disseminating strategic change thorough the organization*, which reduces the agility to react to unforeseen changes;
- *the difficulty in measuring the contribution of each activity performed by the organization to the achievement of the strategic goals*, which makes it more difficult to identify and address internal weaknesses;
- *the inefficient communication channel between business and IT*, which increases the efforts necessary to identify the requirements for new or changed business processes.

Information systems science does not offer much support to overcome such barriers. Tools and systems in use by companies are too focused either on the management side or on the operational side. There is little support to connect these two levels. BPMSs lack functions to ensure the alignment between business processes and strategic goals [63]. Decision support systems are not prepared to deal with changing environments [90, 120]. Moreover, business intelligence systems are too concentrated on the management level, lacking features for the interaction with employees at the operational level [59]. So, the problem that motivated this thesis work is the lack of IT support to transmit and monitor strategic changes over operations and business processes.

Due to these barriers and the lack of tools to overcome them, managers are unable to rapidly update the organization's strategy. Even if they determine new courses of action on time, it is hard to ensure that the organization has really incorporated the necessary changes. On the other hand, if an organization initiates a reaction but does not define the strategic goals and actions, they risk themselves falling into chaotic states [106, 119], which undermine their long-term performance.

1.4 Research Goals and Objectives

This research aims at *allowing companies to attain and improve their strategic flexibility through a better use of information technology*.

To attain this goal, we need to address the issues confronted by managers and IT developers in changing environments and provide mechanisms that help them overcome the barriers to implement the necessary adaptations.

We propose the development of an IT solution that should be capable of offering the following benefits:

- improve the capacity to identify which operations contribute to each strategic goal and to monitor their performance on that task;
- reduce the efforts required to implement strategic changes;
- improve the employees' awareness about how the firm's strategic goals affect their operations and decision choices.

Since many organizations are recognizing the importance of business process management as a framework to design and implement their operations, we choose BPM as the technological basis to develop our solution.

1.5 Summary of Contributions

The main products of this thesis are a **new design concept** for *business process management*, called *strategy-aware* BPM (SA-BPM), and a corresponding **architecture** for the implementation of SA-BPM systems. Such a system can provide more efficient mechanisms for the alignment of strategic goals and business process models. It accomplishes this by providing:

1. a conceptual basis and tool support to *identify and disseminate* the linkage between a business process and the organization's goals;
2. a *modular* infrastructure that *reduces the maintenance efforts* for updating business processes due to strategic changes;
3. a conceptual basis and tool support to *improve the alignment* between an employee's decision choices and the strategic directives of the company;
4. a conceptual basis and tool support to objectively *assess the performance of the organization* and to *measure the business processes' contribution* to its strategic goals.

Our architecture integrates with existing strategic planning and performance management tools used by a firm's managers. Such integration is necessary to allow that managers use these tools, which are tools they are more comfortable with, to determine requirements for the IT staff. The IT staff, on the other hand, must understand how the managers use these tools and must work in synchrony with them. This helps improve the quality of the *communication between business and IT units*.

It is also a product of this thesis a **causal model** of the dynamics of the effects of uncertainty over firm performance. This model compiles literature findings about the factors that influence an organization's behavior in the presence of uncertainty and how they affect its performance. On the basis of this model, we propose in this thesis a **methodology** and a set of **guidelines** to help reduce the negative impacts of environmental uncertainty over performance.

1.6 Outline

The structure of this thesis is divided into three main parts: I) the **Business Setting** - studies the Management literature to identify the problems confronted by organizations in dynamic environments and the methods used by them to cope with them; II) the **Technology** - discusses these problems under the Computer Science perspective and proposes a solution for them; and III) **Transferring Technology to Business** - describes a methodology for the application of the concepts proposed in this thesis and presents an application scenario that illustrates its use. These three parts contain the following chapters.

Part I - The Business Setting

Chapter 2 - Business Background This chapter reviews the concepts of business models, strategies, strategic flexibility, and strategic planning. The focus of the study is on scenarios with high uncertainty and volatility of the environment.

Chapter 3 - A Model of the Effects of Uncertainty Over Firm Performance In this chapter, we review a number of empirical and conceptual works that studied the issue of management in uncertain environments. From this study, we design a theoretic causal model that explains the interaction between factors that influence the performance of organizations when the uncertainty of the environment increases.

Part II - The Technology

Chapter 4 - Information Systems Background This chapter presents a review of IT literature on business process management, management support systems, context awareness, and strategic alignment.

Chapter 5 - Applying Information Systems to Mitigate the Effects of Uncertainty We derive, in this chapter, a collection of guidelines that aim to mitigate the effects of uncertainty over firm performance. These guidelines indicate how current information technologies can reduce or counter-attack the effects of certain factors that contribute to the decline of business performance.

Chapter 6 - SA-BPM: Theoretical Foundations and Implementation Architecture In this chapter, we define the theoretical foundations of *strategy-aware business process management* and design an architecture for the implementation of *SA-BPM systems*. A proof that our design approach reduces the maintenance efforts of business processes and a case study evaluating its benefits are also presented.

Chapter 7 - ROSAS: Results-Oriented Strategy Automation Systems In this chapter, we describe a prototype implementation of a SA-BPM system. The system is called “ROSAS” and is built upon systems in use by large companies today.

Part III - Transferring Technology to Business

Chapter 8 - Flexible Results-Oriented Management In this chapter, we introduce a new management methodology that aim to explore the benefits of the strategy awareness concepts. The methodology is based on existing work on strategy management and includes a proposal for the modeling of relationships between strategic goals. The integrated use of the strategy awareness concept and this methodology delivers the capacities required to mitigate the effects of uncertainty and improve strategic flexibility.

Chapter 9 - An Application Scenario In this chapter, we describe a fictitious scenario that demonstrates the practical applications of the concepts defended in this thesis. The scenario demonstrates how the order shipment processes of a luggage manufacturing company are aligned with its strategic goals and how the concepts presented in this thesis improves the strategic flexibility of the company. A simulation is used to quantitatively measure the gains obtained through the adoption of our approach.

Chapter 10 - Conclusions This chapter presents concluding remarks, discusses limitations of the work, and makes a comparison with related work.

PART I

The Business Setting

CHAPTER 2
Business Background

The Way of Strategy is the Way of nature. When you appreciate the power of nature, knowing rhythm of any situation, you will be able to hit your enemy naturally and strike naturally.

— (Miyamoto Musashi, The Book of the Five Rings)

2.1 Overview

Several researches show that, when the Information Technology (IT) unity of an organization does not understand its Business concerns, the business value of IT assets can not be fully captured [43, 86, 91]. The alignment gap between Business and IT imposes a big deal to the company and may result in the decline of its performance and competitiveness [77].

In this chapter, we review the literature on strategy and strategy management. Our intent is to investigate the notion of strategy and to understand how managers have been dealing with the subject of uncertainty in complex and volatile environments. The study presented in this chapter provides not only a necessary foundation for the work presented in this thesis, but also a better understanding of its motivations and usefulness.

2.2 Business Models

The core Business of an organization is defined by its *business model*. There is not a generally accepted definition of business models in the Business literature [17, 109]. Yet, the concept is regarded as fundamental to describe how companies perform their activities and how they position themselves into the market.

Shafer et al. [103] perform a thorough review of relevant literature in business models and identify a number of components that business models usually comprise. They grouped these components into four major categories: 1) *strategic choices*; 2) *value creation*; 3) *value capture*; and 4) *the value network*. In one statement, Shafer et al. describe business models as a *firm's underlying core logic and strategic choices for creating and capturing value within a value network* [103].

The **strategic choices** made by a firm reflect the decisions taken by the executives to position the company into the market and to assure its profitability. It determines what will be the company's mission and objectives, its target customers, pricing, differentiation, among other factors. This provides major guidelines for the definition of the organization's products, operations, and policies.

Value creation and capture refer to two fundamental functions necessary for the viability of the organization. Value creation is the way that the company creates differentiation among its competitors. It comprises the mechanisms that make its products and services more "valuable" to the customer than the competing products and services. To *create value*, companies usually develop unique resources, competencies, and improved or differentiated business processes that are difficult to imitate [109].

Value capture determines the costs of production and the profitability of the organization's offerings. The way the value created by the company is captured is decisive to its viability. Customers will only pay for what they consider to be worth, given the value that they attribute to the product/service. While value creation is concerned with making products valuable, value capture is concerned with converting this value into *revenue* for the firm.

Value creation and capture occur within a **value network**, which includes suppliers, partners, distribution channels, and customer relationship. The business model must define how these entities will inter-relate to provide profitability to the company (ensuring its viability in the long range).

An example of a successful business model is the case of *Dell Inc*. The key decision on Dell's business model was to directly work with customers in order to provide them technology faster, better level of service, and improved customer relationship [109]. This showed to deliver a lot of value to the customers. Dell's competitors had difficulty in replicating such model, since they had already established channel partners and resellers that would be badly impacted by such decision.

Another example is the case of *Google Inc.* [109]. Their value proposition was based on providing to users search results in a way that was more valuable for them. They accomplished this by implementing superior algorithms for ranking search results that reflected the relevance of the web pages from the user point of view. In order to capture value from this model, Google created a model for advertising based on sponsored links, while avoiding degradations of the user's searching experience.

2.3 Business Strategy

According to Casadesus-Masanell and Ricart [17], the last two decades exhibited substantial advancement on the understanding of strategy and its competitive value for organizations. Both in the industry and academic fields, there was a growth in the comprehension of the dynamics of competition and of the factors that positively influence a company's competitiveness in the market scenario.

Despite such advancement, these authors affirm that often the concepts of *business model* and *strategy* are not clearly distinguished [17].

The concept of strategy has originated from the military field, but it is nowadays pervasive in Business literature. It encompasses a variety of interpretations and uses [107]. According to Chandler's [20] definition, a strategy is composed of *goals*, *courses of action* (to meet goals), and *resource allocations* (to implement actions).

Further work on this subject emphasized the competitive element by stating that the *purpose* of a strategy is to *maintain or improve an organization's performance*. This means that strategies provide the ability to "neutralize threats and exploit opportunities, while capitalizing on strengths and avoiding weaknesses" [107]. In this regard, strategies usually involve competition and the ability to surpass the adversaries. This relation to the military field is the reason for ancient works on military strategy, such as Sun Tzu's *The Art of War* and Musashi's *Book of the Five Rings* to be revisited today under a Business perspective by many executives.

The relationship between strategy and business model is sometimes subtle, but there is a clear distinction between the two concepts. Teece [109] affirms that business strategies differ from business models in the sense that business models provide the **initial** value proposition of the company, while strategies try to **maintain** a sustainable competitive advantage along the organization's life time.

Casadesus-Masanell and Ricart [17] advocate that a strategy is "a firm's contingent plan as to what business model to adopt". The current business model of a company is the *realization* of its strategy. In this sense, changes to the environment may require changes to the business model and these changes are performed according to the strategic plan of the firm.

In this work, we stick with Chandler's definition. In his definition, Chandler does not contradicts the visions of Teece, Casadesus-Masanell, and Ricart, but gives a definition that is more precise and that addresses the practical aspects of how a strategy is constructed (what it is *made of*, instead of what it is *made for*).

2.4 Strategy management

Enterprises must develop a capability for establishing and tracking the success of their strategies. This is the concern of *strategy management*.

The primary tasks associated to strategy management are strategy planning, implementation, monitoring, and governance. Wagner [120] describes a model of the core processes necessary for strategy management. This model is illustrated in Fig. 2.1.

The process starts with the definition of an organization's **missions and goals**. Next, an analysis of **internal and external factors** is performed. The objective is to evaluate **strengths**, **weaknesses**, and capabilities under the perspective of the environment, to find **opportunities** and identify **threats**. The information gathered is used to make strategic **choices**. Once strategic **goals** are established, **gap assessment** is performed to determinate what **initiatives** (actions) should be conducted to attain the goals. Also, metrics for tracking **performance** are determined.

Strategic planning is an essential task of strategy management. Through this process, a strategy is formed and the structures and activities necessary to implement and monitor it are defined. Strategic planning involves processes that incorporate a wide range of organizational behaviors and capabilities [12]. As such, it is a broad subject which has been focus of discussion of both academics and practitioners for a long time. Management, behavioral, and information sciences approach the theme from different perspectives. There is a wealthy of approaches, methodologies, and concepts. Information systems literature usually focus on investigating the IT support for strategy management (e.g., through decision support tools or knowledge-

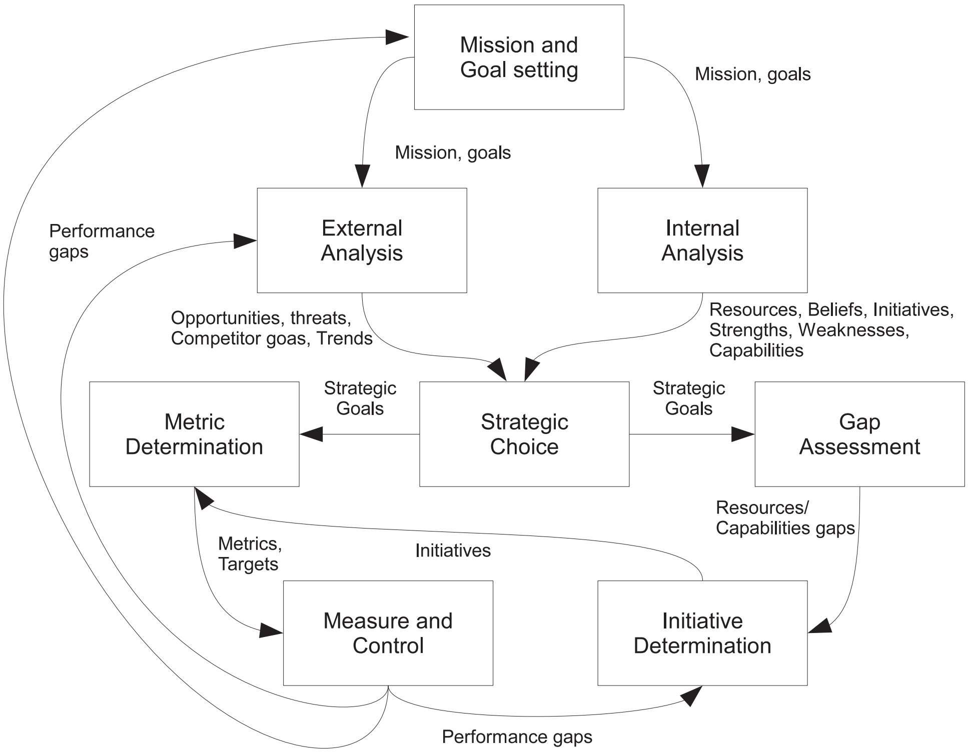

Figure 2.1 High-level dataflow of strategy management [120]

management systems) [120], the strategic role of the alignment between Business and IT [7,77], and the design and effectiveness of strategic information systems (i.e., systems that are core to a company's strategy) [19, 35].

Management and business literature approach strategy management through the investigation of how companies formulate and implement their management methodologies and of which factors make certain strategies better than others [17, 110].

2.4.1 Results-Oriented Management

In this work, we adopt a strategy management methodology called Results-Oriented Management (ROM) [102] (also know as Results-Based Management (RBM)). ROM will be useful to better define the strategic concepts employed in our work and the management methodology that we propose. This section describes the basics of ROM and shows a practical example of application.

ROM is a strategy management style that has as major characteristic the capacity to translate global (or corporate) goals into divisional and *individual* goals. This means that a ROM strategy can be broken down to the level of the individual, helping determine the responsibilities of each person to the strategy's success. This is proposed with the objective of getting people involved in the process of results delivery.

Results-oriented management has been extensively discussed in the context of public administration and national development programs. Organizations such as The World Bank, the United Nations (UN), and the Organization for Economic Co-operation and Development (OECD) have been applying ROM for years [68, 84, 113]. According to The World Bank [36], results-oriented management "*demands that managers regularly analyze the degree to which their activities and products have reasonable probability of achieving the desired results, and to make continuous adjustments accordingly to ensure results are achieved*". Therefore, ROM provides a means by which business performance assessment can drive the continuous improvement of strategic plans.

In ROM, strategic planning is performed as an exercise that begins with answering the question of *what the results are that the organization wants to achieve*? It then moves backwards to investigate what actions it can perform to produce these results. Along the planning process, the use of objective methods to analyze the *cause-effect* relationships between activity outputs and corresponding organizational outcomes contributes to the design of a results-chain that better approximates the reality. The planning process has five steps:

1. **Impacts**: analyze current situation of the firm and define long-term, global objectives translated as business impacts (e.g., "improved customer retention"). Define performance indicators for measuring these impacts.

2. **Outcomes**: identify which business outcomes should be achieved in the short/medium-term to reach the long-term impacts (e.g., "reduced complaints"). Define performance indicators for measuring these outcomes and establish baselines and targets for them in a specified time frame. It is important to remark that outcomes have an *external* focus.

3. **Outputs**: on the basis of a cause-effect analysis, identify what the organization needs to produce to generate the outcomes desired (e.g., "reduced number of defects"). Define production indicators to measure the production of these outputs and establish baselines and targets for them within a time frame. Outputs have a *internal* focus.

4. **Activities**: define which actions the company will execute to produce the outputs established, within the required time frame (e.g., "initiate a production process improvement project").

5. **Inputs**: identify which resources are necessary to perform the activities defined. Plan for acquiring *resources* and *competences* that the company does not hold.

This notion can be better understood by an example. Consider the tree depicted in Fig 2.2.

The top root represents an example of long-term impact. In this case, the company wants to improve customer retention. In the level immediately below, there are three outcomes. The managers decided that these three outcomes will lead to an improved customer retention. They may have arrived at this conclusion by market research, through the advise of business consultants or even on the basis of business literature.

Next, the managers conducted a detailed assessment of the company's current situation in what concerns the three outcomes established and objectively determined what factors affect the outcomes. For example, for the outcome "reduced number of complaints", the managers analyzed which factors most influence the customer complaints. They perceived that product

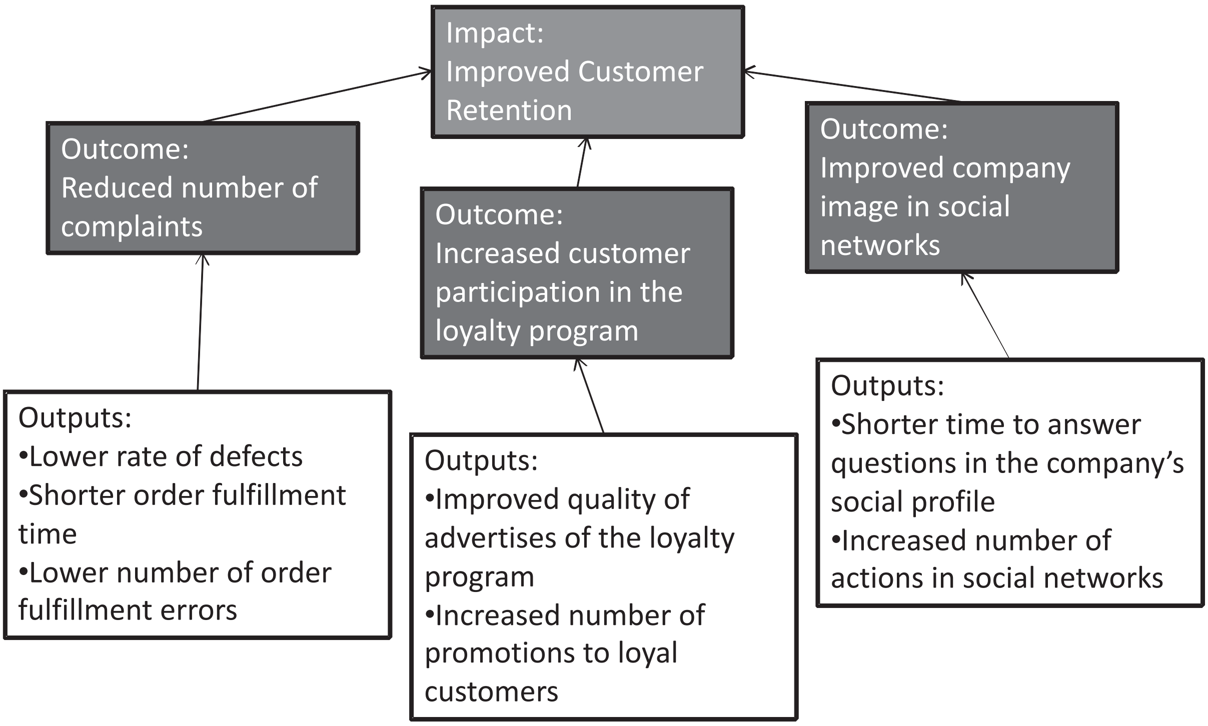

Figure 2.2 Results-oriented strategy example

defects, order fulfillment delays and wrong product deliveries comprised most of their customer complaints. So, they decided that part of the strategic goals for the company in the short/medium-term would be to improve these factors.

Likewise, they analyzed the factors that influenced the customer participation in the loyalty program and the company's image in social networks and defined outputs to improve these factors.

The next step in the design of the company's strategy is to choose courses of action by which the outputs defined are produced. This corresponds to the definition of **activities** that aim to produce the outputs. For example, one activity to be included in the plan could be the conduction of *a business process improvement project to reduce the order fulfillment time*. Another example could be the *definition of new rules for selecting marketing companies to promote the loyalty program*. The process proceeds with the definition of the **inputs** required to perform these activities, which may include *contracting of outsourcing companies* and the *acquisition of external financial support* to implement the activities.

Through such a planning process, the results-oriented approach is able to guarantee that there is a direct link between all activities defined in the company's strategy and the results wanted. Also, operational and administrative activities performed in the company's daily business can be identified with the outputs they impact. For example, the activity of "package order" is directly related to the output "lower number of order fulfillment errors", which is ultimately connected to the impact on customer retention. This is called *traceability* [82] and is an important feature provided by ROM.

2.5 Business Performance and Performance Measurement Systems

Measuring a firm's performance is essential for tracking the success of its business model and strategies and for revealing issues that should be addressed. Nudurupati et al. [80] adopt the definition of performance measurement as the "process of quantifying effectiveness and efficiency of actions". A *performance measurement system* (PMS) is defined as "the set of metrics used to quantify both the efficiency and the effectiveness of actions".

Still according to Nudurupati et al. [80], before the Japanese production growth in the 1970's, the focus of performance measurement was on financial metrics, such as "revenue", "profit", and "sales". As the Japanese firms showed to be much more efficient than the Western companies, metrics of productivity and efficiency started to gain more importance [80].

Radhakrishnan et al. [91] present three levels of performance measurement in use nowadays:

- *economy level*: investigate macroeconomic financial indicators (e.g., revenue generated per employee and return on investments - R.O.I.);

- *industry level*: measure *industrial* productivity (e.g., labor cost per unity produced, average time from order to cash, average machine downtime);

- *firm level*: investigate *organizational* performance indicators, which reflect the stability and growth of the company (e.g., net income, market share, sales growth etc).

The challenge in constructing an adequate performance measurement system for an organization is to define the set of metrics, also called *performance indicators*, that actually reflect the reality of the organization and the factors that impact its performance in its business field. Limitations on the capacity of the organization to collect and process operational and market data impose further difficulties to managers.

Melnyk et al. [73] describe a case study in which such challenges are faced by a company that is changing its business model. The negative impact of defining wrong metrics to measure the company's performance is illustrated by them in the case of a company that wants to improve its innovation capacity. This company decided to measure innovation by a metric defined as the "percentage of sales of new products". The higher are the sales of new products, the better should be the company's capacity to innovate. However, what the company actually got was a reduction in sales of older products, which increased the percentage of sales of new products. Although the metric showed an increase in the innovation, the organizational performance was actually in decline.

For this reason, performance indicators must be defined on the basis of a deep understanding of the company's operations and strategy. Also, they must be continually monitored and under review. Economy, industry, and firm level metrics indicate different points of view of the company's performance. They must be viewed in a holistic way to enable managers to draw adequate conclusions from the information shown by them.

2.6 Strategic Flexibility

Organizations frequently fail to recognize problems and react to them in a timely fashion. Market uncertainties, psychological biases, and management weaknesses prevent decision makers from clearly identifying their bad results [104]. Furthermore, the infrastructure's rigidity impairs the implementation of strategic changes within the time required [86]. Thus, to avoid getting stuck into wrong paths, companies need to become more flexible and adaptable [100, 119].

Strategic flexibility is the organization's ability to identify changes in the environment and quickly reposition itself in response to those changes, by adapting, halting or reversing current strategies [64, 104, 127].

Strategic flexibility requires the existence of processes and competences for the ongoing review of the company's commitments and to assess its current position. Also, it is important to construct a flexible infrastructure to respond quickly to changes [100]. For example, some manufacturing machines are able to produce different variations of the same product in a product family. These machines are more flexible than those that can only produce one kind of product. A company that employs such more flexible machines can deal with variations in consumer demand with more easy than companies that do not employ them [58, 119].

Shimizu and Hitt [104] define three capabilities that organizations must develop in order to attain a strategic flexibility:

1. **attention**: the ability to pay attention to negative feedback;

2. **assessment**: the ability to collect and assess negative data objectively;

3. **action**: the ability to initiate and complete change in a timely fashion.

These capabilities include both the necessity to measure performance and review plans adequately and the necessity of possessing the resources, skills, and competences required to perform change.

Golden and Powell [38] review the variety of existing terminologies and conclude that strategic flexibility can be generally defined as *the capacity to adapt*. Sanchez [100] affirms that "what clearly emerges from the diverse studies of strategic flexibility is the basic finding that the traditional strategic management objective of choosing a single *best* plan of action is likely to be an unrealistic objective in an uncertain environment". According to him, firms improve their chances of success by broadening their range of *strategic options*.

Sanchez [100] advocates that resource flexibility is essential to strategic flexibility. He proposes three dimensions in which such flexibility can be perceived: *range*, the number of alternative uses for a resource (e.g., to manufacture or distribute different products); *switching*, the costs or difficulty in switching from one use of a resource to an alternative use; and *time*, the time required to switch from one use to another. He adds that, besides resource flexibility, the firm requires coordination flexibility to be able to integrate and apply such resources in a flexible way.

Volberda [119] further investigates such "coordination flexibility" mechanisms, splitting the concept into what he calls *structural* and *strategic* flexibilities. Structural flexibility refers to the firm's capacity to adapt decision and communication processes in response to revolutionary changes. Strategic flexibility is defined as the capacity to adapt the goals of the organization and to change the nature of organizational activities.

Another point of view in organizational flexibility is presented by Teece et al. [110] as the concept of *dynamic capabilities*. This is a concept widely known in the Business literature [125]. Teece et al. define it as the ability of a firm to achieve new forms of competitive advantage by appropriately *adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences* to match the requirements of a changing environment. This notion highlights the need for developing an infrastructure and labor force that is prepared to change, which is in agreement with the view of Sanchez [100] of strategic flexibility.

The theory of dynamic capabilities focuses mainly on the capacity to change. It does not provide guidance on how to recognize the necessity to change and how to redefine the company's strategy when such necessity is perceived. Zahra et al. [125] contend that a better definition of dynamic capabilities should be one that separates the ability itself from its outcome. Zahra et al. argue that dynamic capabilities are abilities to reconfigure the firm's resources *in the manner deemed appropriate by the firm's decision makers*. These decisions, however, may or *may not* lead to an improved performance of the organization [18, 125].

Hence, although companies that demonstrate dynamic capabilities are more apt to change, they still need a strategic planning methodology for deciding what should be changed and when, and to measure the effectiveness of such decisions [119]. As Shimizu and Hitt [104] advocate, the capacity to plan and manage change is essential to strategic flexibility. A study on strategic planning and management cultures reported by Sköldberg [106] shows that different management approaches may lead to different capacities to deal with change.

Although strategic planning has essential role in strategic flexibility, we have not seen any work on strategic flexibility investigate the planning methodologies adopted by firms. Most works approach strategic planning as a binary variable: formal planning and non-formal planning. However, there is a whole spectrum of planning cultures that have been recognized by management literature. A conceptual investigation of these literature findings may help us better identify the factors that contribute to strategic flexibility.

In Section 2.7, we approach the strategic planning approaches adopted by firms in turbulent and uncertain environments.

2.7 Strategic Planning in Uncertain Environments

The role of strategic planning in highly unpredictable or turbulent environments has been largely discussed by management researchers [12, 40]. While earlier approaches to strategic planning focused on detailed formal plans, the increasingly uncertainty of the economic and market scenarios in the Internet era provoked a growing criticism over this planning model [40]. Most critics are based on the arguments that formal planning requires the capacity to predict the future in a much higher level of detail than it is possible in practice [6].

Several alternative approaches surged with the aim of increasing the flexibility of strategic plans, and to equip organizations with instruments to deal with market uncertainties. Comparing the similarities and differences of the approaches taken by several successful organizations, Brews and Purohit [12] identify four dimensions by which strategic planning approaches can be defined:

- **symbolic planning** - compelling, long-term, enterprise-wide vision/mission statements that are only changed in major strategic shifts;
- **rational (or formal) planning** - formal plans comprehensive in their formulation of specific goals/objectives, action plans, programs and budget-based implementation routines. Those plans are harder to change due to their high level of detail;
- **transactive (or incremental) planning** - plans iteratively formed on an ongoing basis, based on continual adaptation and market feedback;
- **generative planning** - plans that focus or encourage innovation, embrace bottom-up discussions, rely on decentralized decision-making, and present a lower level of prescribed actions.

The findings of Brews and Purohit [12] reveal that the transactive and generative dimensions are more often perceived in firms that operate in more complex and unpredictable settings. According to their results, *the higher is the uncertainty of the scenario, the less important is formal planning to the organization*.

In a more in-depth study, Grant [40] investigates the evolution of the strategic planning methodologies adopted by eight of the world's largest oil companies. This industry is considered to be largely influenced by economic, political, and environment factors that contribute in shaping a very turbulent environment. His results show that, from the 1980's to the 1990's, the planning systems adopted by these firms became much less formal. Strategic plans became shorter and formal presentations were replaced by open discussions. Furthermore, decision-making responsibilities shifted from top managers to functional managers (evidences of generative planning). Functional managers received autonomy to decide how to pursuit the results expected by the managers. Top managers, on the other side, focused more on symbolic planning (vision/mission) and performance results. This is in agreement with the findings of Brews and Purohit [12] about the reduction of formal planning in changing environments.

In a study considering banking, computer products, and food industries, Andersen [6] compared the effects of centralized formal planning and functional autonomy over firm performance. His results indicate that there is a significant positive impact of formal planning into the business performance of the food and banking firms. However, for the computer products firms, functional autonomy showed stronger positive effects. The author argues that formal planning was less important for the computer industry due to the complexity and dynamism of their environment. Such results corroborate with the theory that formal planning is reduced in dynamic settings, but highlight that it is not completely abandoned, but has a complementary function.

As the presence of formal planning reduces in changing environments, a question arises about what is its role in these settings. *Why is formal planning still necessary?* Brews and

Purohit [12] found that the factor that contributes to the presence of more or less formal planning is the firm's size. Larger firms seem to require some kind of formal planning as *a means to integrate its operations in its diverse functions*. Looking again to the case of the oil firms, Grant [40] shows that the more decentralized was the strategic decision making of the firms, the greater the emphasis on strategic planning as a *coordination device*. To accommodate these two apparently opposing forces, the formal plans in use by these companies placed more emphasis on company-wide performance targets instead of operations. By this way, they do not interfere with the autonomy of the functional units.

These researches demonstrate that, to successfully cope with change, organizations need to perform strategic planning in a way that promotes open discussions, embraces decentralized decision-making, and focus on performance results. However, the company also needs formal planning and defined goals to establish a central coordination device for integrating its operational units. Companies that loose strategic focus become uncontrollable. Such companies lack of administrative stability, becoming "chaotic" [119] and loosing efficiency [106].

2.8 Summary

This chapter reviewed the business literature on strategies and strategic flexibility in uncertain environments. Firstly, the concept of business models and strategies was presented. Then, we discussed the notion of strategic flexibility, its definition, and characteristics that should be exhibited by organizations that attain this state.

The chapter ends with a discussion about how strategic planning has been conducted by organizations in uncertain environments and which are the characteristics of successful strategic planning methodologies in these settings.

From this discussion, we conclude that *strategy* is the **process by which an organization selects and deploys a business model** to compete in its market environment. A strategy defines **goals and courses of action** by which the organization will pursue those goals. Planning, implementing, monitoring, and updating strategies are the major tasks of strategy management.

When confronted with turbulent and uncertain environments, companies need to develop the capacity to recognize problems with their strategy and to react in a timely fashion. This is called *strategic flexibility*.

As the discussion presented in this chapter shows, strategic planning is a critical determinant of the capacity of an organization to react to market changes. Although more flexible planning approaches are demanded in uncertain scenarios, **the absence of clear goals and constraints leads to a state of chaos**, marked by poor efficiency. As the case of the oil industry reveals, **to improve goal alignment, companies should strengthen their performance monitoring mechanisms** as a mean to create demands for goal accomplishment. Furthermore, **tough decentralized decision-making is essential to foster a company's flexibility, some level of formal planning is necessary** to improve the integration and coordination of the firm's functional units.

CHAPTER 3

A Model of the Effects of Uncertainty Over Firm Performance

Indeed, I have found that it is usually in unimportant matters that there is a field for the observation, and for the quick analysis of cause and effect which gives the charm to an investigation.

— (Sir A.C. Doyle, The Adventures of Sherlock Holmes)

3.1 Overview

Researchers have been investigating the relationship between uncertainty and organizational performance for a long time [75]. Empirical and theoretical works have demonstrated the existence of several factors that contribute to the increase or the decline of a firm's performance in face of unpredictable environment changes. However, these works are very heterogeneous in their approach. They address the problem under different hypotheses and considering distinct variables. To better understand the dynamics of uncertainty and performance, we define a new *causal model* that explains how an increase in the uncertainty of the market, economic, and political conditions may reduce the management capacity of organizations and reduce their performance.

A causal model as presented in this work is a collection of factors that are related to each other in a cause-effect relationship. On the basis of this model, statistical analysis may be performed to quantify the extent of these relationships. Thus, the cause-effect relationships are hypotheses that may be tested by quantitative research methods. We, however, do not construct the model as a step to conduct quantitative research. Instead, we review several quantitative and qualitative works available in the literature and construct the model on the basis of their conclusions. Therefore, it is a model that explains the conclusions already shown by current research work rather than a model that is proposed for further research. Its value lies in its capacity to integrate these conclusions, currently scattered among several works, into a single and coherent model. This model is not to be confounded with mathematical models, which are often employed by computer scientists. It is not constructed to be understood by a machine or to be processed by an algorithm. Rather, it is offered to the human intellect, which will be able to interpret its meaning in the complex context of organizations and draw new conclusions of particular importance to the field.

With such a model in hands, we are able to identify the requirements for a solution to mitigate the negative effects of uncertainty (such negative effects are identified in the sections to follow). Thus, the main purpose of the model presented in this section is to provide a framework for the identification and mitigation of the negative effects of environmental uncertainty over the performance of the firm. At the present study, we are interested in performance at the organizational level (see Chap. 2), which means that we refer to the financial stability of the organization, as well as consumer satisfaction. Most works that study the business performance of companies in the management literature are interested in the performance at this level.

After analyzing the concepts, frameworks, and empirical results described in several research works within the scope of strategy management, we extracted a collection of factors that were included in our general causal model. These factors are shown in Table 3.1. Some factors are subject of empirical evaluation of works, while others are only used to construct conceptual models based on experience. There are also works that describe specific case studies. This is described in the "Type" column of Table 3.1.

In our causal model, we used a number factors that are formally or explicitly mentioned in at least one work from the literature. However, we also considered works that refer to the same principles, but indirectly or without explicit mention. These situations are described in the "Mention" column of Table 3.1 as "explicit" and "implicit", respectively.

The modeling approach used by us is similar to others used in the information systems research literature, such as DeLone and McLean's [29] investigation on *information systems success* factors and Clark et al.'s [111] investigation of the *dynamics of management support systems*. DeLone and McLean argue that any attempt to organize past research includes a certain degree of arbitrariness, since some studies do not fit easily in the overall classification framework proposed [29]. According to Clark et al., the main objective is to discuss a coherent organization of prior research that allow us to "provide a cogently argued logic about the relationships among the components" [111].

The decision to include or not in this model a factor found in the literature was made on the basis of coherence and compatibility criteria. Our aim was to integrate the results of these works so that they could complement each other. In situations were the findings of a given study are too specific, we discarded this work because it would be difficult to integrate it in the whole scenario. As such, we do not claim that this model is complete. However, it is a more general model than what can currently be found in the literature. This allow us to get a better view of the effects of uncertainty than what could be got from each of the cited works when taken individually.

The resulting causal model from the combination of all factors described is presented in Fig. 3.1. We use the same graphical notation as used by Clark et al. [111] to describe the interaction of elements. A graph is constructed with factors as vertices and arrows connecting them. Arrows with positive signs indicate that increasing the factor at the origin of the arrow contributes to the **increase** of the factor that the arrow points to. Negative signs indicate that an increase in the source factor contributes to the **reduction** of the factor pointed by the arrow. Observe, for example, that an increase in the *uncertainty* of the firm's environment increases the managers' *inability to predict*, which increases the chances of taking *inadequate decisions*. As can be seen, other factors also impact the capacity to decide, such as *unclear goals* and *information gaps*. The model also shows that *information gaps* are increased when *decisions are centralized* in the firm.

Factor	Works	Type	Mention
Uncertainty	Milliken (1987) [75]	conceptual	explicit
	Grant (2003) [40]	case study	explicit
	Shimizu and Hitt (2004) [104]	conceptual	explicit
Inability to predict	Milliken (1987) [75]	conceptual	explicit
	Grant (2003) [40]	case study	explicit
	Shimizu and Hitt (2004) [104]	conceptual	implicit
Assumption biases	Shimizu and Hitt (2004) [104]	conceptual	explicit
	Teece et al. (1997) [110]	conceptual	implicit
Resistance to change	Baden-Fuller and Volberda (1997) [8]	conceptual	implicit
	Shimizu and Hitt (2004) [104]	conceptual	explicit
	Zahra et al. (2006) [125]	conceptual	explicit
Centralized decisions	Bloom et al. (2010) [10]	empirical	explicit
	Andersen (2000) [6]	empirical	explicit
Delayed decisions	Teece et al. (1997) [110]	conceptual	implicit
	Andersen (2000) [6]	empirical	implicit
	Shimizu and Hitt (2004) [104]	conceptual	implicit
	Bloom et al. (2010) [10]	empirical	explicit
Information gap	Ginkel and Knippenberg (2009) [116]	empirical	explicit
	Allaire and Firsirotu (1990) [5]	conceptual	implicit
	Yan et al. (2010) [123]	empirical	implicit
Coordination and integration	Barua et al. (1997) [9]	conceptual	explicit
	Teece et al. (1997) [110]	conceptual	explicit
	Andersen (2000) [6]	empirical	explicit
	Zahra et al. (2006) [125]	conceptual	explicit
Unclear goals	Skölderg (1992) [106]	conceptual	explicit
	Volberda (1997) [119]	conceptual	explicit
	Melnyk (2010) [73]	case study	implicit
Inadequate decisions	Shimizu and Hitt (2004) [104]	conceptual	explicit
	Melnyk (2010) [73]	case study	implicit
Unprepared resources	Teece et al. (1997) [110]	conceptual	explicit
	Shimizu and Hitt (2004) [104]	conceptual	explicit
Limited responses	Sanchez (1997) [100]	conceptual	explicit
	Golden and Powell (2000) [38]	conceptual	explicit
Late responses	Teece et al. (1997) [110]	conceptual	explicit
	Golden and Powell (2000) [38]	conceptual	explicit

Table 3.1 Factors included in the model

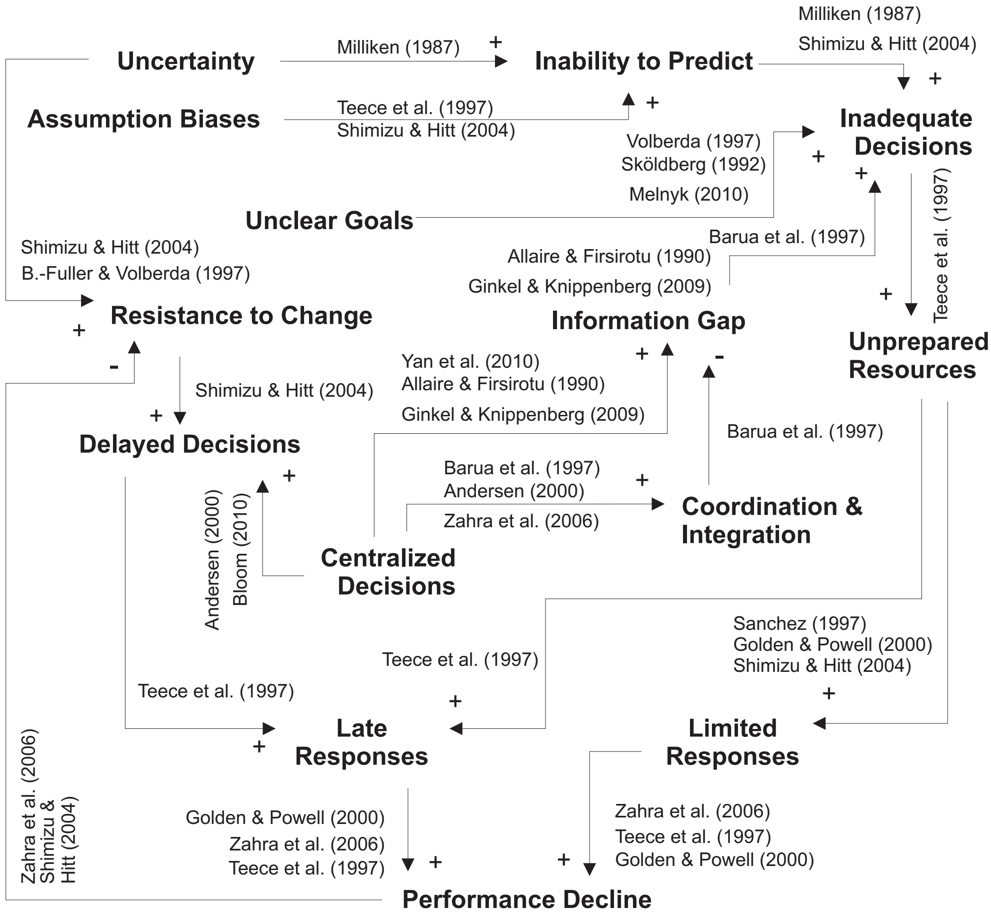

Figure 3.1 Uncertainty Effects Model

Each arrow is also annotated with citations to the works that support the corresponding relationship between the factors. For example, the relationship between *centralized decision making* and *delayed decisions* was empirically observed both by Andersen [6] and Bloom et al. [10]. The relationship between the *resistance to change* and *delayed decisions*, on the other hand, was proposed by Shimizu and Hitt [104] in a model based on their study of real companies.

Each of these relationships has been identified in the literature, but in isolated works. Presenting them in an integrated framework allow us to design a path through which a company can mitigate the undesired effects of environmental uncertainty. For example, if we increase the clarity and dissemination of goals throughout the organization, the chances of inadequate decisions are reduced. This subject will be approached in the next chapters.

We now detail each of these factors and relationships and explain the arguments provided in the literature to support them.

3.1.1 The Inability to Predict

When we are subject to situations in which our current position and/or our future destination are uncertain, our decision capacity is largely reduced. We may not be able to identify which choices are available for us or may not be able to completely predict the results of our choices.

It is worth notice that the volatility or variability of the environment is not necessarily unpredictable [75]. The organizational environment may be very volatile, yet changes may occur in a predictable way. Thus, this does not necessarily imposes any difficulty to the organization. Therefore, a better understanding of the concept of uncertainty is demanded if we intend to investigate its implications to an organization's performance. Milliken [75] argues that there are three distinguishable types of environmental uncertainty:

- **state uncertainty** - this is the type of uncertainty of an administrator when he/she perceives the organizational environment (or some of its components) to be unpredictable. It means that one is not able to understand how components of the environment might be changing;

- **effect uncertainty** - this type of uncertainty is defined as an inability to predict the *impact* that an environmental change will have on the organization, even if the environmental change is itself predictable;

- **response uncertainty** - even when the change is predictable and its impact over the firm is also known, this type of uncertainty may still remain. It is defined as a lack of knowledge of an organization's *response options* (what to do) and/or an inability to predict the likely *consequences* of a response choice when a need to act is perceived.

The three types of environmental uncertainty described by Milliken [75] share a common symptom. Regardless of the type of uncertainty that is present in the environment, the factor that makes it difficult to manage is an increase in the *inability to predict*. Hence, the *inability to predict* is a mediating factor of the effects of uncertainty over organizational performance. This is remarked by the speak of John Browne, CEO of BP, an oil industry major [40]:

> "*We gave up trying to forecast what would happen some time ago – we'd just learned from experience that even the most sophisticated models can't predict the reality of oil prices or any other key variables*".

The environment uncertainty is not the single factor that impacts a manager's capacity to predict. There are also psychological variables in place. As Shimizu and Hitt [104] point out, over time, "managers develop a particular mind-set along with a set of decision rules and heuristics based on their experiences" [104]. Successful managers often become overconfident and assume that their decisions are unlikely to fail. As a result, they "unconsciously ignore negative signs regarding their decision outcomes" [104].

Shimizu and Hitt [104] add that top managers decision rules are often routinized and taken for granted within the organization. This reduces the organization's capacity to pay attention to important new information regarding the environment. As such *assumption biases* increase around the firm, the ability to adequately analyze information and predict the future reduces.

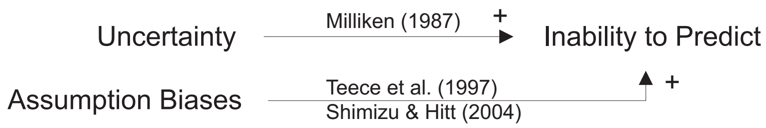

Figure 3.2 Inability to Predict Model

Figure 3.3 Resistance to Change Model

Hence, assumption biases are positively correlated with inability to predict. In this regard, Teece et al. [110] affirm that "narcissistic organizations are likely to be impaired [in rapidly changing environments]".

Therefore, the inability to predict is increased by both environmental uncertainty and biased attitudes. This relationship is illustrated in Fig. 3.2.

3.1.2 Resistance to Change

Another factor mentioned by Shimizu and Hitt [104] is the *resistance to change*. The more uncertain is the environment, the higher is the people's resistance to change established routines. People often believe that "consequences of changing are usually less well-known than the consequences of not changing" [104]. In this regard, Baden-Fuller and Volberda [8] discuss that organizations must develop mechanisms to reconcile the paradox of conflicting forces for change and stability.

The resistance to change results in several problems to an organization, which might negatively impact its performance. When people are resistant to implement changes, the decisions tend to be delayed [104]. Often, such delays impair the exploitation of business opportunities. Also, delayed decisions may make the company continue pursuing activities that are unlikely to be successful, resulting in severe losses.

This can be exemplified from the cases of *Kodak* and *Motorola* companies. Both firms underestimated the effects of digital technology and resisted to get into the digital era. With such a behavior, they not only lost a very profitable business opportunity, but they also continued investing in the analog technology for too much time [104]. Shimizu and Hitt [104] report that many companies studied by them delayed their responses for more than one year after the poor results started to appear.

Thus, although a resistance to change may be seen as a problem on its own, its impact over firm performance is mediated by an increase in the *delaying of decisions* and response actions. Thus, the more resistant to change is the organization, the more time it takes to recognize the situation and to take decisions on how to respond to environmental threats and opportunities.

These interrelated factors are illustrated in Fig. 3.3.

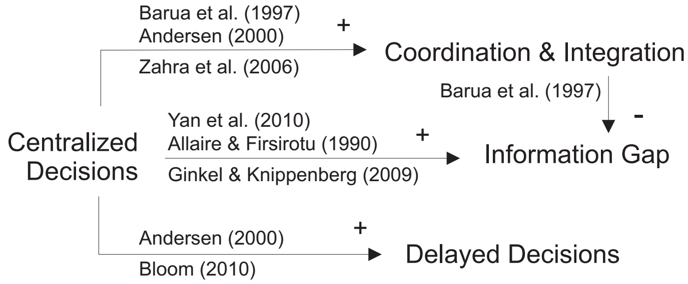

Figure 3.4 Centralized Decisions Model

3.1.3 Centralization of Decisions

A survey conducted by Bloom et al. [10] among firms in India shows that one of the major problems of companies in developing countries is their tendency to *centralize decisions*. Most companies lack of delegation of decision making from owners to senior managers. According to Bloom et al. [10], such centralization impair the firm's growth, since growth is limited by the time supply of the owner. They report on several companies that participated in their survey that exhibited substantial drops in their productivity due to broken equipments. The problem is that plant managers did not have the authority to order parts to repair such equipments and the owners were often traveling on business, delaying the equipment repairing.

Several authors have approached the relationship between decision-making characteristics and firm's performance in the context of uncertain and turbulent organizational environments [6, 12, 40].

The literature suggests that centralized decision-making has both positive and negative impacts over performance. One of the negative impacts is an increase in *decision delays*. Centralized decision-making impairs the capacity to respond to changes timely, once decisions require more steps and more time to be done [6, 10]. A second negative impact is an increase in the *information gaps* [5, 116]. The scope and complexity of the firm may grow beyond of top managers' capacity to comprehend all necessities of all units. Also, firms may shift to new business areas which call for different and more specialized skills [5]. This makes low-level managers much more informed to take decisions than top managers [123].

A positive impact of centralization is an improved capacity to *coordinate and integrate* activities and projects [6, 110]. Standardized procedures and integrated information systems reduce information gaps and improve the managers' capacity to take adequate decisions [9, 89]. In this context, strategic plans can be accounted as an instrument for centralization of decisions [5]. Centralized strategic plans are claimed to provide better coordination of actions and improved functional integration, which improve the organization's performance [6]. However, strategic plans are difficult to adjust in accordance with new events observed by decentralized managers [6]. This reduces its effectiveness to coordinate the action of autonomous managers.

These connections are illustrated in Fig. 3.4.

3.1.4 Inadequate Decisions

The ability to take good decisions does not depends only on the manager's skills. Organizational influences and external factors can increase or decrease the manager's capacity to make adequate choices at a given time.

One of these factors is the *inability to predict* the future [75]. Shimizu and Hitt [104] affirm that even highly intelligent managers struggle with the decision that should be taken after acknowledging poor outcomes. In a case reported by them, the managers were uncertain about whether the poor outcomes arose from organizational problems or from transitory market conditions. Much of their decisions were taken in the assumption that transitory conditions were taking place. Only after three years the directors perceived that they have been making wrong decisions and that changes were demanded [104].

The *information gaps* also prevent administrators from getting a clear grasp of the situation and its requirements [5, 116]. According to Barua et al. [9], it is common the situation in which two or more units must exchange their information, but this information is being collected in a form only useful to the unit that is collecting it.

For example, Barua et al. [9] report the case of Southern Cross, Inc. When the managers of this company needed to perform a company-wide analysis to isolate the root cause for unsatisfactory sales performance, they required information from several sources. However, the data from each source showed several inconsistencies, such as grouping the same products into different categories. As a result, additional efforts had to be made to firstly standardize the information before they could start analyzing it.

Ginkel and Knippenberg [116] affirm that decision-making groups with distributed information often make suboptimal use of their information resources. One of the difficulties imposed by distributed information is a reduced knowledge of *who knows what*.

The relationship between top managers and functional managers may also be marked by large information gaps [123]. Allaire and Firsirotu [5] discuss that, in firms that adopt a "numerous-driven" planning culture, the functional managers have much more information about the business than the executives. Very often the strategic plans turns into a *post facto* control mechanism focused only on the financial/quantitative aspects. According to Allaire and Firsirotu, when the results sour, the board members may be the last to know [5]. Furthermore, when merges and acquisitions are made and companies start working at new businesses, more specialized skills are required [5]. It is likely that the corporate managers will not have the skills necessary for taking the most adequate decisions in the areas apart from the initial business of the company.

A third factor that diminishes the managers' capacity to decide adequately is the *absence of clear goals* [106, 119]. In Volberda's chaotic type of organization [119], the absence of strategic directions makes the range of possible procedures very large. Making a choice becomes a very difficult task in such setting.

Even if goals are well-defined, when uncertainty is observed and a strategic change is required, there is a need for changing goals as well. This period of change makes unclear which goals are to be kept and what will be the new goals. In a case study described by Melnyk et al. [73], a company was shifting from a cost leadership strategy to a differentiation through innovation strategy. Unfortunately, managers at different levels of the company comprehended

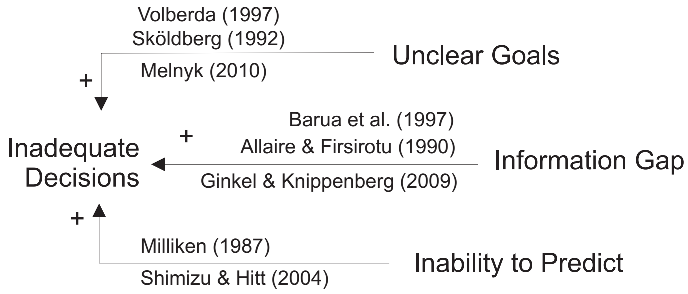

Figure 3.5 Inadequate Decisions Model

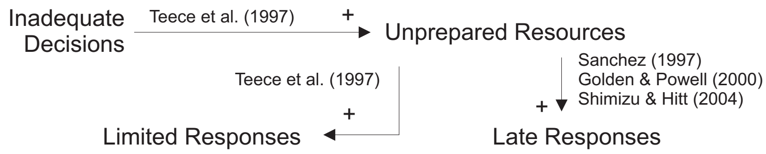

Figure 3.6 Unprepared Resources Model

the new goals differently, taking decisions under different assumptions. As a result, the company did not attain its goals for innovation, failing to adapt to the new market conditions.

These three factors are illustrated in Fig 3.5.

3.1.5 Resource Unpreparedness

The Resource-Based Theory (RBT) [110] explains that competitive advantage is obtained through unique, hard to imitate resources and competences. However, when the environment changes, the competitive advantage of the firm can only be sustained if its skills and resources can be reconfigured to new functions, as demanded. As Teece et al. [110] analyze, the capacity to reconfigure a firm's resources and competences is limited by its current resource base. They affirm that the positions where a firm can go is a function of its current position. An implication of this fact is that many investments tend to be much longer term than managers think. They not only determine the current commitments of the firm, but may also determine its future options.

To be able to explore new ventures, the organization must prepare its resource base to perform current functions and also to learn new functions [18, 38]. If investments are made in the wrong way, the resource base of the company will not be prepared to changes in the market requirements. In changing environments, the lack of good management skills naturally moves companies into a state of *unpreparedness*. Only good managers can embody the organization with resources that are prepared to adequately respond to environmental changes.

Such state of unpreparedness limit the *range of responses* available to the company in the occurrence of unforeseen events [38, 100, 104]. Furthermore, the company's speed of reaction will be reduced by the need to develop and acquire new resources and competences. Thus, opportunities are lost due to *late responses* [110].

These factors can be seen in Fig. 3.6.

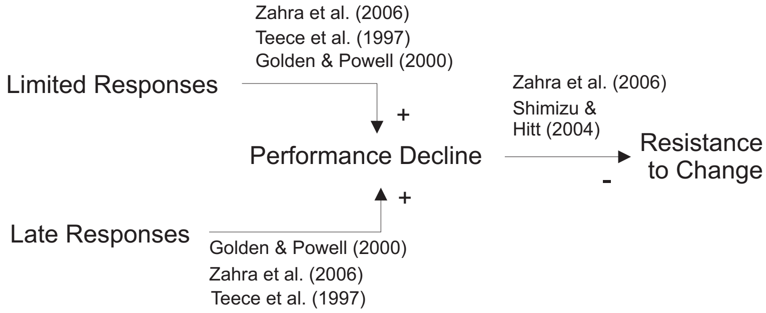

Figure 3.7 Performance Decline Model

3.1.6 Performance Decline

According to Golden and Powell [38], *limited response capacity and reduced response agility* are the major reasons for the poor performance of organizations in uncertain environments. This is in agreement with other authors that have been researching the subject of dynamic capabilities [110, 125].

On the other hand, when performance declines, *resistance to change* is also reduced. The reason is that people recognize the urgency and the need to change and are more open to alter the *status quo* [104, 125]. Biased assumptions, however, may not be impacted in the same way. This is because managers often self-justify and believe that the cause of poor performance is something else than their own attitude and decisions [104].

The feedback from bad performance results is not sufficient to provoke changes to the company strategy. As Shimizu and Hitt [104] discuss, there are several factors that prevent managers from taking actions to address such performance problems, making the performance decline signals "invisible".

Fig. 3.7 illustrates the interaction of these factors.

3.2 Summary

In this chapter, we presented a conceptual investigation around the effects of uncertainty over firm performance. We drew from existing models found in the literature to construct a more general view of the subject. Our causal model explains the interactions between several factors that have been recognized by other works, but giving a more complete view than what is get from each work isolated.

It is clear from our investigation that the effects of uncertainty reduce the management capacities of the organization. It is this limited management capacity that results in performance decline. Our findings show the negative effects that show up when managers lack the ability to deal with uncertainty: unclear goals, resistance to change, information gaps, and assumption biases. These, in turn, result in delayed and inadequate decisions and in unprepared resources. These factors limit the speed and the range of the firm's response to change, resulting in the performance decline.

Our model helps managers to understand the dynamics of management in uncertain environments and may be a valuable tool in the construction of uncertainty mitigating mechanisms. In fact, we use this model to derive an information systems approach to mitigate the effects of uncertainty, described in Chapter 5.

Part II

The Technology

CHAPTER 4

Information Systems Background

Knowledge is a treasure, but practice is the key to it.
— (Lao-Tzu, Tao Te Ching)

4.1 Overview

In this chapter, we review several modern technologies that have been applied to automate and manage organizations, with a focus on flexible solutions. These technological solutions compose the basis for the design decisions made by us in the development of this work.

4.2 Process-Aware Information Systems

The introduction of the concept of *business processes* into information systems science provoked profound changes in the way enterprise systems are understood and developed. Business processes are at a higher level, since they are used as a structure to model the work practices in an organization. Nevertheless, it is also an application design methodology, useful to improve the flexibility and maintainability of information systems. In this section, we present a basic overview of business process theory and terminology.

A *process* consists of a number of activities that need to be carried out in a particular order to complete a given task [2]. *Business processes* are processes that describe the flow of work within an organization. Business processes deliver as output goods or services that are of business value for the organization's customers [128]. These customers may be either internal or external to the organization.

A common way to describe and communicate business processes is through *process models*. Such models represent, using a specific notation, how the people in the organization understand their work practices and how they believe that the work should be done [31]. The design of a business process model requires a crosscutting analysis of the organization's activities, people, and departments.

One of the objectives of process models is to drive the operations of the organization. Since the model describes what is desired or expected, following the flow of activities determined by a process assures that the work is done in the manner deemed appropriate by the company's decision makers. The act of putting a process model into execution is called *process instantiation* or *process enactment*. Each *process instance* is also called a *case*.

A *process-aware information system* (PAIS) [32] is a system that is able to *interpret process models* and provide automated support for the *management* and *execution* of an organization's business processes. As the system's behavior is driven by process models, evolving and updating business process models automatically updates the functionality offered by PAISs. This is an important benefit of PAISs. As business people are more comfortable with describing their process of work, the capacity to create high-level models that are promptly understood and automated by information systems is very advantageous for them. However, it is often necessary the mediation of the IT in order to make the process models executable. Despite that, business process automation gained large importance, due to its capacity to reduce the communication gap between business and IT.

PAIS support processes at two different phases: *build-time* and *run-time* [92]. The build-time environment comprise tools for defining, configuring, and verifying executable process models. The run-time environment is concerned with the creation, execution, and management of process instances through a *process engine*.

A *workflow* [25] is a model for business processes aimed to support automation. It defines an *a priori* flow of activities that must be strictly followed by the PAIS for the execution of the business process. A PAIS that gives support to workflows is called a *workflow management system* (WfMS) [25].

Business Process Management (BPM) [31] is an academic and industrial field devoted to the study and application of business process concepts. Dumas et al. [31] define BPM as a:

> *Body of principles, methods and tools to design, analyze, execute and monitor business processes.*

BPM offers a theoretical background that enable people to create better business process models and to improve the organization's capacity to manage, optimize, and evolve its business processes. Moreover, it provides means to promote the strategic alignment of the company's operations. Harmon [46] describes the job of the process manager as the person who continually adjusts processes to meet the organization's expectations. This is illustrated in Fig. 4.1.

The first responsibility of the process manager is to define or *plan the process*. The manager sets goals, establish budget, and acquire resources necessary to the execution of the process. Once implemented, the *process is executed* someway. It may be completely manual or may be supported by a PAIS. Once the process is in practice, the manager is responsible for monitoring its outputs or results. The objective is to measure the effectiveness and efficiency in achieving the desired goals. The manager uses this information to *control the process*, diagnosing deviations and taking corrective actions.

The BPM tasks can be organized in a cycle of activities, called the BPM lifecycle. Figure 4.2 depicts the BPM lifecycle, adapted from zur Muehlen [128]. BPM begins with *process design*, when the organization's work practices, goals, strategies, and resources are analyzed to identify and model its business processes. Next, *process implementation* is performed, when the infrastructure to support and automate the execution of business processes is designed and deployed. During *process enactment*, process instances are derived from the process model. Measurements of the process performance are extracted through *monitoring*. These measurements provide information for simulation and analysis of the process performance. The results

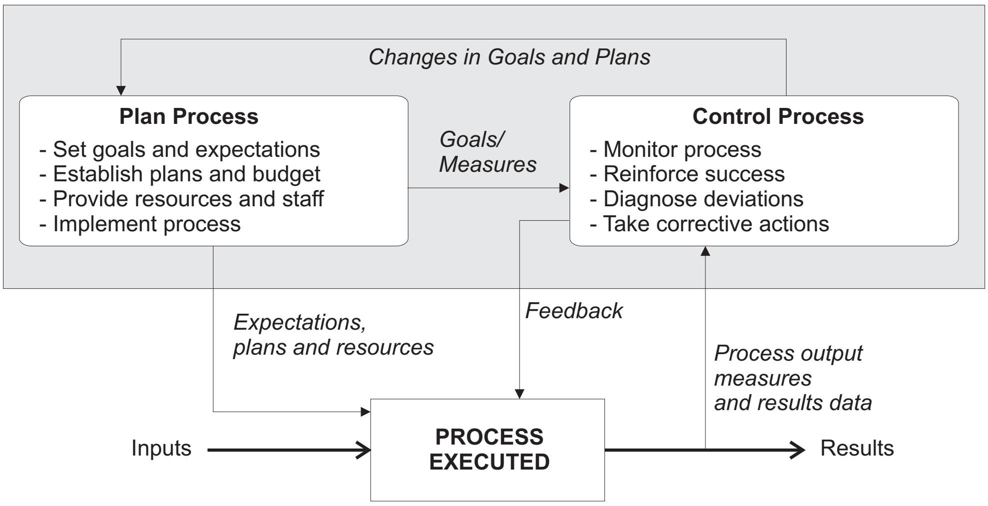

Figure 4.1 The process manager's job, according to Harmon [46]

of these analysis are input to *process evaluation*. At this step, the managers verify the adequacy of the process performance in contrast with goals and targets of the company. If necessary, measures for the improvement of the process are defined. The output of this phase is the input for beginning a new cycle. The lessons learned drive the *redesign* of the process models. *Business Process Management Systems* (BPMS) are information systems that support the BPM lifecycle, making the job of the manager easier.

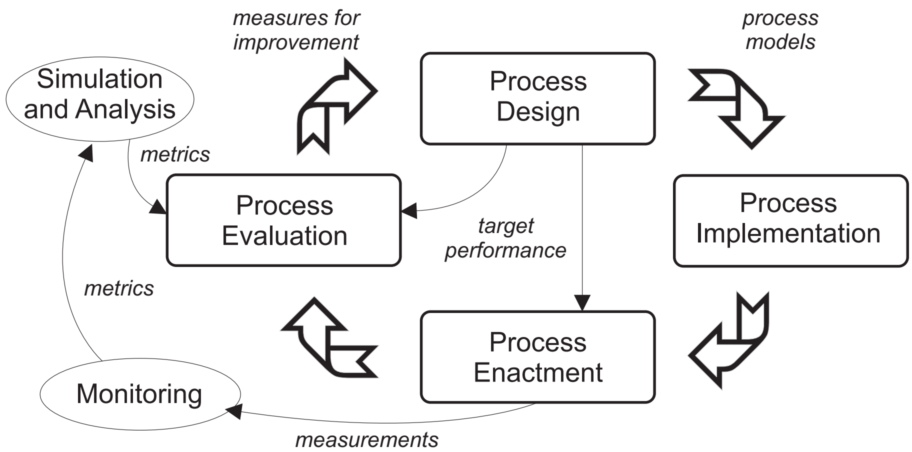

Figure 4.2 BPM lifecycle (adapted from zur Muehlen [128])

Process awareness showed to be an important technology to support a better alignment between Business and IT. Although the idea of making a model that drives the operations of information systems may seem simple at first glance, decades where necessary until this concept and technologies were fully developed [128]. Its benefits are so striking that BPM technologies are seen today as an essential element of modern enterprise management.

4.2.1 Business Processes and Petri Nets

The concept of a **business process** can be formalized through the use of *Workflow nets* (WF-nets) [2]. This formalization approach has been used by several works in the literature [3, 32]. WF-nets have semantics expressed by Petri nets [76]. In this section, we summarize the concept of Petri nets and present the formal definition of a business process in terms of WF-nets. The use of WF-nets to describe and analyze business processes is widespread in the Computer Science literature [32].

A Petri net [76] is a directed graph composed of places and transitions, which comprise the nodes of the graph, and arcs, which connect places to transitions. Places are used to describe the state of the system modeled by the Petri net, while transitions indicate how the Petri net can move from one state to the other.

Definition 4.1 (Petri Net)**.** *A Petri net is a tuple $\langle P, T, I, O, M_0 \rangle$, where*

- *P is a finite set of* places*;*
- *T is a finite set of* transitions *($P \cap T = \emptyset$);*
- *$I : (T \times P) \rightarrow \mathbb{N}$ is the input function, which defines the multiplicities of directed arcs from places to transitions;*
- *$O : (T \times P) \rightarrow \mathbb{N}$ is the output function, which defines the multiplicities of directed arcs from transitions to places;*
- *$M_0 : P \rightarrow \mathbb{N}$ is the initial marking.*

Definition 4.2 (Transition Precondition)**.** *Let $t \in T$. The set of all places p such that $I(t, p) > 0$, denoted by $I(t)$ or $^\bullet t$ is called the* pre-condition *of t. Each place in this set is also called an* input *place of t.*

Definition 4.3 (Transition Postcondition)**.** *Let $t \in T$. The set of all places p such that $O(t, p) > 0$, denoted by $O(t)$ or $t^\bullet$ is called the* post-condition *of t. Each place in this set is also called an* output *place of t.*

The state of a Petri net is defined by its *marking*. A marking is a function $M : P \rightarrow \mathbb{N}$ that indicates the number of tokens present on each place of the net. Tokens are represented by small filled circles inside a place. A transition is *enabled* at its current marking according to the number of tokens present on its precondition, according to the following enabling rule.

Definition 4.4 (Petri Net Enabling Rule)**.** *A transition $t \in T$ is said to be enabled in a marking M iff:*

- $\forall p \in {}^\bullet t, M(p) \geq I(t, p)$.

The dynamic behavior of a Petri net is governed by the *firing rule*. Only enabled transitions can fire. The firing of an enabled transition removes tokens from all of its input places and inserts tokens in its output places. Because the state of a Petri net is given by the distribution of tokens in its places (marking function), a transition firing may change its state, generating a new marking function.

Definition 4.5 (Petri Net Firing Rule). *The firing of a transition t enabled in the marking M leads to a new marking M' such that*

$$\forall p \in ({}^{\bullet}t \cup t^{\bullet}), \quad M'(p) = M(p) - I(t, p) + O(t, p) .$$

The notation $M_i[t\rangle M_j$ is commonly used to indicate that a certain marking M_j is *directly reachable* from M_i, by firing transition t. A **firing sequence** is a sequence of transitions $s = [t_1 t_2 \dots t_n]$ such that

$$M_0\ [t_1\ \rangle\ M_1\ [t_2\ \rangle\ M_2\ \dots \quad M_{n-1}\ [t_n\ \rangle\ M_n\ .$$

We define the concept of a *node path* to assist us in the definition of WF-nets. Taking a Petri net as a graph composed of arcs and nodes, a node path is a sequence of nodes (either places or transitions) that connect a place to another. Although this definition is not usual when studying Petri nets, it contains the conditions that help us define what is a *valid* WF-net in simple terms.

Definition 4.6 (Node Path). *A node path from a place p_1 to a place p_2 in a Petri net $\langle P,T,I,O,M_0\rangle$ is a sequence $s = [a_1 a_2 \dots a_n]$ of nodes $a_i \in P \cup T$ such that:*

- $a_1 = p_1$ *and* $a_n = p_2$;
- *for each place a_i in s, $i < n$, $I(a_i, a_{i+1}) > 0$;*
- *for each transition a_i in s, $O(a_i, a_{i+1}) > 0$.*

A *Workflow net* (WF-net) [1] is a Petri net that has a single start place (the input place) and a single end place (the output place) and all other nodes are in a node path from the input place to the output place.

Definition 4.7 (Workflow Net). *A Petri net $\langle P,T,I,O,M_0\rangle$ WF-net iff:*

- *there is exactly one input place p_I, such that $O(t, p_I) = 0$ for all $t \in T$;*
- *there is exactly one output place p_O, such that $I(t, p_O) = 0$ for all $t \in T$;*
- *for all nodes $z \in P \cup T$, there is a node path from p_I to p_O which includes z.*

4.2.2 Complexity of Business Process Models

It has been argued that the probability of errors in modeling business processes increases with the complexity of the model [15]. Several metrics have been proposed to measure the complexity of a business process model. Most of them were adapted from metrics to measure software complexity [41]. These metrics measure the difficulty to understand a software program and reflect its maintenance cost.

A fundamental complexity metric for software programs is the *Lines of Code* (LoC) metric. It simply counts the number of lines in a program code. Despite its simplicity, it is widely adopted by software development companies [15]. Cardoso et al. [15] propose an adaptation of LoC to business processes in the form of a *Number of Activities* (NoA) metric, which simply counts how many activities are in the model. Variations of this metric also count the number of control flow structures (splits and joints) [15].

The problem with NoA and similar metrics is that they do not take the structure of the model into account [41]. Thus, a well-structured model will have the same NoA of a badly-structured process with the same number of activities.

Another metric adapted by Cardoso et al. [15] from software engineering is McCabe's Cyclomatic Complexity, which counts the number of independent control paths in a program. This metric is developed from graph theory and is considered more precise then LoC. It is widely employed in large-size projects [15].

Cardoso et al.'s adaptation of McCabe's Complexity to process models is called *Control-Flow Complexity* (CFC) [15]. It takes advantage of the fact that process model are already graphical structures. The CFC metric counts the number of possible execution paths introduced by a split (XOR, OR, AND) in the model. The number of possible execution paths introduced by a XOR-split is the number of its outgoing branches. For an AND-split, it is just one. An OR-split allow for $2^n - 1$ paths, where n is the number of its outgoing branches.

The adaptation of other metrics from software engineering have been proposed by the literature [15, 41]. An experiment conducted by Mendling et al. [74] compares the capacity of a set of metrics to predict the actual understandability of the models. Their findings are that the most convincing factor related to understandability is a metric called *Average Connector Degree*. This metric counts the average number of input and output arcs at routing elements. Another factor found to have high impact in understandability is the *Density*, defined as the number of arcs in the model divided by the maximum number of possible arcs between the model's elements. Other metrics, including CFC, showed no significative correlation with understandability.

Research on measuring the complexity of process models help us identify which factors can make models easier to understand and maintain and may support the development of best practices, improved tools, and better modeling notations.

4.2.3 Business Process Decomposition

An approach used to reduce the maintenance efforts for software programs as well as business process model is *decomposition* [51, 93]. The idea is to reduce the complexity of a software or process by decomposing it into modules or subprocesses.

Johannsen and Leist [51] propose a framework for assessing the quality of a decomposed business process model. They define five conditions for "good" decompositions:

- **minimality**: the model should not present redundant structures (which the authors recognize as being difficult to assess);
- **determinism**: the execution flow must be precisely defined;
- **freedom of losslessness**: no information must get lost during the decomposition;
- **minimum coupling**: the minimum coupling is fulfilled by a decomposition that presents the minimum set of variables exchanged between subprocesses and the higher-level pro-

cess. It suggests that subprocesses should be merged to reduce the interaction between them;

- **strong cohesion**: cohesion is seen as the "dual" to coupling. A subprocess has strong cohesion when the set of variables manipulated by it is mostly independent from the set of variables manipulated by other subprocesses in the same decomposition level.

These conditions help modelers improve their design when decomposing a process. They give directions both for when a high-level activity is detailed into a subprocess or when a subset of activities is abstracted into a subprocess that combines them.

The notion of decomposition also offers an instrument to reduce the complexity and maintenance efforts for business process models. Moreover, decomposition also enables reusability [93]. Subprocesses designed for common tasks can be reused to compose different business processes. This speeds up the modeling time, improving productivity.

4.2.4 Business Process Flexibility

The subject of uncertainty has also been a focus of investigation in BPM research. Academics agree that there are scenarios in which it is not possible to model all possible execution paths of a business process. The environment is either too complex or uncertain to be modeled by a workflow [81]. As a result, a number of situations are excluded from the models, requiring people to deviate from the predefined flow to effectively deal with them [115]. In this context, a number of works have proposed alternatives to workflows with the aim of making business processes more flexible.

According to Nurcan [81], current approaches to flexibility can be classified in two broad categories: *a priori* flexibility and *a posteriori* flexibility.

A priori flexibility (or flexibility by selection) uses modeling formalisms that offer the capacity to deal with environmental change without changing the underlying process definition. Thus, the task of making the process adaptable is performed at design-time.

The declarative paradigm of business process modeling is an example of a priori flexibility [94]. Declarative models do not specify strict order relation between activities in a process. Instead, *business rules* are used to restrict certain options and oblige the execution of steps necessary to fulfill the process requirements. As long as the execution flow obeys to these rules, all remaining options are open to the user's choice.

DECLARE [87] was the first tool to support the declarative paradigm. In DECLARE, a process is defined by a set of activities and a set of constraints. The constraints are expressions in Linear Temporal Logic (LTL) [50] that describe all the execution traces that are valid. At runtime, DECLARE utilizes a model checking algorithm to verify the rules and requests/blocks user actions as necessary to make the current execution path valid.

DCR graphs [49] is another approach to declarative process that is similar to DECLARE. However, DCR graphs describe business rules by means of a graph-based formalism. This formalism is more efficient than LTL because it does not require the generation of the entire state-space of the system, as it is required for LTL model checking.

Case Handling Systems (CHS) [117] offer what is called *implicit modeling* [44]. In a CHS, the process definition describes the normal or *preferred* workflow. However, participants may skip or redo activities if necessary. The designer is also able to limit these possibilities by assigning authorization levels for each action. Thus, some activities may never be skipped or may never be redone.

A posteriori flexibility (or flexibility by adaptation) allows process definitions to be changed at runtime, either affecting a single instance or all running instances of the process.

ADEPT [28] is an example of system that provides a posteriori flexibility. It allows process definitions to be changed at runtime through adding, removing, or moving activities in the workflow (*ad-hoc* change). The change process is controlled to guarantee the soundness of the resulting model.

The works enumerated in this section rely on the user to implement process adaptations. It is for the user the task of deciding how the process should be changed to handle an unpredicted situation. However, there are also works that implement autonomous mechanisms, through which the process is automatically adapted to the environment conditions. Before we discuss these works, we would like to introduce the notion of *context-aware* information systems.

4.3 Context-Aware Information Systems

Business processes and enterprise applications do not exist isolated, but are part of a complex environment involving internal and external influences that affect the daily operations of an organization. *Context-aware information systems* are systems intended to have the capacity to consider such environmental factors in its operations.

A system is said to be context-aware if it can collect information about its environment, interpret it, and adapt its functionality to the current context of use [124].

Context-aware literature is more prominently interested in physical context (data collected by physical sensors) [124]. To improve user satisfaction, physical context and user profile information are combined to infer the high-level context in which the user is inserted. Context acquisition, inference, querying, and management have been focus of research on this domain [122].

Defining the context model is an essential task in context-aware applications. The model instructs the system on how to interpret the information captured from its environment. Weijun et al. [122], for example, propose an ontology-based probabilistic model for context reasoning. Their model describe the surrounding environment by logical predicates. At runtime, the system infers probabilities for predicates on the basis of current sensor information. The probability of each predicate affects adaptations that are made by the system to improve the user experience.

Another trend in context-aware systems is on infrastructure-supported context awareness [66]. A single infrastructure may provide services for several applications. In this way, it can centralize many tasks, such as inferencing and caching. This provides a number of benefits, for example, reduced maintenance complexity, improved platform independence, and reduced processing costs.

SOCAM (Service-Oriented Context-Aware Middleware) is an infrastructure built on top of OSGi (Open Service Gateway Initiative) technology to support context awareness [42]. OSGi is a standard architecture for the creation of component based applications that supports the design of service-oriented applications. SOCAM uses the Web Ontology Language (OWL) to model contexts. Its contexts are organized in a hierarchy of contexts that include a general purpose high-level ontology. Domain specific ontologies can be plugged in the system to describe low-level contexts. This allows for the rapid prototyping of context-aware applications.

OSGi provides a great level of flexibility to SOCAM. Its infrastructure is able to integrate several components in a plug-in style manner. SOCAM's context is captured by modular *context provider* components that may be distributed in the environment (vigilance cameras, temperature sensors, etc.). The information captured from these components are converted by them into OWL representations, so that other components can share and reuse it. Context providers are managed by a *service-locating service* (SLS) that allows a provider to advertise its presence. SOCAM also offers a *context knowledge base* service that provides a set of APIs for other components to query and update the context knowledge. A *context interpreter* is responsible for keeping the consistency of such knowledge base. All these features are provided on top of the OSGi framework [42]. Figure 4.3 illustrates SOCAM's architecture.

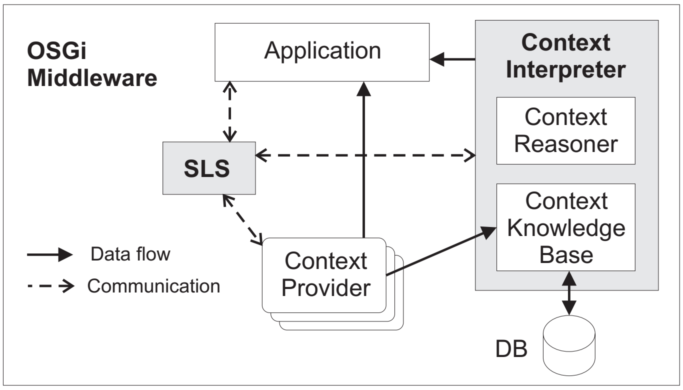

Figure 4.3 SOCAM architecture

From the various works available in the literature [124] [66], we observe four main elements that compose a context-aware system. These elements are illustrated in Fig. 4.4.

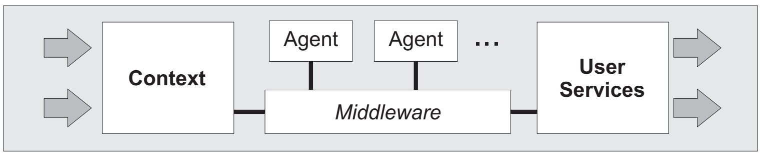

Figure 4.4 Elements of a context-aware application

The **context** element comprises *context modeling*, *context data collection*, *context reasoning* (infer high-level context from low-level context), and *context data management* (store and distribute the contextual information captured).

Agents are the entities responsible for *observing context information* and *performing adaptations* to the system accordingly.

The **middleware** element provides the infrastructure for the collaboration of agents and for context sharing.

Finally, the **user services** element provides the user functionality in a context-aware manner.

These architectural elements are used by us in the design of strategy-aware information systems.

Despite the wide diffusion of context awareness among researchers, Hong et al. [124] observe that the concept is not fully implemented in real life. Most applications are limited to small regions, laboratories, schools, or smart rooms. Its major area of application has been identified to be ubiquitous computing, but very few business applications have emerged yet.

4.4 Context Awareness Meets Process Awareness

Rosemann et al. [97] present a thorough study of the application of what he also calls "context awareness" to business processes. They identify several situations in which business processes require contextual information. This subject is closely related to the necessity of *flexibility* in business process models, which we define below.

Business process flexibility is defined as the ability to change a process without the necessity of completely replacing it [97]. As current volatility of the market environment requires changes to occur frequently, the capacity to change processes rapidly is an important factor to improve competitiveness [81].

Explicit consideration of contextual information in business process modeling improves the understanding of the cause-effect relationships between environment demands and process behavior [97]. This helps decrease reaction time and improves risk management. Context models clarify which environmental variables should be monitored and context-aware process models adapt themselves in response to changes on these variables.

As an example of context-aware business process, Rosemann et al. [97] describe the check-in process of an airline company. The process is subject to change in response to different levels of security alert. For instance, when an alert of bomb is issued by the airport, the tests for explosive goods become mandatory. The arrival and departure of VIPs is also a factor that affects the procedures of the airline. These contextual variables change the process requirements and may cause the inclusion, removal, or change of activities in the process model.

Thus, context-aware business processes are flexible business processes in which context variables determine when and which adaptations should be made at runtime.

4.4.1 Context-Aware Business Process Flexibility

According to Loke [66], context-aware artifacts may present three levels of competence:

- *Level 1*: reactive artifacts that perform simple actions in response to sensor readings;
- *Level 2*: reasoning artifacts that build a model of the situation and act only when they recognize the appropriate situation;
- *Level 3*: proactive artifacts that not only maintain situation models, but also plan a series of actions in response, possibly acting proactively.

A context-aware approach for a priori flexibility is provided by REFlex (Rules Engine for Flexible Processes) [16] [105]. REFlex is yet another declarative process approach. It also uses a graph-based formalism to avoid generating the entire state-space, like DCR graphs. However, its expression power is superior to that of the DECLARE and DCR graphs, since REFlex business rules can contain data dependencies. Thus, contextual information is used at runtime to decide whether certain business rules should be enforced or not in the current process instance. REFlex is a reactive system, since it does not interpret the contextual variables.

AO4BPEL [21] also offers a kind of a priori flexibility. AO4BPEL expands the scope of the Business Process Execution Language (BPEL) to support *aspect-oriented programming* (AOP). In AOP, aspects are cross-cutting concerns that are shared among several software artifacts. An aspect defines a piece of code that is replicated and inserted at several points of the application's code.

The idea proposed by AO4BPEL applies the principle of AOP to business process modeling. AO4BPEL's aspects define fragments of business processes that can be inserted into one or more process models. At runtime, an aspect-aware execution engine combines aspects and processes to construct the process to be executed. The aspects to be activated for each process instance can be chosen on the basis of contextual information. AO4BPEL is also reactive, since it does not offer a context model.

The following approaches present a more advanced capacity to interpret the context. They are level 2 systems.

The concept of *worklets* was proposed by Adams et al. [4] as a mean to create adaptable business processes. A worklet is a workflow that is designed to execute only a specific part of a larger process. Worklets are attached to workflows by substituting, at runtime, an activity in the workflow by the worklet. Worklets are stored in a knowledge repository and are selected from contextual information. To model the context, the worklets approach uses *Rip-Down Rules* (RDR). RDRs are structured as a set of rules organized in a binary tree. The tree represents a hierarchy of condition/conclusion questions that conducts the process of context inferencing. Terminal nodes indicate conclusions. The conclusion determines which worklet will be selected to participate in the process. This is illustrated in Fig. 4.5, which applies for the process of giving treatment to a patient in a hospital [4]. In this example, the symptoms of the patient are input to the system by a doctor. Next, the system checks the conditions of the patient based on this data and includes in the process the activities necessary for the adequate treatment of the patient. The root node of the tree checks if the patient has fever. If so, the *Treat Fever* activity is included. If not, it checks whether the patient has wounds, in case which it includes the activity *Treat Wounds*. Next, the system checks if the patient has abdominal pain, and so on.

A framework called CEVICHE (Complex EVent processIng for Context-adaptive processes in pervasive and Heterogeneous Environments) [47] proposes an adaptation approach which employs Complex Event Processing (CEP) [67]. CEP is capable of recognizing complex patterns of events to identify specific environment situations. The framework uses an extension of BPEL that supports the description of "adaptation points". An adaptation point defines a pattern of events that should be monitored and the alternative process that should be executed when such pattern is recognized. The BPEL engine employed in the CEVICHE approach supports changing the process definition on-the-fly, which facilitates the adaptation process. The

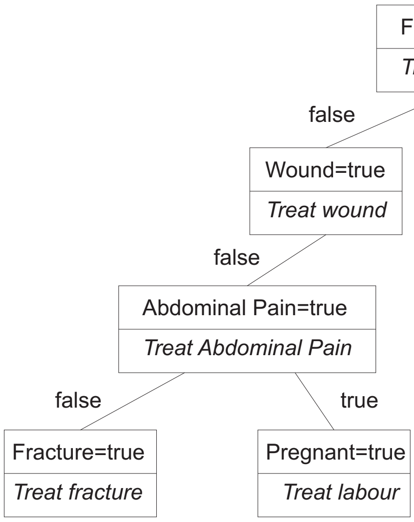

Figure 4.5 Example of RDR tree [4]

architecture of CEVICHE is illustrated in Fig. 4.6. A *CEP plug-in* converts the pattern definitions into the language of the particular CEP engine employed. The *translator framework* interprets the process specification and deploys the process into the BPEL engine. It also informs the *adaptation manager* about all process alternatives available and their corresponding application context. When the context is recognized, the adaptation manager selects a process alternative from the database and performs the adaptation.

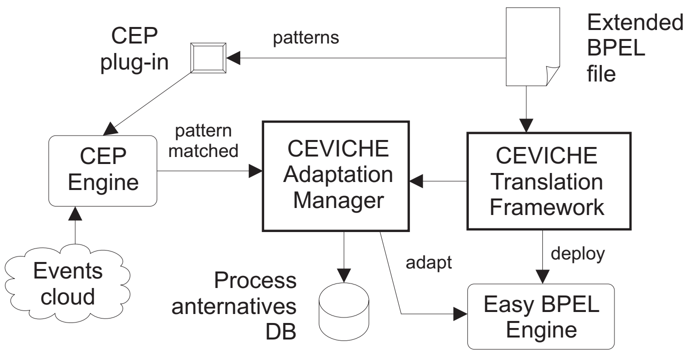

Figure 4.6 CEVICHE architecture

BVCCoN (Business process Variability Configuration with Contexts and NFRs) [30] is an approach that proposes the integration of business process modeling with modeling techniques from the requirements engineering field. The process variability is described with the concept of *variation points* and *variants*. A variation point is an activity in a business process, for example, *Sound fire alarm*. Examples of variants are *Sound fire alarm manually* and *Sound fire alarm automatically*. The BPMN syntax is augmented by the authors to allow for the graphical modeling of variation points and variants.

To model the context (in this case, defined by non-functional requirements), the BVCCoN approach proposes SIGs (Softgoal Integrated Graphs). SIGs model *goals* (e.g., performance and reliability), and *operationalizations*. Several operationalizations offer different *levels of contribution* to the goals. To integrate SIGs and the process view, the operationalizations are linked to variants of the process model. This link may be conditioned to contextual facts. The Object Constraint Language (OCL) is employed to infer facts from contextual variables. At runtime, one of the variants available for each activity is chosen to take part in the process instance. A unique feature of BVCCoN is that the choice does not depend only on the context, but also on the priorities of the goals and the level of contribution of each variant to those goals.

Recognizing that the diversity of factors that may influence the context of a business process is virtually unlimited, Rosemann et al. [97] propose a *Context Framework*. This framework's purpose is to facilitate the procedure for context identification in business processes. Rosemann et al.'s framework identify four hierarchical levels of context variables that may affect business processes. These levels, or layers, are described as below.

1. **immediate layer**. Comprises the variables currently in use to model most business processes, such as data dependencies, resources, and applications;
2. **internal layer**. Covers information on the internal environment of the organization. This includes norms, values, strategy, financial resources, and stakeholders interests;
3. **external layer**. Consists in the external environment of the organization. Factors such as customers, competitors, suppliers, and capital providers are included in this layer;
4. **environmental layer**. This is the outermost layer and comprises factors that are beyond the business network of the company but that may still influence the business processes. Examples of factors in this layer are society, nature, technology, and economy.

The elements of one layer may have direct impact on the execution of a business process or may be mediated, moderated, or even mitigated by another element in a more inward layer. The hierarchy proposed by Rosemann et al. help identify which relevant context should be considered when modeling a business process.

There are few approaches for context awareness in business processes that we consider *proactive* (level 3). These approaches comprise a number of works that propose *risk-aware business process management*. The idea of risk awareness is to introduce risk identification and mitigation activities in the process management lifecycle. The BPM lifecycle is adapted to include tasks such as: design-time risk evaluation, determination of risk conditions, and real-time risk diagnosis and mitigation.

Risk-aware business processes have been approached in a variety of studies. Suriadi et al. [108] perform a comprehensive literature review on the subject. Most works focus on extending business process modeling notations to include information on risks. This helps compute risk probabilities related to business processes. However, we believe that works that do not use the risk information at run-time can not be classified as context-aware BPM in the terms proposed by Rosemann et al. [97]. Rather, they should be seen as a process-aware risk evaluation approach, since the models support the task of risk analysis in the context of process models. They are useful to support the design of business processes that better manage risks.

Suriadi et al. [108] identify only two approaches that deal with risk awareness at run-time. Conforti et al. [26] propose process models annotated with risk conditions. The probabilities of the occurrence of risks can be determined on the basis of information about current running process instances and historical data. The approach allows for the run-time monitoring of risk conditions. When these conditions are fulfilled, alerts are triggered to request actions from users. Kang et al. [54] proposes a similar approach that offer a run-time risk detection mechanism that issues alerts to users when risks are identified. Although these two approaches do not implement any process adaptation mechanisms as other context awareness approaches, they provide information to the user, so the user can take adequate actions for each situation. These approaches are proactive, since alerts are triggered when probabilities of occurrence of failures are high, but before actual failures occur. Nevertheless, run-time adaptation is still a research gap in this area [108].

4.5 Management Support Systems

Management Support System (MSS) is a general term to describe all information systems that are used to support management actions [111]. This includes Decision Support Systems (DSSs), Knowledge Management Systems (KMSs), and Business Intelligence (BI).

MSSs are the information systems that are closer to business managers. Generally, they offer features that aim to help managers take better decisions. For this reason, most MSSs can be classified as DSSs. The main tasks of MSSs are to enable managers to capture and analyze information about the company's activities, to adequately share this information with relevant stakeholders, and to objectively evaluate decision alternatives on the basis of this information [111].

4.5.1 Decision Support Systems

Decision Support Systems (DSS) are information systems designed to support the decision making process in organizations [90]. Research on DSS spreads over several disciplines, such as artificial intelligence, operations research, and management information systems [65]. Several different techniques for supporting decision making have been proposed and used in a large set of applications. As a result, what is called DSS take many different forms for different managers, vendors, and consultants [90].

In general, a DSS consists in three components: data management, model management, and interface (or dialogue management) [65]. The data management component is responsible for data and information retrieval. It employs data warehousing techniques to obtain information from several sources. The model management component is used to formulate problems and solutions. The interface component enables user interaction, produces reports, graphs, and display solutions.

The integration of DSS and other enterprise systems produces what is called Integrated Decision Support Systems (IDSS). An IDSS is able to capture business models from ERP, Customer Relationship Management (CRM), and Supply Chain Management (SCM) systems. For Liu et al. [65], IDSS improves the performance of isolated DSS, but still lack flexibility.

They argue that IDSSs should evolve into the so-called Integrated Decision Support Environments (IDSE). IDSEs are described as service-oriented solutions that allow DSSs to be quickly reconfigured to respond to new decision requirements in dynamic business situations [65].

4.5.2 Business Intelligence & Analytics

An essential task of strategy management is the performance measurement and assessment. To track the progress of the company in the achievement of its goals, companies need to define *performance indicators*. Such indicators also serve the purpose of enabling the diagnostics of the current state of the company's internal and external environment.

Business Intelligence (BI) and Business Analytics (BA) [59] are technologies that have as primary purpose to deliver valuable information to support decision making. To that end, they integrate several data processing and analysis techniques that are capable of extracting useful information from raw data from diverse sources. BI and BA provide access to business information in an understandable form that fits the needs of business stakeholders [53]. They compose an efficient approach to implement performance measurement systems.

The term BI became popular in the 90's. In the 2000's, BA was introduced as a complementary component of BI [22]. Together, business intelligence and analytics (BI&A) are becoming increasingly important for organizations [22]. Information technologies provide companies with large volumes of data about its operations. Thousands of transaction records, performance indicators measures, and network traffic data are produced everyday. Making sense of all this information to the benefit of the organization is one of today's biggest trends in information technology.

According to Gartner's evaluation of the BI&A market [101], some of the essential features of BI&A platforms are:

- **reporting**: the ability to create formatted and interactive reports, possibly parameterized, with distribution and scheduling capabilities;

- **dashboards**: the ability to publish web-based (or mobile) reports that intuitively display performance metrics compared with a goal or target value;

- *ad hoc* **queries**: enables users to ask questions of the data without the necessity of mediation of the IT staff to create reports;

- **online analytical processing (OLAP)**: enable a style of analysis known as 'slicing and dicing'. Users are able to navigate the data through multimensional "drill paths". They can observe the data from any dimension (e.g., product type, region) or combination of dimensions (e.g., product type by region) and calculate measures in real-time (e.g., number of sales, revenue);

- **scorecards**: take metrics in a dashboard and apply a strategy map to align performance indicators with strategic objectives;

- **interactive visualization**: the ability to display numerous aspects of the data efficiently through interactive charts or pictures.

It has been acknowledged that the information provided by BI&A should be directed towards changing an organization's processes and improving strategic alignment [59] [89]. To gain a competitive advantage, a firm needs not only a good strategy, but also an adequate operationalization and monitoring of that strategy. BI&A techniques help administrators identify threats and opportunities more quickly and provide the means by which these factors can be adequately addressed.

An example of the use of BI&A to strategic alignment is described by Laursen and Thorlund [59]. They illustrate the case of a radio station that is interested in increasing its market share. To that end, the managers decided that increasing the *average listening time* of the radio's listeners would be their major goal. Customer profiles would be collected to retrieve their listening preferences in order to direct the radio's programs to meet the tastes of their listeners. This would require detailed information about listeners preferences for each day hour and each week day. The task of BI&A would be to collect, integrate, and extract useful information from surveys and internal assessments about customer preferences. This information should be tailored to the goal of improving the average listening time. With such an information in hands, the operations conducted by decision makers and DJs would then be driven by the statistics and reports provided by BI&A. As a result, the radio's content would better meet listeners expectations, improving their listening time.

This example illustrates how BI&A and strategic management are tightly coupled. BI&A information is only useful if the organization has clear goals and if their operations are goal-driven.

In the situation of a company that confront uncertain and turbulent scenarios, the BI&A processes must be flexible enough to cope with frequent changes in strategic priorities and goals. Moreover, the technology employed must be modular, to allow for rapid reconfiguration of the BI&A's products and capabilities. This agrees with Liu et al.'s [65] concept of Integrated Decision Support Environments (IDSE) previously mentioned. This requires a higher level of integration between Business and IT. If strategic alignment practices do not reach the processes of BI&A development and of use of BI&A information, then the benefits of business intelligence may not be perceived.

4.6 Strategic Alignment

Strategic alignment is the task of making an organization's operations and policies conform with its strategic goals. It aims at ensuring that the decisions and investment priorities of all organizational units are done in the direction of achieving such goals.

IS research has approached the debate of strategic alignment mostly from the perspective of IT investments [7, 77]. The major concern is to guarantee both that the business can recognize the opportunities offered by IT and exploit them and that the IT is able to fulfill these business needs. IT departments must be able to design strategies for developing the capabilities necessary to improve the competitive advantage of the organization. This requires that both the IT strategy and the business strategies are harmonized. If the IT strategy is adequately harmonized with the firm's strategy, the firm can capture higher value from IT investments.

The IS literature identifies several characteristics that an organization should develop to attain a better alignment between business and IT [33, 77, 86]:

1. business are able to exploit the opportunities offered by new technologies;

2. IT investments are driven by business objectives;

3. business and IT are continuously aligned.

In summary, it is essential to be able to recognize the possibilities offered by IT and design strategies that exploit them. These strategies define new goals that must be attained by the organization. IT infra-structure is then adjusted or further developed to follow the courses of action determined by the organization for accomplishing these new goals. This is also called *Business-IT alignment* [7, 55, 77].

The subject of strategic alignment has been one of the top 10 issues for IT executives in the past decade [77], however, there are many companies that do not understand or underestimate the role of IT in their business planning. For example, in a survey considering the pharmaceutical industry in USA, Nash [77] assessed that several organizations lack management practices to provide IT staff an understanding of business objectives and strategies, and do not implement business-based metrics. The study reveals a poor level of communication and partnership between business and IT people.

We can infer that a first step in the direction of business-IT alignment is the development of management skills and communication channels for integrating business and IT people. Particularly, IT managers must develop a business view and must actively participate in business discussions and decisions. Furthermore, IT activities should be planned and monitored with respect to their role in the organization's strategies. The organization must establish processes that nurture such an integration. In this regard, Kang et al. [55] state that, if enterprise resources do not support enterprise strategies and enterprise members do not grasp with the strategies they contribute to, these strategies are certain to fail.

The second feature that companies must develop to improve business-IT alignment is the deployment of a flexible, reusable infrastructure, capable of being adapted in the face of requirements change. In this regard, Peppard and Ward argue that several companies grow its infrastructure *clandestinely*, by small increments of particular applications with direct benefits. They are not developed to serve business in times of change, frequently making it fragmented and technically incompatible [86]. Recent advances in information systems development have recognized such a necessity. Service-Oriented Architecture (SOA) [79], for example, is a technology that aims at reducing time-to-market, reduce IT costs, and improve operational efficiency. It does so by an architectural design that fosters reutilization and integration to the business [27, 60].

An analysis of these works shows that efficient business-IT alignment can be improved by investing in all the three fundamental components of a firm's IT function: *infrastructure*, *people*, and *processes* [33]. Such investments should be conducted as follows:

- *IT infrastructure investments* should be directed towards the acquisition and development of flexible resources that provide shorter development cycles and reutilization;

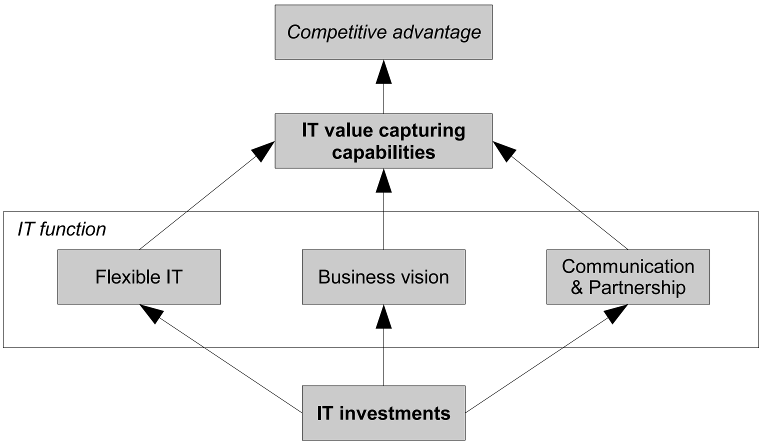

Figure 4.7 From IT investments to competitive advantage

- *IT people investments* should be directed towards the development of a business vision inside the IT function (skills and behaviors);
- *IT processes investments* should target the creation of structures that nurture the communication between business and IT, and that align IT operations to business objectives.

Such three roots are the basis for the construction of competitive advantage through IT, as illustrated by Fig. 4.7. These three directions of investment increase the company's *capabilities* to capture value from IT. They are essential to transform the investments into competitive differential for the organization.

IS literature is scant with respect to strategic alignment from the perspective of the whole organization. In this case, we would be interested on research work that helps to make the connection between business and operations easier to track and maintain. These works should offer tools to improve the manager's job.

Gable [35] performs a review on *all* papers published by the *Journal of Strategic Information Systems* (JSIS) since 1991 until 2009. He classifies the 316 papers into three categories:

- *IS for strategic decision making* (12% of total) - this group includes strategic planning, information planning, and decision support;
- *strategic use of IS* (57% of total) - this group is related to the aspects of business-IT alignment and the strategic application of IS;
- *strategies for IS issues* (31% of the total) - includes a more broad set of topics, such as IS management, IS development, and IS adoption.

Strategic alignment for the whole organization should be among papers of the first category (12%). However, this topic is not visited. Most papers deal with strategic planning within the IT function, while others explore knowledge management in the scope of IT investment decisions.

There are some work that evaluate current management support tools with respect to their support for *strategy management* [13, 120]. Wagner [120], for example, evaluate a variety of strategic planning & management systems and propose a set of requirements that should be implemented by them in a next-generation class of strategy management systems. These requirements include improved support for change management, the ability to employ intelligent data analysis methods, and the capacity to decompose strategies in levels and propagate changes from one level to the others.

Kang et al. [55] propose a model to describe and automatically analyze the linkages between strategies, business processes, and performance metrics. These authors argue that, in order to disseminate strategies thorough the enterprise, it must be able to:

- align "*super*" strategies and "*sub*" strategies;
- align strategies and business processes;
- align strategies and performance metrics;
- align performance metrics and business processes;
- align business processes and supportive resources; and
- assure that alignments are recognized by enterprise members.

Kang et al. develop a framework in which these links are described as *facts*, modeled using an ontology and an enterprise architecture meta-model [55]. This model is used to generate information to improve decision making and performance measurement capacities.

4.6.1 Process Improvement and Goal Alignment

According to Lepmets et al. [63], the literature is lacking studies on how process improvement can be used to align a process' goals with the business goals of an organization. These authors argue that any connection between an organization's business goals and process improvement "has relied on coincidental concern" rather than on the direct representation of business goals within the improvement methodology context [63]. They empirically tested these arguments through a survey with IT service providers and software development companies. The survey analyzed whether process assessment, the activity of identifying and quantifying which aspects of the process should be improved, was linked with business goals alignment. Their results show no correlation between process assessment and goals alignment in the process improvement projects conducted by their 63 respondents.

Despite these arguments, BPM literature is full of examples of methodologies that define the goals of process improvement on the basis of the organization's strategic goals. Harmon [46], for instance, describes a methodology in which strategic goals are refined into value-chain improvement goals, which are then mapped to individual process goals.

However, it is true that there are also several examples of methodologies that do not take strategic alignment into account during process improvement. Harmon himself describes certain process redesign patterns that focus on other aspects, such as performance, showing only marginal connection with strategic alignment [46]. These include "simplification": remove redundancies and duplicated efforts; "gaps and disconnects": identifies and remove gaps of communication between process departments; and "value-added analysis": eliminate unnecessary activities from the process.

In the *value-added analysis pattern*, each process or activity is analyzed from the point-of-view of the customer. In this analysis, a process or activity is said to add value if it meets three criteria:

1. the customer is willing to pay for it;
2. it physically changes or transforms a product or service;
3. it is performed correctly on the first try.

A non-value adding process or activity is that one which involves preparation or setup, is focused on control or inspection, or simply results in moving a product from one place to another. Harmon affirms that a process is typically made up of 20% value-adding activities and 80% of other activities [46]. Some activities may be value-enabling, meaning that they do not add value by themselves, but enable the execution of value-adding activities. Activities that do not add value and are not value-enabling are candidates to be eliminated from the process.

The value-added analysis takes the consumer's point-of-view, but does not take into account the placement of the firm in the market, its competitive differentiating values, and the relationship between a process' activities and these values. A reason for this disconnection between process redesign methodologies and goal alignment is because the improvement goals are assumed to be already defined prior to the start of the improvement project. It should be the executives and managers' task to define process improvement goals in alignment with the overall firm's strategy [46]. Once these improvement goals are defined, the objective of process improvement is just to achieve them.

A common framework used by managers to connect strategic goals and process goals is the Balanced Scorecards methodology (BSC) [46, 56, 128]. This methodology helps managers to design strategies and performance metrics linking operations to results. Business process goals can not only be connected to the strategy through BSC performance metrics but can also help collect and monitor such metrics. For this reason, and due to the popularity of the BSC methodology among executives, many packaged solutions offer standard business process models that are already mapped into BSC metrics [13]. This provides a framework for off-the-shelf strategy management integrated with BPM.

4.6.2 Going Beyond Balanced Scorecards

The major problem with off-the-shelf packaged solutions is that they are easily reproducible by other companies. Competitive advantage can only be achieved by the development of unique characteristics difficult to imitate [86, 110]. Moreover, these solutions may limit the strategic flexibility of the organization.

The problem identified by Lepmets et al. [63] occurs because many managers do not recognize strategic alignment as a fundamental task for organizations and do not consider strategic flexibility as a goal to be pursued. Traditional process redesign patterns described by Harmon [46] take a firm's strategy and corresponding performance metrics as something fixed, mostly requiring only adjustments to targets. Many companies design their BSC metrics through expensive management consultancies, which usually take a long time to conclude. They are not willing to change their strategies frequently.

The recent technological advancements discussed in this Chapter clearly indicate that organizations need to adapt their operations much more frequently than it used to be two decades ago [86]. The discussion presented in the first part of this thesis also demonstrates the need for changing strategies rapidly to react to unforeseen events. Changing a strategy requires defining new goals, new performance indicators, and the alignment of business processes with these new goals. Current approaches to business process improvement and redesign are far from reaching this kind of agility. This justifies the development of adaptable process models as a solution to deploy processes that can be rapidly changed.

Looking from this perspective, adaptable process models are an alternative to larger business process improvement projects for companies that want to improve their strategic flexibility. What we need, however, is an approach to connect these adaptable models to the firm's strategy, to ensure that adaptations are applied in alignment with the business goals of the organization. Such adaptations could improve the fit between operations and strategies in highly turbulent environments.

4.7 Summary

In this chapter we introduced the concept of process-aware information systems (PAIS) and business process management (BPM), and discussed factors that affect the maintainability of business process models. Then, we introduced the notion of context-aware information systems and presented a number of works that propose flexible and context-aware BPM systems.

We also described the characteristics of management support systems (MSSs) and discussed the subject of strategic alignment.

What this study shows is that, although BPM is an efficient approach to the design of enterprise information systems, there are settings in which it requires more flexible implementations. The capacity to use this flexibility to fulfill the strategic needs of the organization, however, is not explored by current research. Strategic planning and management have been only superficially approached by BPM research. Although strategic alignment has been cited in many works, there is still a large gap that separates strategic planning theories and methodologies from the BPM field.

CHAPTER 5

Applying Information Systems to Mitigate the Effects of Uncertainty

"I confess," said the lieutenant, "that just at present I am not able to clear away the uncertainty of the future; but I feel confident that by careful observation at various points we shall arrive at conclusions which not only will determine our path, but perhaps may clear up the mystery about our geological structure."

— (Jules Verne, Off on a Comet)

5.1 Overview

In this chapter we investigate the IS literature to find directions on how to apply information technology to mitigate the negative effects that environmental uncertainty has over a firm's performance. The basis for this study is the uncertainty model described in Chap. 3 The result is a set of guidelines for the development of enterprise applications that can eliminate undesirable effects of uncertainty, such as unclear goals and delayed decisions. These guidelines underpin the design decisions made by us on the development of SA-BPM systems.

5.2 Mitigating Actions

We first determine which actions can be implemented to mitigate the effects that uncertainty has over a firm's performance. There are several factors in the uncertainty model presented in Chap. 3 that we cannot control. However, some of them can be acted upon to diminish their effects. We can make the following considerations about each factor of the model:

- *Uncertainty*. This is a characteristic of the environment. We consider that we are dealing with environments that are intrinsically uncertain, thus, we cannot reduce this uncertainty by any particular method;
- *Assumption Biases*. We can reduce the influence of assumption biases by introducing objective methods for performance assessment and decision making;
- *Unclear Goals*. We can reduce this factor by implementing methods for clearer goal definition and improved dissemination of goals around the company;

- *Information Gap*. We can reduce information gap by using methods to structure and align data with strategic requirements. This reduces the time and effort required to get the information necessary for taking strategic decisions;
- *Centralized Decisions and Coordination & Integration*. Giving autonomy to organizational units improves the firm's agility, but makes coordination more difficult. We can balance these factors by implementing methods for coordinated decentralized decision making;
- *Resistance to Change*. We can reduce the resistance to change by reducing the efforts required to implement change and by enhancing performance feedback;
- *Inability to Predict, Inadequate Decisions, Unprepared Resources, Delayed Decisions, Late Responses, Limited Responses, Performance Decline*. These factors are, indeed, the effects caused by other factors in the model. We cannot act upon them directly, but by reducing their causes, we can reduce or eliminate their effect as a consequence.

On the basis of these considerations, we propose the following characteristics that a company should exhibit in order to mitigate the effects of uncertainty described in our model:

1. Goals are Clear and Rapidly Disseminated;
2. Operational Information is Interpreted Strategically;
3. Decision Making is Decentralized in a Coordinated Manner;
4. Performance Assessment uses Objective Methods;
5. There are Efficient Methods to Implement Strategic Change.

Figure 5.1 displays a changed version of the uncertainty model in which we introduce these elements, replacing their negative counterparts. Observe that the new elements act by reducing the negative effects, which reduces their influence over performance decline.

Having defined these five characteristics, we now analyze how information technology can be employed to implement them in an organization.

5.3 Goals are Clear and Rapidly Disseminated

The concept of *line of sight* (LOS) [11, 14] in management research explains that human resources have considerable participation in the achievement of a firm's strategy. However, to fully benefit from their human potential, organizations need to ensure that their employees understand their own role in the strategy of the organization. LOS has been defined as "an employee's understanding of the organization's goals and what actions are necessary to contribute to those objectives" [11].

The challenge in enhancing LOS is how to implement efficient communication channels that transmit strategic objectives and performance targets from top managers to employees [11].

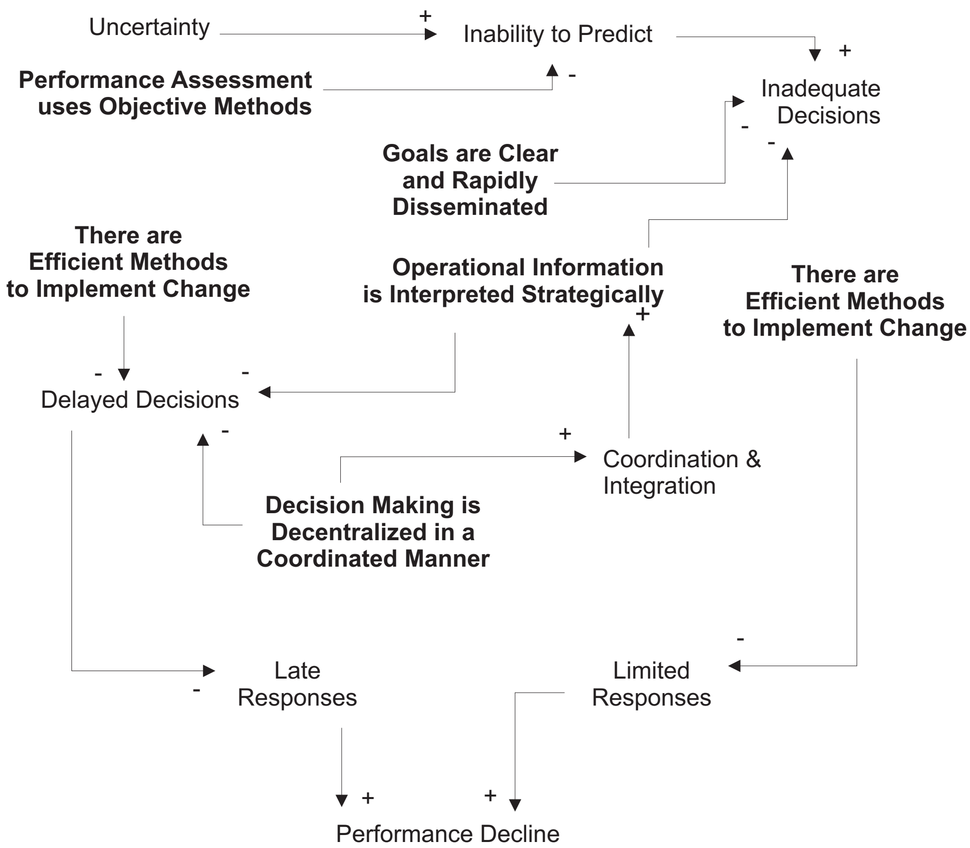

Figure 5.1 Model with Uncertainty Mitigating Factors

The OMG proposed the Business Motivation Model (BMM) [82] to make information systems developers more aware of the organizational goals and concerns. Through model-driven development methods, a set of goals, policies, and strategic actions can be refined into the requirements of enterprise information systems. This helps the IT unit to take decisions in alignment with the business and strategic concerns of the organization. To this purpose, the BMM defines a machine-readable language for modeling business plans. Through BMM concepts, information systems features can be traced back to the organizational decisions that motivated them. If we expand the idea of the BMM beyond the limits of the IT unit, we can think of a mechanism through which a person's activities in an organization are traced up to the strategic goals to which each activity is important.

Kang et al. [55] propose the use of fact-based ontologies [83] to capture the relationships between a firm's strategic goals, performance metrics, business processes, and resources. Through their ontology, an organization can describe the links between these elements. This information is, then, used to compute matrix visualizations that help people understand the company's alignment requirements for each task. Both Kang et al.'s method and the BMM propose a set of concepts through which business and strategic requirements can be described in a structured way, which improve their clarity.

Such methods proposed in recent IS research conform to the need for enhancing the LOS in an organization. Although human resource management research has proposed diverse methodologies to improve LOS [14], information systems seen to play an important role in this subject. Since most enterprise activities today involve the interaction with information systems, if we can use these systems to transmit strategic information to employees, the communication between top managers and operational staff can become much more efficient.

Another point discussed in IS research is the capacity of software systems to automatically adapt their functions in response to changes in business needs. This has been discussed in Chap. 4. Context-aware information systems are software systems that can adapt their operations to match the requirements of the environment. If we can apply this technology within the context of strategic goals and performance targets, we can achieve information systems that react to changes in the strategy, making employees automatically incorporate these changes in their work.

From these arguments, we propose the following guidelines to clarify and disseminate goals more efficiently through the enterprise:

> **Guideline 1**. Store strategy models in information systems and use these systems to automatically inform employees about the strategic goals that influence their activities and decisions.
>
> **Guideline 2**. Adapt information systems functions automatically to improve the alignment between operations and strategic needs.

A method for modeling and storing strategies is proposed in Chap. 6. A hierarchic approach is adopted to make the strategy models easy to manage from the executives' point-of-view, but also detailed enough to give directions at the operational level. From the information system's point of view, the models are simple to model and maintain using ordinary data structures.

5.4 Operational Information is Interpreted Strategically

According to Gorla et al. [39], information quality *mediates* the relationship between information systems quality and organizational performance. In statistics, a mediator variable (say, X) represents the underlying mechanism through which one variable (say A) indirectly affects another variable (B). So, if X mediates the relationship between A and B, thus A does not directly affect B, but instead A affects X, which then affects B. Hence, Gorla et al.'s [39] study shows us that, if system quality is poor, information quality diminishes and, as a consequence, organizational performance is negatively affected. Thus, information systems have a major role in determining the capacity of the firm to find and use the information they need.

The decisions about how data is collected, stored, consolidated, and presented affect the capacity of the organization to make decisions. For instance, governments around the world have been investing on the integration of their information systems to improve the service offerings to citizens. In a project conducted at a Federal Agency in Brazil, we observed that the information being produced and stored by most Ministries is heterogeneous and rarely standardized. Ministries usually need to collect data from all municipalities (for example, number of teachers in schools). However, municipalities' operations are adapted to their own contexts and the information produced is severely impacted by constraints in its resources, skills, and labor force. Thus, the use of this information at the strategic level, i.e., at the Ministry level, frequently requires further efforts to verify and improve the accuracy and quality of the information before any analysis can be performed.

IS research field has approached the problem within the knowledge management stream. Liu et al. [65] perform a wide review on papers and software systems that support the integration of decision support systems in decentralized decision making. Data and information integration is a fundamental part of this process [89], but Liu et al. also cite the integration of decision models, the integration of processes, the integration of analysis services, and presentation integration as playing a major role as well [65].

The capacity to integrate data collection, processing, and presentation in all these perspectives helps reduce the information gaps in an organization. Moreover, Laursen and Thorlund [59] affirm that the central goal of data integration is to improve strategic alignment and strategic decision making capacity. Companies need to give a strategic interpretation to the large amount of data generated from the execution of operations and business processes. If managers cannot employ this information strategically, they will not obtain competitive advantage from it. Popovic et al. [89] affirm that the mature application of *business intelligence* focus more on knowledge workers' actual needs, not merely in providing rapid delivery of information. They claim that, to that purpose, a better connection between business strategies and business process management is needed. This would enable the monitoring of strategies from top-level down to the levels of individual business activities [89]. Furthermore, this can also be used to improve the LOS, by making employees aware of the linkages between their activities and strategic-level results. This is supported by the findings of Laursen and Thorlund [59].

From these studies, we can derive the following guidelines:

Guideline 3. Collect and store information from business processes in a form directly accessible by top-level managers, with clear linkages to the strategic goals to which they are connected.

Guideline 4. Make strategic information available to employees in a format that can be used to improve the performance of their own tasks.

Observe that such features should respect any non-disclosure policies of the organization. Thus, the access to privileged information should be only granted to privileged people. For example, an employee that is executing a financial transaction probably needs to login with his/her credentials to execute the transaction. The same credentials could enable this employee to have access to the strategic directions of the company regarding that kind of transaction, not allowing unauthorized people to access such classified information.

5.5 Decision Making is Decentralized in a Coordinated Manner

Although decentralized decision making is mostly a management choice, the capacity to make it in a coordinated way can be improved with the help of information systems.

A common problem found in the literature regarding decision coordination between autonomous units is that of coordination between production and marketing departments [61]. If these two departments do not communicate, then a number of complaints surge at both sides [34]: “why don’t we have enough capacity?” (marketing); “why don’t we have accurate forecasts?” (production); “we need larger inventories of the right merchandise” (marketing); “we need to reduce inventory costs” (production). Such problems undermine the performance of both departments and reflect similar issues that may occur among other organizational units.

Lee & Lee [61] propose the use of a meta decision support system for coordinating the decisions made by production and marketing departments in a functionally decentralized firm. To this end, the authors employ the framework of *coordination theory* [70]. According to this framework, there are four components in coordination: *goals*, *activities*, *actors*, and *interdependencies*. Goals are the motivations of activities that are performed by actors. Activities may show interdependencies and coordination is the act of managing such interdependencies. The meta DSS approach proposed by Lee & Lee [61] firstly defines two objective functions that must be optimized for each department. Then, they propose a decision algorithm in which information is exchanged during the computation of the optimum values of each function. The variables updated for a function in an iteration cycle are input to the next iteration cycle of the second function, and vice-versa.

The coordination theory employed by Lee & Lee can also be used in a more general setting, in which multiple units must coordinate their decisions. Goals, activities, and actors are all information that can be obtained from the strategic plan of the organization. It is the *interdependency* between activities and actors that determines the need for coordination and its requirements. Thus, for any process of decision making, the information about such interdependencies is key to ensure the coordination between the units [70].

From these studies, we propose the following guidelines to allow for coordinated decentralized decision making:

Guideline 5. Use information systems to store and communicate the interdependencies and relationships between the strategic goals and activities of different organizational units.

Guideline 6. Employ a decision support system that can incorporate the information about interdependencies between units in its decision process.

5.6 Performance Evaluation uses Objective Methods

Subjective analysis and decision methods foster the propagation of wrong assumptions, allows for the pursuit of personal instead of organizational interests, and reinforces the attitude towards negation of the facts [104]. Objective and automated performance evaluation methods are essential to counter-attack this problem.

OMG's Capability Maturity Model Integration (CMMI) framework [24], for example, defines a process area that specifies the requirements for *Decision Analysis and Resolution*. This process area defines a set of best practices for organizational decision making. The main purpose is to guarantee that decision alternatives are evaluated with objective methods against established criteria. Information systems can be used to ensure the use of these methods in the daily activities of the organization. Business processes, for instance, could incorporate decision algorithms in their flow, conducting employees to take decisions on the basis of predetermined criteria.

At the top managers' level, statistical methods could provide executives with more accurate information about the performance indicators that drive their decisions. Rodriguez et al. [95], for example, propose the use of methods based on *structural equation modeling* (SEM) to find and quantify cause-effect relationships between performance indicators. Their method offer the capacity to:

- confirm or discard *a priori* intuited (based on experience) relationships between indicators and quantifying their magnitude;
- objectively demonstrate the existence of other important relationship between indicators and quantifying their magnitude.

Information systems can offer these methods to managers or even proactively apply them. Correlations discovered by the system could be informed to the managers to trigger possible actions from them.

These ideas forward us to the definition of the following guidelines:

Guideline 7. Implement statistical methods that automatically analyze performance indicators to provide richer and more confident information to managers, allowing them to confirm or discard hypotheses about the environmental conditions.

Guideline 8. Incorporate formal decision algorithms in business processes to conduct users to make objective decisions on the basis of established criteria.

5.7 There are Efficient Methods to Implement Strategic Change

The translation of new strategic requirements into new practices of work often involves updating functions of information systems. But, if the organization does not have efficient instruments to implement these changes, the IT may impair the agility of the organization [62]. In many cases, the solution adopted for faster deployment is to work around the IT function and make *ad-hoc* implementations. For example, in the 2013 Cisco Global IT Impact Survey [23], which interviewed 1,300 IT decision makers in 13 countries, 76% of the IT leaders said that business leaders "roll out new applications without engaging IT". Also, 38% said they are brought into the process late.

If strategic changes are not efficiently and adequately implemented, the resistance to change is higher and changes are delayed. Some of the difficulties faced by organizations to achieve efficiency on this task are:

- difficulty in communicating the change requirements from managers to IT [45, 69, 85];
- difficulty in identifying what components should be changed in the firm's IT resource-base [60];
- difficulty in updating information systems to incorporate change [53, 81].

To overcome such difficulties, an organization needs to establish effective communication channels between business and IT [33, 86], must deploy an infrastructure that is ready for change [27, 81, 100], and must implement processes for the management of change and governance of IT assets [27, 60, 86].

It has been shown that the decomposition of software applications in more fragmented modules improves the maintenance efficiency [51]. A remarkable example of this principle is the widespread adoption of Service-Oriented Architectures (SOA) [53] as the standard paradigm for agile enterprise application development [27]. SOA has been adopted by many companies for many years now and has already proven the value of modularity and reuse [52]. Thus, it is widely recognized in the information systems literature that modular applications are more apt to change. This applies also to business process models [51]. Modularity improves reusability, reduce time-to-market, and reduce maintenance costs. These factors contribute to reduce the resistance to change.

Such features, however, can only be exploited if strategic change can be rapidly informed to IT and effectively understood by IT [33, 86]. The use of ontologies has been proposed as a mean through which IT and business can communicate by sharing a common set of concepts [69, 82, 83]. Also, processes for deriving low-level software requirements from business-level requirements have also been proposed in the IT literature [45, 85, 121].

All these works discuss a variety of topics and propose different technologies and methodologies. Nevertheless, we can derive two major guidelines that summarize the directions for the efficient implementation of strategic change.

Guideline 9. Use modular architectures to foster reusability, reduce time-to-market, and reduce maintenance costs.

Guideline 10. Implement tools through which Business and IT can exchange information using a shared framework, and management processes that ensure the regular interaction between the two to achieve organizational goals.

5.8 Summary

In this chapter, we proposed a set of guidelines for using information systems to mitigate the effects of uncertainty over firm performance. These effects were analyzed in the uncertainty model presented in Chap. 3.

To design our guidelines, we firstly analyzed which factors in the model could be controlled by our intervention. Then, we proposed five characteristics that should be developed by companies to reduce the influence of uncertainty over its performance. These are: (1) *goals are clear and rapidly disseminated*; (2) *operational information is interpreted strategically*; (3) *decision making is decentralized in a coordinated manner*; (4) *performance assessment uses objective methods*; and (5) *there are efficient methods to implement strategic change*.

Finally, we investigated IS literature to find directions for how to attain those characteristics from the development of an information system. These directions were summarized in the ten guidelines described.

The guidelines proposed offer more information to help people meet the strategic goals of the organization. It is also necessary a well-planned graphical user interface that helps people to get this information in an efficient manner. The information should reach the right people at the right moment and should be easy to interpret by the person that receives it. These are concerns that must be in the mind of software developers that are designing solutions to adopt the guidelines proposed in this chapter.

CHAPTER 6

SA-BPM: Theoretical Foundations and Implementation Architecture

When the perfect man employs his mind, it is a mirror. [The mirror] conducts nothing and anticipates nothing; it responds to (what is before it), but does not retain it. Thus he is able to deal successfully with all things, and injures none.

— (Chuang-Tzu, trans. by James Legge)

6.1 Overview

In this chapter, we introduce the concept of *Strategy-Aware Information Systems* (SAISs) and describe the application of this concept to the field of Business Process Management (BPM). The resulting product is a new *methodology* for BPM, which we call **Strategy-Aware Business Process Management (SA-BPM)**. The main principle of this methodology is a design approach oriented towards strategies and business results.

SAISs aim at increasing the fit between strategic priorities and organizational activities and at improving strategic flexibility. The necessity for SAISs is more prominently perceived in uncertain and turbulent environments, where an organization needs to continuously adapt its strategy to keep pace with the market changes. The translation of strategic requirements into information systems functionality is often problematic and time-consuming. The correspondence between IS features and strategic necessities is largely dependent on the capacity of the IT staff to understand the organization's strategic priorities [33, 86]. Such a situation contributes to raise the risks associated with strategic changes and impairs the flexibility of the organization.

Strategy awareness, a concept proposed in this thesis, is a specific kind of context awareness. According to Hong et al. [124], context awareness' objective is to improve an application's value by offering an enhanced experience to its users. In SAISs, the objective is to rapidly communicate strategic changes by making users aware of current priorities of the organization. The context model of a SAIS describes the organization's strategy (its goals, initiatives, priorities, and targets). Moreover, business performance data is collected and interpreted from the point of view of the operation that the user is executing. On the basis of this data, SAISs can adapt their operations to improve the achievement of organizational results.

SA-BPM systems are systems that adapt business processes at runtime to include new activities and/or to influence decision making on the basis of an interpretation of strategic data.

For example, if there is an increase in the number of customer's complaints about defective products, the SA-BPM system may adapt the *Production Process* to include more quality assessment steps, or may influence the *Supply Acquisition Process* to ensure a better selection of supplies.

Such adaptations are defined at design time through *Strategic Adapters*. These adapters are fragments of process models that, when included in a running process instance, make it "aware" of these kinds of strategic concerns. Our implementation architecture allows for the quick addition, removal, or update of adapters, in this way improving the strategic flexibility of the organization. Each adapter has access to a centralized *Strategic Context Provider*, which is a module responsible for capturing and storing information from strategic planning and performance management systems.

In this chapter, we describe how strategies are modeled, how adapters capture information about the strategy, and how business processes and adapters are designed and executed in an SA-BPM system.

6.2 Motivating Example

To illustrate the kind of situation in which SAISs are useful, we describe a motivating example in this section. This example illustrates how strategies can be better supported by a system that is strategy aware.

Consider a manufacturing company whose competitive differentiating factor is its innovation capacity. Ongoing investments on learning new technologies are core to its strategy to remain competitive. However, its corporate managers have been noticing that such investments were not being properly applied. Certain divisions of the company expend too much in travelings and do not guarantee equal opportunities to all employees. Such behavior seems to have impacted its capacity to innovate in the last years. To mitigate these effects, the company decided to modify its strategic plan.

The new company's strategy determines two new goals and corresponding performance targets:

- **Goal 1** - reduce *employee travel expenses*
  - *Baseline*: $200,000 spent in travel expenses per year
  - *Target*: $120,000 spent in travel expenses per year
- **Goal 2** - increase *employee participation in training*
  - *Baseline*: 40% of the employees have participated in at least one course in the year
  - *Target*: 60% of the employees have participated in at least one course in the year

Training management is performed through an *employee training management software*. This software tracks employee profiles, courses, and training investments. Since the tool is generic, it does not include any particular feature devoted to this organization's strategy. However, this tool obviously perform a core function in the organization's pursuit of its strategic goals. When a need for training is identified, managers must check several variables and judge the trade-offs involved. For example, which employees require the training at the moment? How much can be spent on travels? and Which are the benefits expected to the company? The manager's choice should align with the company's strategic goals and its performance targets. Although these concerns are directly related to training management, the training management software itself cannot help to evaluate these essential trade-offs.

A SAIS, on the other hand, can provide direct support for the organization's strategic tasks. It does so by interacting with the strategic planning and performance management software in use in order to assist users in taking decisions based on the strategic objectives. The information about goals, priorities, and performance indicators are analyzed by the SAIS and used to adapt the systems functions.

In our example, a *strategy-aware* training management system would capture information about the company's performance targets and determine how a particular decision about employees' training would impact the organization's strategic goals. These tasks would be implemented in *adapter* modules that can be changed independently of the rest of the system. At run-time, these adapters change the way the training management system works.

With the help of the adapters, the strategy-aware version of the training management system would, for example: 1) ensure higher priority to training employees that did not take part in any course for more than a year; and 2) ensure higher priority to training employees living near a course location.

Observe that such priorization policy is not part of the core features of the training management software. This is a feature very particular for this company. It is very likely that such concerns do not make sense to other organizations. Thus, these are not concerns of the training management software itself, but are concerns of *the application of this software in the perspective of our sample company's strategy*. Thus, the adapters help to implement these features through external modules that can be added and removed when necessary.

Consider that, in the second half of the fiscal year, the company's travel expenses have amounted to around \$50,000. By extrapolation, this can be seen as a strong indication that the target for reducing the travel expenses to below \$120,000 will be reached by the end of the year. As a result, the system could reduce the priority for this goal. For example, an employee living far from the course's location, but who did not participate in any course this year, could gain priority over another employee living nearby the course location. This could happen if the second employee had already taken part in another course in the year. The automatic computation of such trade-offs helps managers to take decisions more aligned with the company's goals and performance, in a dynamic fashion.

SAISs can also help to identify problems with the company's strategy. In our example, the SAIS could store a log register for each training program contracted, i.e., amount of disbursements, course subject, the number of employees enrolled in the course, the employees' identification, their role in the company, their work addresses, etc. This allows the managers to audit the performance of its strategy in very detail. Now, suppose that the priorization policy is being applied as required, but that this is *not* reflected in more favorable business outcomes. Then, managers have an indication that the strategic plan is not effective. Therefore, they can further analyze these logs to understand what is wrong and define new strategies.

The SAIS approach allows for a better **separation of strategic concerns** from the core features of the system. When strategic goals change, the new functionalities can also be changed accordingly, while the core features of the system remain untouched. In this example, if the company moves away from its goal to reducing travel expenses, the corresponding adapter can be simply removed. The system will then stop using such a parameter to calculate recommendations for the decision makers.

Strategy awareness can be incorporated in a wide variety of systems. Customer Relationship Management (CRM) systems, Business Process Management Systems (BPMS), and Knowledge Management Systems (KMS), for example, could be adapted to include strategic concerns. Their functionality would be augmented to include functions that are specific to current strategic plans of the organization. In this work, we focus on the concept of SAIS when applied to BPM, leading to the SA-BPM systems.

6.3 Strategy Models and Strategy Awareness

In this section we define and discuss the notion of *strategy awareness* and formally define *strategy models*. Strategy awareness is the particular characteristic that differentiate a regular information system from a strategy-aware information system.

Our argument in this thesis is that information systems that "understand" the strategic objectives of the organization can more effectively mitigate the effects of uncertainty over firm performance. The basis for these arguments are presented on the first part of the thesis. In this section, we define a strategy model and analyze what can make a system strategy-aware. These concepts provide a concrete definition to what means for a system to "understand" the strategy of the firm.

To better describe the concept of a **strategy**, we employ the framework of Results-Oriented Management (ROM) [102]. ROM assumes that a strategy is modeled as a sequence or "chain" of cause-effect relationships, called the **results-chain**. The initial event in the results-chain is the action or initiative performed by the organization and the effects generated are the business results achieved. A firm's strategy comprises several actions and several expected results. Multiple actions can contribute to the same result, while a single action may contribute to multiple results. We call each entity of a results-chain, generally, as an "*element*". Each element is associated with a level of the results-chain. For example, actions are elements that are at the "actions" level, while outcomes are elements at the "outcomes" level. Elements of a *lower* level contribute to the achievement of elements of higher levels.

Although the results-chain concept has been employed in the management literature [84], there is no formal mathematical definition to this concept. To better employ this concept on this thesis, we propose the following formal framework to describe results-chains and their properties.

Definition 6.1 (Results-Chain). *A results-chain is a directed acyclic graph defined by a tuple* $\langle E, \lambda, C \rangle$, *where*

- E *is a non-empty set of* elements, *which are the nodes of the graph;*

- $\lambda : E \rightarrow \mathbb{N}^+$ *is the* level function, *mapping each element to a certain "level" in the results-chain;*

- $C \subset E \times E$ *is the* contribution relationship, *which express the edges connecting elements. If* $(x,y) \in C$, *then* x contributes to the achievement of y. *An element can only contribute to another element from a level above its own level. Thus,* $(x,y) \in C \Rightarrow \lambda(y) = \lambda(x) + 1$.

The *base level* of a results-chain is the level for which there is no element contributing to it.

Definition 6.2 (Base Level of a Results-Chain)**.** *The base level* i *of a results-chain* $R = \langle E, \lambda, C \rangle$ *is a level such that* $\forall x,y \in E : \lambda(x) = i \Rightarrow (y,x) \notin C$.

The *top level* of a results-chain is the level whose elements do not contribute to any other elements in the chain.

Definition 6.3 (Top Level of a Results-Chain)**.** *The top level* j *of a results-chain* $R = \langle E, \lambda, C \rangle$ *is a level such that* $\forall x,y \in E : \lambda(x) = j \Rightarrow (x,y) \notin C$.

Figure 6.1 displays a results-chain with four levels. The top level is the Level 4 and the base level is Level 1.

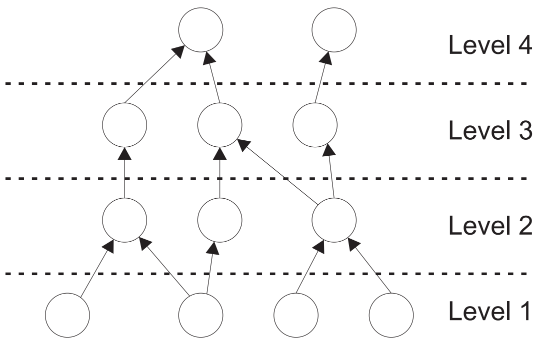

Figure 6.1 Results-chain with four levels

Usually in the ROM approach, a results-chain is composed of four levels. But in general, strategies are modeled in at least two levels: the *actions* to be performed and the *goals* to be achieved. However, in such two level strategies, elements tend to be unbalanced. High level goals such as "improve brand recognition" are mixed with goals like "buy a new machine for product assembly". The four levels of the ROM approach allows for a better balance of the strategy because of its hierarchical structure.

Each level of a results-chain has a special denomination commonly used in the business context:

- **Level 1**: *Actions* (also called initiatives);

- **Level 2**: *Outputs* (also products or tactics);

- **Level 3**: *Outcomes* (also short/medium-term goals);

- **Level 4**: *Impacts* (also vision or long-term goals).

We say that the results-chain is *incomplete* if there is an element that is not at the base level and also has no element contributing to it, or there is an element that is not at the top level and does not contribute to any other element. Otherwise, it is said to be *complete*. An example of incomplete results-chain is displayed in Fig. 6.2. We assume that all results-chain in this work are complete, unless otherwise stated.

Definition 6.4 (Incomplete Results-Chain). *A results-chain $R = \langle E, \lambda, C\rangle$ with top level j and base level i is incomplete if there is an element e such that either:*

- $\lambda(e) < j$ *and* $\nexists x \in E : (e,x) \in C$ *or;*
- $\lambda(e) > i$ *and* $\nexists x \in E : (x,e) \in C$.

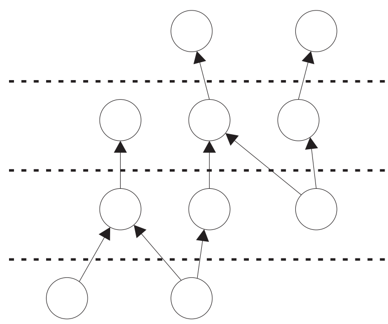

Figure 6.2 Incomplete results-chain

A *partial results-chain* is a section of a results-chain that is also a results-chain. The highlighted area of the results-chain shown in Fig. 6.3 is also a results-chain. Thus, it is a valid partial results-chain.

Definition 6.5 (Partial Results-Chain). *A results-chain $R' = \langle E', \lambda', C'\rangle$ is a partial results-chain of another results-chain $R = \langle E, \lambda, C\rangle$ if*

- E' *is non-empty and* $E' \subseteq E$;
- $\forall x \in E' : \lambda'(x) = \lambda(x)$;
- $C' = (E' \times E') \cap C$.

Companies monitor the performance of their strategies through performance indicators. A performance indicator is a metric that is measured along time to track the performance of the company, such as "*net profit margin*", "*sales growth rate*", or "*number of complaints received*". It usually has a *baseline* value associated, which is the reference value to be improved. It also has a *target* value, which is the value that the organization wants that indicator to reach. A results-chain together with priority assignments and performance indicators is called a *quantitatively managed* results-chain.

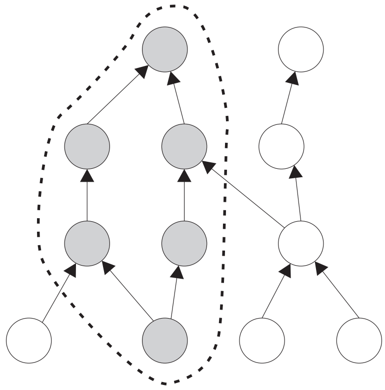

Figure 6.3 Partial results-chain

Definition 6.6 (Performance Indicator)**.** *A performance indicator is a tuple* $p = \langle f, x_0, x_t \rangle$ *where* f *is any discrete function defined in the time domain,* x_0 *is the indicator's* baseline *value, and* x_t *is the indicator's* target *value.*

Definition 6.7 (Quantitatively Managed Results-Chain)**.** *A quantitatively managed results-chain is a tuple* $\langle R, I, \Pi, \mu \rangle$*, where:*

- $R = \langle E, \lambda, C \rangle$ *is a results-chain;*
- $\Pi : E \to \mathbb{N}^+$ *is a priority function, mapping each element of E to its priority. The higher the value, the higher is the priority of the element to the company;*
- I *is a non-empty set of performance indicators;*
- $\mu : E \to \mathscr{P}(I)$ *is a function which assigns to each element of E a set of performance indicators.* $\mu(e) \subseteq I$.

The concept of a quantitatively managed results-chain formalizes most elements commonly found in strategic plans. Observe that a strategic plan does not needs to be designed in the ROM approach. Any plan that is designed into a hierarchic structure can fit in the concepts presented in this section..

Once we have formally defined what a strategy is, we now discuss which properties an information system should present to be considered a strategy-aware information system.

The literature on context-aware information systems gives directions to what features a context-aware system commonly exhibits [124]. According to this literature, "context awareness" means that the system maintains a model that represents their context information and interprets this model to determine the behavior of its operations. The model changes to match environmental modifications, provoking changes to the behavior of the system.

The concept of "process awareness" also offers a guidance on how a kind of "awareness" can be incorporated into a system [32]. Process awareness means that the system interprets a process model and decides which operations can/must be executed on the basis of the information provided by this model. The model is (manually) changed to match new business requirements and this change automatically affects the behavior of the system.

Strategy awareness can be defined in a similar way. The system should maintain a model of the company's strategic context and should determine its behavior on the basis of this model. We consider the strategic context of the firm as being composed of its strategic plan and its current performance (measured by performance indicators). To be able to determine its behavior on the basis of such context, the system must have a mechanism to link strategy and operations, determining how the strategy impacts each of the system's operations.

The following list of features delimits the requirements for strategy awareness and determines if a system is strategy-aware:

1. *capacity to interpret strategy models*: the system is able to interpret strategy models. This means that it can identify which are the expected results of the strategy and which are their corresponding performance indicators and targets;

2. *capacity to link strategy and operations*: the system is able to capture information about which strategic goals are linked to which of its operations. In other words, it must be able to identify how the employee's activities are connected to the elements of the results-chain;

3. *capacity to provide strategic information to the user in the operation's context*: the system is able to retrieve strategic information from the strategic plan and performance indicators and present this information to the user in the context of the operation that is being executed;

4. *capacity to influence the execution of operations on the basis of strategic information*: the behavior of the system during the execution of operations is determined by the strategic information collected at run-time;

5. *loose coupling*: when strategic plans change, the change can be implemented in a modular way, without requiring a complete rebuild of the system.

From these properties, we can extract a more concise definition for the concept of strategy awareness:

Strategy Awareness is an information system's ability to influence the execution of operations (by changing inputs, parameters, and resource allocations) in order to respond to changes in the strategic necessities and priorities of the organization.

Information systems that exhibit strategy awareness are called *strategy-aware information systems* (SAIS). Strategy awareness brings new opportunities for strategic alignment and performance monitoring.

To link organizational operations and strategic results we define the concepts of **work product** and **work product type**. A work product is an output of an operation. For example, the output of the *schedule meeting* activity is a new *meeting schedule*. The output of *ship products* is *products shipped*. A single operation may produce multiple different work products. A work product *type* is the grouping of similar work products. For example, *meeting schedule* is a work product type and *the schedule for the 2014's annual meeting* is a work product of the type *meeting schedule* (or an *instance* of that work product type).

Work product types also define *variables*, which are the properties of the work product. For instance, the "date of meeting" is a variable of *meeting schedule* and "12 March 2014" is the value of the "date of meeting" property of *the schedule for the 2014's annual meeting* work product.

Definition 6.8 (Work Product Type). *A* work product type ω *is a tuple* $\langle V, \psi \rangle$, *where* V *is a set of variables, defining the* properties *of the work product type and* $\psi : V \to \mathscr{P}(\mathscr{U})$, *mapping each variable in the set* V *to a set of acceptable values. The set* $\mathscr{U}$ *is the* universe *set.*

Definition 6.9 (Work Product). *A* work product *is a tuple* $\langle \omega, \alpha \rangle$, *where* $\omega = \langle V, \psi \rangle$ *is a work product type and* α *is a value assignment function, that assigns a value* $\alpha(v)$ *for each variable* $v \in V$.

To link work products and strategies, we add a new base level (or **Level 0**) to the results-chain. The elements at this level describe which work product type contributes to the actions at the level above. For example, in a strategy that proposes the action "*prefer virtual meetings*" (Level 1), the work product type *virtual meeting scheduled* (Level 0) is one that contributes to it.

Formally, we accept that a work product type $\omega = \langle V, \psi \rangle$ can also be an element in a results-chain. We do not distinguish the nature of this element from any other element in the model. What work product types have in particular is the tuple $\langle V, \psi \rangle$ associated to each one. Semantically, work product types should only contribute to *actions*, so they must be at the base level of the results-chain. This is illustrated in Fig. 6.4.

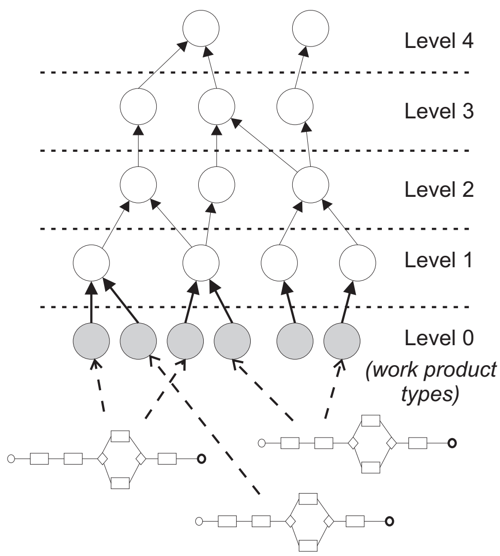

Figure 6.4 Results-chain with work product types and linked to processes

All operations that *generate* a work product of a certain type are linked to the strategy through the work product types level (Level 0) of the results-chain. Hence, operations and strategic elements are linked through this concept. Again referring to the *meeting schedule* example, the act of scheduling a meeting, executed by an employee, generates a work product of the *meeting schedule* type. Fig. 6.4 illustrates business processes linked to work product types in the results-chain. Through the analysis of the results-chain, we can identify which actions of the results-chain the employee's act is linked to. This allow us to know which strategic results are ultimately affected by the operation executed by the employee.

We also consider the case in which only a subset of work products of a certain type show valid contributions to the results-chain. In this situation, although an employee's action generates the work product, only work products with specific value assignments (α function) are considered relevant to the strategy. To express this notion, we introduce the concept of **constrained work product types**.

Definition 6.10 (Constrained Work Product Type)**.** *A constrained work product type is a work product type $\omega_C = \langle V, \psi_C \rangle$ that is derived from another work product type $\omega = \langle V, \psi \rangle$ by reducing the set of possible values in ψ to ψ_C, such that:*

- $\forall v \in V : \psi_C(v) \subseteq \psi(v)$;
- $\exists v \in V : \psi(v) \backslash \psi_C(v) \neq \emptyset$.

For example, the work product type *virtual meeting scheduled* is a constrained work product type derived from *meeting schedule*, in which the "meeting type" property can only have the value "virtual".

It is essential to guarantee coherent and complete definitions of work products thorough the organization. Different departments must agree on a common set of concepts and terms to define the work products generated by their unit. To this end, the use of a controlled vocabulary or an ontology of the business domain of the organization is necessary. The *Semantics for Business Vocabulary and Business Rules* (SBVR) [83], proposed by the OMG, is an useful standard to be applied in this context. In SBVR terminology, a work product type can be expressed as a *fact type*, while a work product is expressed by a *fact*. Work product type constraints can be expressed by *business rules*. We recommend the use of SBVR as a standard to define a company's set of work product types in practical applications.

6.3.1 Analysis of the Results-Chain

Since the elements of the results-chain are connected to each other through *contribution* relationships, it is useful to analyze the connections between a given element and the rest of the chain. For instance, these connections show to a user how he/she is involved with the strategy at all levels when doing his/her daily job.

Moreover, these links are important to indicate the impacts that a strategic change has over the operations of the firm. Hence, if the managers decide to change the element which states that *travel expenses should be reduced*, the analysis of the results-chain shows which work product types are affected.

The following concepts support these tasks. The **contribution trace** identifies all elements to which a given element *e* contributes. It is graphically represented by the highlighted nodes

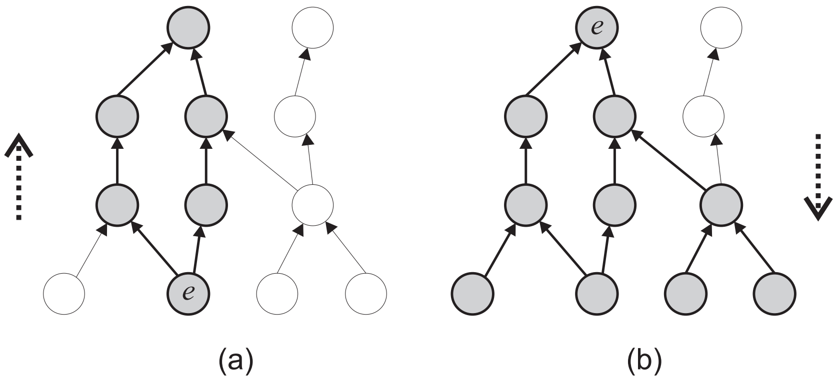

Figure 6.5 Traces in a results-chain: a) contribution; b) reverse

in Fig. 6.5 (a). The **reverse trace** identifies all elements that contribute to a given element e. It is represented by the highlighted nodes in Fig. 6.5 (b).

Definition 6.11 (Contribution Trace)**.** *A contribution trace* $\tau(e,R) = \langle E_\tau, \lambda_\tau, C_\tau \rangle$ *is a partial results-chain that describes the contributions of an element* $e \in E$ *of a results-chain* $R = \langle E, \lambda, C \rangle$ *defined by the following rules:*

1. $e \in E_\tau$;
2. $\forall x \in E_\tau : (x,y) \in C \Rightarrow y \in E_\tau \wedge (x,y) \in C_\tau$;
3. $\forall x \in E_\tau : \lambda_\tau(x) = \lambda(x)$.

Definition 6.12 (Reverse Trace)**.** *A reverse trace* $\kappa(e,R) = \langle E_\kappa, \lambda_\kappa, C_\kappa \rangle$ *is a partial results-chain that describes which elements contribute to a given element* e *of a results-chain* $R = \langle E, \lambda, C \rangle$*. A reverse trace is defined by the following rules:*

1. $e \in E_\kappa$;
2. $\forall x \in E_\kappa : (y,x) \in C \Rightarrow y \in E_\kappa \wedge (y,x) \in C_\kappa$;
3. $\forall x \in E_\kappa : \lambda_\kappa(x) = \lambda(x)$.

We use the trace concept to express the relationship between a work product type and higher-level strategic elements. We define the *association* relationship to express this fact.

Definition 6.13 (Work Product Associated with Element)**.** *Let* $R = \langle E, \lambda, C \rangle$ *be a results-chain. A work product type* $\omega \in E$ *is associated with a strategic element* $e \in E$ *when* $e \in \tau(\omega, R)$.

We say that a work product (i.e., an instance of a work product type) is associated with an element when the work product *type* is associated with that element.

The **Strategic Coverage** is a measure of how much an element contributes to the entire results-chain. It takes into account both the structure of the results-chain and the priorities of each element. It is thus an useful metric to compare the relative importance of elements of the results-chain.

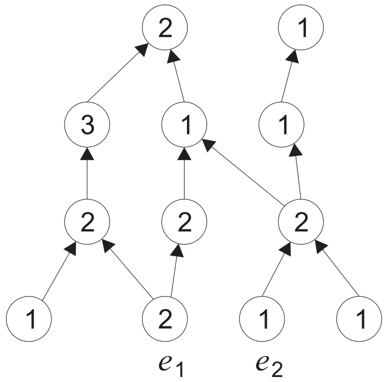

Figure 6.6 Elements and priorities

Definition 6.14 (Strategic Coverage)**.** *The strategic coverage of an element e of a quantitatively managed results-chain $Q = \langle R, I, \Pi, \mu \rangle$ is the quantity:*

$$SC(e,Q) = \sum_{x \in E_\tau} \Pi(x) \ ,$$

where E_τ is the set of all elements that make part of the contribution trace $\tau(e,R)$.

For example, in the results-chain of Fig. 6.6, the priorities of each element are annotated inside the respective node. Summing up the values of the nodes in the contribution trace of e_1 and of e_2, we can find their respective strategic coverages:

$$SC(e_1,Q) = 2+2+2+1+3+2 = 12 \ ; \quad SC(e_2,Q) = 1+2+1+1+1+2 = 8 \ .$$

This metric provides a way to measure the relative importance of elements to the strategy on the basis of the elements that an element contributes to and their priorities. Thus, according to the SC, e_1 is more important to the strategy than e_2 because it contributes either to more elements or to elements that have higher priorities than the elements of e_2.

Another metric that we propose to compare elements is the **Performance Gap**. It is a measure of how far an element is from reaching its target performance values. We compute the performance gap on the basis of the performance indicators of the element and an auxiliary function h. This function determines weights to each performance indicator. The objective of h is to take into consideration the fact that certain indicators are more important to measure the performance of an element than others.

Definition 6.15 (Performance Gap)**.** *The performance gap of an element e of a quantitatively managed results-chain $Q = \langle R, I, \Pi, \mu \rangle$, in an instant n, is the quantity:*

$$PG(e,Q,n) = \sum_{i \in I} h(i) \ \mathtt{max} \left(0, \frac{x_{it} - f_i(n)}{x_{it} - x_{i0}} \right) \ ,$$

where $i = \langle f_i, x_{i0}, x_{it} \rangle$ and function h is defined by $h : I \to [0;1]$ and $\sum_{i \in I} h(i) = 1$.

The quantity computed by function *PG* has value *zero* if all the indicators have reached their target values at instant n. Its value increases as the indicators get farther from the target at instant n. It does not have an upper bound. Nevertheless, if the value of all indicators at time n are within the range between the baseline value and the target value, then the value of *PG* is at most equal to 1. The value is higher than one only in the case that any of the indicators has a value that is *worser* than its baseline value.

It is also useful to compute the **Extended Performance Gap**, which we define as the accumulated performance gaps of each element in a contribution trace. This metric is useful to identify sections of a results chain that are going behind their expected progress, either due to the actions themselves or due to the lack of results that should be generated by them.

Definition 6.16 (Extended Performance Gap)**.** *The extended performance gap of an element e of a quantitatively managed results-chain $Q = \langle R, I, \Pi, \mu \rangle$ is the quantity:*

$$EPG(e, Q, n) = \sum_{x \in E_\tau} PG(x, Q, n) \ ,$$

where E_τ is the set of all elements that make part of the contribution trace $\tau(e, R)$.

This equation sums the performance gaps of all elements in a results trace. Thus, it associates to a given element a value that takes into account the gap in performance not only of that element but also in all elements that should be affected by the success of the element of reference. For example, if x contributes to y and x is close to its target, but y is not, the extended performance gap takes this relationship between x and y into account and shows that there is something wrong with x. Ideally, if all elements that contribute to y reach their target values, y should also be close to its target as a consequence. If it is not, then there is a problem with the design of the strategy that deserves further attention from the managers.

6.4 Business Process Design Approach for SA-BPM Systems

When new strategies are formulated by an organization, business processes that are involved with the strategic goals must be analyzed to identify the need for change [63]. Usually, this is done through *business process redesign* projects [46]. The drawback of the traditional approach to BPM is that each business process model is supposed to fulfill all strategic requirements of the organization. This makes process modeling a costly and time-consuming task. The necessity to make a single model fulfill every aspect of the strategy also makes strategies difficult to change. Changing a single goal/initiative may require the redesign of several business processes. Thus, efficient business process management has essential role in contributing to the strategic flexibility of the firm. Rapid planning and implementation of strategic goals is decisive for a sustainable competitive advantage [38]. To achieve this, we propose the use of adaptable models that can incorporate changes in the *strategic* context of the organization.

Although the idea of extending business processes with context information has been previously proposed in related work [97], the literature does not addresses the relationship between strategic planning and context in BPM [63]. As already discussed on chapter 4, most works either consider the process context as being the data associated with a process instance [4, 21] or assume that context information can be captured in the form of events or sensor data [30,48]. This limits the scope of the information that is considered "context" for the process. Furthermore, these approaches require specific languages and notations to represent the context of business processes. This reduces the efficiency of strategic changes, since the new strategic necessities must be translated by specialized employees into a different notation. These factors justify the necessity to develop a new solution that better approaches the strategic context.

The solution proposed in this work is a design approach for business processes in which a process is decomposed into smaller parts. One of these parts is the *core process model*, which contains the main activities of the process; the other parts are the *adapters*: process fragments that can be coupled to the core process to implement strategic specific concerns and decision rules. At run-time, core processes are *adapted* by the SA-BPM process engine to include the activities defined by their corresponding adapters.

Besides including activities in process instances, an adapter also collects information about the strategy and interprets this information in the context of the process that is being executed. For example, if an employee of a car rental company has the activity "*inspect vehicle*" to execute, the adapters could collect all information that may affect vehicle inspections and present to the user recommendations about whether he/she should focus on cleanness, tires pressure, or damage. This recommendation may be based on strategic targets to reduce complaints about dirtiness, to improve lifespan of tires, or to increase safety.

Within our approach, changing strategic goals and targets will require changes to adapters, but will not need the redesign of the core process. The design of adapters affords a *modular* implementation of strategy awareness. Each adapter is dedicated to a single strategic concern or goal. In this way, the goals can be changed independently of each other. Moreover, new adapters can be added to the system and old adapters may be removed. Such modularity is essential to strategic flexibility [93, 100].

We now begin to formally introduce the conceptual basis for the study of SA-BPM. We adopt WF-nets as a formal definition for business processes (see Sec. 4.2.1) and introduce new concepts that are particular to our approach. The first concept of fundamental importance in our design is that of a *business process path*. It defines the path taken by the process participants during the execution of a workflow to generate a certain output.

Definition 6.17 (Business Process Path)**.** A business process path *of a WF-net* $W = \langle P, T, I, O, M_0 \rangle$ *is a finite sequence of activities that can be executed in a instance of* W*. It is expressed by a sequence* $\rho = [t_1 t_2 \dots t_n]$*, where, for all* $i \in [1; n]$*:*

- $t_i \in T$*;*
- *if* $i < n$*, then exists a* firing sequence $[t_i x_1 x_2 \dots x_k t_{i+1}]$, $x_i \in T$.

We say that a business process path ρ **generates** a work product of type ω if the execution of the corresponding activities in an instance of the process produces the work product of that type.

A path is **minimal** if it has the minor size possible to allow the generation of a work product.

Definition 6.18 (Minimal Business Process Path for Product)**.** *A business process path $\rho = [c_1c_2 \ldots c_n]$ is minimal to generate a product ω if there is no other path $\rho' = [x_1x_2 \ldots x_k]$, $k < n$ that can generate ω.*

If there is no path in a business process that can be said to generate a work product of a certain type, then the process and the work product type are **disconnected**. Otherwise, they are **connected**.

Definition 6.19 (Disconnected Business Process and Work Product Type)**.** *A business process is* disconnected *from a work product type ω (and vice-versa) if there is no path on it that generates ω.*

A work product type that is disconnected from all business processes of the organization is said to be a **missing work product type**.

If there are connected work product types that cannot be generated simultaneously in a single process instance, then we have a situation of conflict between the paths. This is expressed by the concept of *mutual exclusiveness*.

Definition 6.20 (Mutually Exclusive Business Process Paths)**.** *Two business process paths, $\rho_1 = [a_1a_2 \ldots a_N]$ and $\rho_2 = [b_1b_2 \ldots b_M]$ are mutually exclusive in a WF-net $W = \langle P, T, A \rangle$ if there is no possible execution path in W that contains both ρ_1 and ρ_2.*

We say that a business process is **conditionally connected** to a work product type when the work product type is constrained (see Def. 6.10). In this case, there is no guarantee that the execution of the business process will generate a work product of the constrained type.

A business process is said to be **strategically relevant** to a results-chain if there is a work product type in the results-chain that *should* be generated by the process. The decision about whether the process should or not generate a work product is made by the business analyst, a person that identifies the requirements of the firm's business processes. If there is not such a work product type, the process is called **disconnected from the strategy**. Observe that it is not necessary that the process generates the work product type, it just needs to be *required to generate*. If it is required to generate the work product but it does not, then there is a path *missing* in the process and the process should be redesigned to include that path.

We now formalize workflows that execute in SA-BPM systems. When a business process is redesigned to be composed of a core process and a collection of adapters, we say that this process is *adaptable*. To formalize this concept, we define two structures that extend WF-nets: the **Strategic Adapter Net** (SA-net) and the **Adaptable Workflow Net** (AWF-net). Then we define how AWF-nets and SA-nets are composed to make **adapted workflow instances**.

Definition 6.21 (Strategic Adapter Net - SA-net)**.** *A strategic adapter net s, also called SA-net, is a tuple $\langle W_s, \omega_s \rangle$, where W_s is a WF-net, called the* adapter's model *and ω_s is the work product type generated by W_s.*

Definition 6.22 (Adaptable Workflow Net - AWF-net)**.** *An adaptable workflow net p, also called AWF-net, is a tuple $\langle W_p, S_p, \delta_p \rangle$ where:*

- *$W_p = \langle P_p, T_p, A_p \rangle$ is a WF-net, called the core process model;*

- *S_p is a set of SA-nets;*
- *$\delta_p : T_p \to \mathscr{P}(S_p)$ is a function that defines which adapters affect which transitions of the WF-net.*

Observe that each adapter is devoted to affect a single activity in the process, but multiple adapters can affect the same activity. The actual workflow to be executed is called the **adapted workflow instance** of the AWF-net.

Definition 6.23 (Adapted Workflow Instance)**.** *Let $p = \langle W_p, S_p, \delta_p \rangle$ be an AWF-net and $W_p = \langle P_p, T_p, A_p \rangle$. An adapted workflow instance of p is a WF-net $W = \langle P, T, A \rangle$ which is the result of the combination of p and its adapters $s \in S_p$, through the following steps:*

- *for each $t \in T_p$*
- *if $\delta_p(t) \neq \emptyset$, add a transition t' to T_p;*

  1. *for each $\langle W_s, \omega_s \rangle \in \delta_p(t)$*
     (a) *add all places, transitions, and arcs from W_s to W_p;*
     (b) *let p_{Is} and p_{Os} be the input and output places of W_s, respectively. Set $O(t', p_{Is}) = 1$;*
     (c) *for all $p \in {}^\bullet t$, set $I(t', p) = I(t, p)$ and then set $I(t, p) = 0$;*
     (d) *set $I(t, p_{Os}) = 1$.*

The AWF-net definition merges the WF-net corresponding to the core process with those of the SA-nets that affect the process. This is done through the addition of a AND-split and AND-join before each affected transition. The AND-split starts the parallel execution of the SA-nets. Thus, in an instance of an AWF-net, all adapters that affect a given transition are executed in parallel before that transition can be enabled. When all adapters are done, the flow continues normally.

As an example, consider the goal to **"reduce monthly travel expenses"**. One of the activities possibly proposed by the managers to achieve this goal is to **"prefer virtual meetings when stakeholders are at distant locations"**. The *Schedule meeting* activity, which may be part of several business processes of the organization, is directly related to this goal. Let us illustrate this situation with the *Project Meeting* process, depicted in Fig. 6.7. To meet the strategic needs, this process includes a *Verify stakeholders locations* activity and, then, a decision point where the user chooses to schedule a virtual meeting or not.

The work product type to be generated by this process is the *virtual meeting scheduled*. It is generated by the path: *Identify project* → *Identify stakeholders* → *Verify stakeholders locations* → *Schedule virtual meeting*.

Now, we are going to redesign this process such that it is composed by a *core* process, less dependent on the strategy, and a *strategic adapter*, that inserts the strategic concern.

The core function of this process is to schedule meetings between stakeholders. The type of the meeting could be interpreted as simply a property of the meeting. This simplification is illustrated in Fig. 6.8. This is our *core* process.

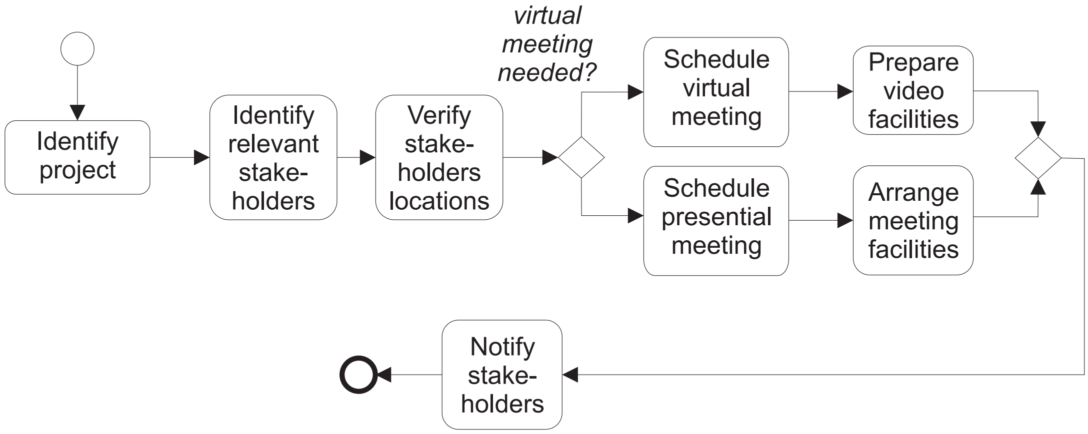

Figure 6.7 Initial Project Meeting Process

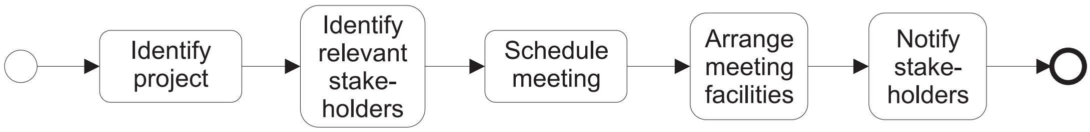

Figure 6.8 Core Project Meeting Process

Unfortunately, it is not clear if this process can fulfill the strategic requirement of reducing monthly travel expenses. Thus, an adapter will be created to ensure that.

A *Check Meeting Necessities* adapter process, illustrated in Fig. 6.9, is created to perform the following activities:

- verify the location of the stakeholders;
- check if they are within allowed distance from a meeting place;
- check for the necessity or not of scheduling a virtual instead of a face meeting in that situation and present a recommendation to the user.

Figure 6.9 Strategic Adapter for the Project Meeting Process

Checking stakeholders location is a manual step. It may involve calling people to find out where they will be in the expected date of the meeting. While this activity is not concluded, the *Schedule meeting* activity cannot be enabled. Only after the conclusion of the *Check Meeting Necessities* adapter, the *Schedule meeting* activity can be executed. At this point, the user has been informed about the necessity to schedule a virtual meeting or not.

Observe that, if goals change, or if directives prove to be ineffective to reach those goals, only the adapters need to be changed. The core design of the processes may remain stable. Since the necessity to verify stakeholders' locations **does not belong** to the core functions of the *Project Meeting* process, in principle, the core process modeler *should not need to take care of these aspects*. SA-BPM systems improve the separation of strategic and operational concerns, but **keep a clear link** between the two. So, if the company move out from the goal exemplified, they can simply deactivate the *Check Meeting Necessities* adapter. Automatically, the *Project Meeting* process will execute in its core format. If a new concern is included, a new adapter is constructed and the new behavior is assumed by the process.

During their execution, SA-nets compute **strategic recommendations** that the SA-BPM system presents to the user. A recommendation is an input to the workflow instance that obliges, suggests, or improves the chances of execution of a path that is estimated to generate the most important work products at the moment. For example, the *Check Meeting Necessities* adapter gives the recommendation to *schedule a virtual meeting* when the stakeholders are at distant locations. We now formally define such recommendations.

We define a strategic recommendation as a function that associates a value to each variable of a work product type $\omega = \langle V, \phi \rangle$. The set of values provided by the recommendation defines the assignments $\alpha(v)$ for some or for all variables $v \in V$. Since each variable may be updated in a different moment during the workflow execution, the recommendations are defined for each activity in the process path that generates ω.

Definition 6.24 (Strategic Recommendation)**.** *Let $\omega = \langle V, \phi \rangle$ be a work product type, T_ρ a set of transitions in a workflow W and $\rho = [t_1 t_2 \dots t_k]$ a path that generates ω, where $\forall i \in [1;k] : t_i \in T_\rho$. A* strategic recommendation *is a function $\mathfrak{R} : T_\rho \times V \to \phi(V)$ assigning a value $\mathfrak{R}(t, v)$ to certain variables $v \in V$ at certain transitions $t \in T_\rho$.*

If a recommendation is fully accepted in a process instance, then a work product is generated according to the recommendation. We call this the **recommended work product**. In the *Project Meeting* process, the recommended work product is a *meeting scheduled* for which a certain "type" variable is set to the value "virtual". The assignment of this property to the product is done at the *Schedule meeting* activity. Thus,

$$\mathfrak{R}(\text{Schedule meeting}, \text{type}) = \text{virtual} \,.$$

Definition 6.25 (Recommended Work Product)**.** *Let ω be a work product type, $\rho = [t_1 t_2 \dots t_k]$ a process path, and $\mathfrak{R}$ a recommendation. The* recommended work product *of $\mathfrak{R}$ is the work product $\langle \omega, \alpha \rangle$ in which*

$$\forall v \in \omega, \forall i \in [1;k] : \mathfrak{R}(t_i, v) \neq \emptyset \Rightarrow \alpha(v) = \mathfrak{R}(t_i, v)$$

In the SA-BPM approach, the strategic recommendations are computed during the execution of the adapters.

A workflow instance that produces all recommended work products is called a **recommendation compliant instance**. If it generates only a subset of these work products, it is called a **partially recommendation compliant instance**. If no work product is generated according to the recommendations, then it is called a **deviating instance**. Getting back to the *Project Meeting* process, a instance is *deviating* if the adapter recommends a virtual meeting but the user schedules a presential meeting.

6.4.1 Analysis of the Maintenance Efforts for Adaptable Workflows

Adaptable workflows provide a more flexible structure for dealing with strategic change. The adapters are focused on the delivery of specific work products to support the strategy, letting the main process to be focused only on the core activities. Without adapters, every time the strategy of an organization changes, all business processes that are relevant to that strategy must be updated (or at least checked for possible updates).

To measure the degree of relationship between strategy and processes, we propose a metric to measure the **strategic maintenance effort**. This metric is built on the basis of three main assumptions:

- as more elements of the strategy are associated with the work products of a process, higher are the chances of a change to be necessary. Thus, the process will demand increased efforts to be maintained in sync with the strategy;
- as more activities in the process are related to the generation of a work product, more "steps" will be necessary to update the process model due to a change on that work product type. Thus, the number of activities necessary to generate a work product increases the maintenance effort;
- the larger and the more complex a process is, the higher is the effort required from the process modeler to update each one of the process' activities.

Let W be a process, $R = \langle E, \lambda, C \rangle$ be a results-chain, and $\Omega \subset E$ be a set of work product types *connected* to the process W.

We define the **work product volatility** as the probability that a change in the strategy affects a given work product type. For this metric, we assume a uniform probability of each element in the strategy to require change. Thus, the volatility of a work product is proportional to the number of elements associated to it compared to the total number of elements of the strategy.

Definition 6.26 (Work Product Volatility)**.** *The volatility of the work product type ω in the strategy R is the quantity:*

$$v(\omega, R) = \frac{|E_\omega|}{|E| - |\Omega|} \ ,$$

where $E_\omega = \tau(\omega, R)$.

Changing a work product type affects the process that is connected to it. The process produces a work product through a path. Multiple paths may generate the same product, but for each work product type there is a minimum path that can generate it. We define the **change size** as the number of activities in such minimum path.

Definition 6.27 (Change Size of a Work Product)**.** *The* size *of a work product change in a business process is equal to the number of activities that need to be updated when the work product changes:*

$$s(W,\omega) = h(\omega)\ ,$$

where $h : \Omega \to \mathbb{N}$ is a mapping from the work product type $\omega \in \Omega$ to the size of the minimum path that can generate ω.

For example, in the initial version of the *Project Meeting* process (Fig. 6.7), the path size is 5 activities: *Identify project* $\rightarrow$ *Identify stakeholders* $\rightarrow$ *Verify stakeholders locations* $\rightarrow$ *Schedule virtual meeting*. Observe that, although only the last activity really produces the work product, it depends on data that is input in the previous activities of the path. Thus, the five activities may be affected by changes to the work product.

Moreover, the more complex is the structure of a workflow, higher is the effort necessary to update it. There is a variety of measures of complexity of a workflow described in the literature [15], as introduced in Chap. 4. A simple one is the *number of activities in the process*, which is a reference to the *Lines of Code* (LoC) metric of software engineering [15]. More elaborated metrics, however, also take into account the structure of the workflow (number of gates, number of possible paths etc.) when computing the workflow's complexity. In this work we do not adopt any specific of these metrics. We assume that there is such a metric that can be used to compare workflow models and that the effort required to update a single activity in the process is proportional to the value of this metric.

Definition 6.28 (Change Complexity)**.** *The* complexity *of a strategic change in a process is the estimated effort to update a single activity in the process, denoted by X_W.*

Another useful metric is the **expected number of maintenance steps**, which is an estimation of how many activities are expected to change in a workflow when the strategy changes.

Definition 6.29 (Expected Number of Maintenance Steps)**.**

$$E_S(W,R) = \sum_{\omega \in \Omega} v(\omega,R)\ s(W,\omega)\ .$$

The *strategic maintenance effort* (MF) metric we propose is built on the basis of the previous metrics.

Definition 6.30 (Strategic Maintenance Effort)**.** *The* strategic maintenance effort *for a workflow W with respect to a results-chain R to which it is connected through work product types Ω is the quantity:*

$$MF(W,R) = X_W\ E_S(W,R)\ .$$

Comparing two workflows, A and B, in the same strategy R, if the value of $MF(A,R)$ is higher than the value of $MF(B,R)$, then at least one of the following affirmations is true:

- the expected number of maintenance steps in A is higher than in B; or
- the complexity of A is higher than the complexity of B.

Traditionally, the approach to solve the problem of missing paths is to redesign the process so that new paths are added to generate the missing work product types. We show now that this approach increases the process maintenance efforts.

Theorem 6.1. *Redesigning a process to include missing paths on it makes it more difficult to maintain.*

Proof. It follows directly from Def. 6.29 that, if we add a new path to a process, we add a positive term to the summation. Thus, the value of E_S can only increase. Also, the complexity X_W of the process cannot reduce with the addition of a new path (a metric that allow so would make possible the absurd situation in which a process is optimized through the addition of several elements to it). The complexity may either remain the same or increase. Consequently, the value of $MF(W,R)$ can only increase. □

By analogy, we can say that, having a process that is fully connected (has no missing paths) and removing activities from it such that missing paths appear will reduce its maintenance effort. Assuming that such a maneuver is possible without harming the process' core objective, then having missing paths in a process may be a desirable condition. But this can only show positive effects to the organization if we have other means to generate the work products that are necessary to pursue the strategic results expected. The adapters fulfill this role.

Finally, when a business process is alternatively connected to its required work product types, it means that there are independent paths in the process and the choice for a path makes another path to be missing. This, however, is not a sufficient condition to make the process more or less easy to maintain than a fully connected process. The reason is that, when a strategic change is demanded, the activities that are affected by this change may be in any path. This will require the same number of maintenance steps, independently of these paths being parallel, mutually exclusive, or interleaving. However, the mutual exclusiveness may have impact into the complexity of the process, depending on the complexity metric chosen [15].

Consider, now, a WF-net $W = \langle P,T,A \rangle$ which is fully connected to a set of work product types Ω. The strategic maintenance effort of W is the number:

$$MF_W = X_W \; E_S(W,R) \; . \qquad (6.1)$$

In the SA-BPM approach, we propose the redesign of W into a new WF-net W_p in such a way that:

1. for each $\omega \in \Omega$, an SA-net S_ω is created. This SA-net is only connected to ω;
2. no path ρ of W is complete in W_p, but becomes complete in combination with the SA-nets created;
3. in the end, W_p should have (ideally) no strategic activity (i.e., no activity that is affected by strategy changes).

In the ideal case, where W_p has no strategic activity, its strategic maintenance effort is reduced to zero, because it is not connected to any work product type:

$$MF(W_p,R) = 0 \; . \qquad (6.2)$$

However, since we have added a number of SA-nets to complement the core process, the maintenance efforts of each of these SA-nets should also taken into account. Each SA-net S_ω is designed to contain paths that generate ω. These paths were all generated by W, the former version of the workflow. Since these SA-nets only contain parts of W, each S_ω is a more simple, purpose specific process than W, which implies that its complexity $X_\omega < X_W$. If, although improbable, the actual case occurs in practice in which $X_\omega > X_W$, then for this case the path to generate ω should be kept into the core process W_p. So, we assume that such a situation does not occurs.

The strategic maintenance effort of each S_ω is given by:

$$MF(S_\omega, R) = X_\omega \; v(\omega, R) \; s(S_\omega, \omega) \; . \tag{6.3}$$

Summing up all maintenance efforts of all of these strategic adapters will lead to:

$$MF_S = \sum_{\omega \in \Omega} MF(S_\omega, R) = \sum_{\omega \in \Omega} X_\omega \; v(\omega, R) \; s(S_\omega, \omega) \; . \tag{6.4}$$

Although we want to remove from the core process all activities that are subject to strategic intervention, some activities will remain in W_p. These are activities that are essential for the purpose of W_p and cannot be removed from the core process. Thus, each SA-net S_ω will contain at most the minimum path to produce ω, but may contain only part of a path, which is completed in the execution of W_p itself.

Theorem 6.2. *The strategic maintenance efforts of all strategic adapters summed up is lower than the strategic maintenance effort of the original process W from which they were extracted.*

Proof. Let us create a term

$$\xi_\omega = X_\omega \; v(\omega, R) \; . \tag{6.5}$$

Since $X_\omega < X_W$, then

Lemma 6.1.

$$\xi_\omega < X_W \; v(\omega, R) \quad \forall \omega \in \Omega \; .$$

The value of $s(S_\omega, \omega)$ is determined by the size of the minimum path to generate ω. Since the definition of a path ignores all activities that do not contribute to the product, the value of $s(W, \omega)$ can safelly be taken to be the same or above the value for S_ω (because S_ω contains at most the minimum path, but may contain only part of it):

$$s(S_\omega, \omega) \leq s(W, \omega) \quad \forall \omega \in \Omega \; . \tag{6.6}$$

Consequently, we can conclude, from Eqs. 6.4 and 6.5, that:

Lemma 6.2.

$$MF_S \leq \sum_{\omega \in \Omega} \xi_\omega \; s(W, \omega) \; .$$

In similar terms, MF_W can be written:

$$MF_W = \sum_{\omega \in \Omega} \xi_W \; s(W, \omega) \; , \tag{6.7}$$

where $\xi_W = X_W \; v(\omega, R)$.

Finally, from the inequalities in Lemmas 6.1 and 6.2, we conclude that:

$$MF_S < MF_W \; . \tag{6.8}$$

□

We can illustrate this easily with the process illustrated in Figures 6.7, 6.8, and 6.9, which demonstrate the redesign of a *Project Meeting* process. In this example, the activity "*Verify stakeholders locations*" is the main part of the original process that is connected with the work product of interest. If the strategic goal to reduce travel expenses is changed, it may affect this activity. As a result, changing this goal affects a process that has eight activities and two alternative paths (due to the XOR gateway) (Fig. 6.7). When we redesign the process (Fig. 6.8 and Fig. 6.9), this activity is taken off from the core process and is maintained in an adapter. The adapter has only three activities. Thus, a change in the strategic goal will only affect three activities at most. The core process (Fig. 6.8) has no activity that should particularly be affected by this goal. All activities in it are there because the process cannot be concluded without them. Thus, the *strategic* maintenance of the adaptable workflow of this example, composed of core + adapter, is lower than that of the original process.

6.5 Architecture for SA-BPM Systems

The design of the architecture proposed in this work is based on three main devices: the guidelines introduced on chapter 5, the properties enumerated in Sec. 6.3, and the theory of context-aware information systems [66, 124].

We shall begin by defining what usually composes a context-aware information system. Two major tasks are performed by such systems:

1. **context acquisition**: the system obtains useful information from the context and stores this information in an internal model;

2. **system's adaptation**: the application's functionalities are adapted to the current context of operation.

An example of architecture that implements these principles is SOCAM [42], which was described on chapter 4.

Now, let us put these two major tasks in the scope of SAISs properties. The context of a SAIS is determined by the current strategic plans and performance indicators of the organization. We call this the firm's *strategic context* and define it as the concept of a quantitatively-managed results-chain. According to the tasks described previously, the system must have a mechanism to acquire context, i.e., to collect information about the context and store it internally, making it available to the application. To this end, we introduce in our architecture the **Strategic Context Provider** module. This module is able to communicate with the *Strategic Planning Application* and with the *Performance Measurement System* of the company. Its objective is to extract information about goals, actions, and performance indicators.

Once acquired, the context information is used to determine the operations that are executed. In a BPM system, the operations are the activities of a business process. Thus, we need a mechanism to determine which activities take part in a business process on the basis of the strategic context. For this purpose, we propose a **Strategic Adaptation Agent** module. This module is able to communicate with the BPM engine to affect the orchestration choices. It can intercept the workflow and insert or remove activities from the process. It can also enrich the user interface with contextual information that may be relevant to support the user on his/her work.

The list of SAIS properties also require a mechanism to link operations (e.g., business process activities) to strategic goals. This is essential to allow the *Strategic Adaptation Agent* to operate more effectively. For this purpose, we introduced the concept of **Strategic Adapters** (or, simply, "adapters"), already discussed. The Adaptation Agent is the entity responsible for combining adapters with adaptable workflows to construct *adapted workflow instances*.

The architecture of an SA-BPM is depicted in Fig. 6.10. The four main components that build an SA-BPM system are summarized as follows:

- *Strategic Context Provider* - entity responsible for acquiring strategic information from external applications;
- *Strategic Adaptation Agent* - component responsible for interacting with the Business Process Management System (BPMS);
- *Strategic Adapters* - business process models that compute contextual information required to make an activity become strategy-aware. Adapters' execution and interaction is controlled by the Strategic Adaptation Agent;
- *Business Process Management System* - the BPMS that is adapted for executing business processes in a strategy-aware fashion.

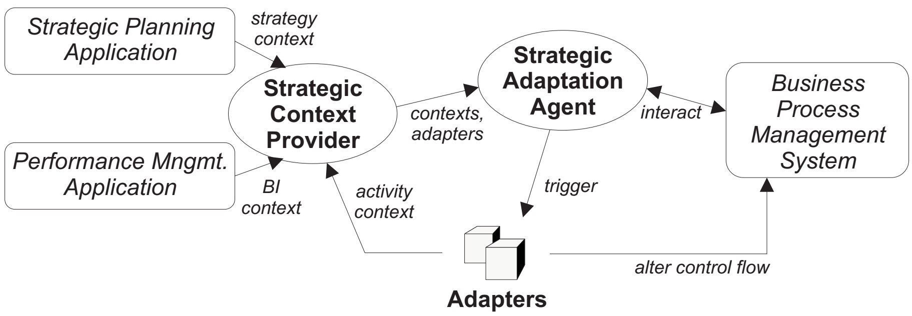

Figure 6.10 SA-BPM Architecture

In this architecture, adapters are also modeled as business processes which are, then, deployed into the BPMS. This allows users to employ the same notation and knowledge to model both business processes and adapters. The Adaptation Agent, which stores the links between processes, adapters, and strategies, monitors the BPMS and triggers the execution of adapters when necessary. The adapters are inserted in the control flow and may require the execution of activities from the users or may invoke web services, for example. The adapters directly communicate with the Context Provider through an API to store and retrieve contextual information. The information stored by the adapters is consulted by the Adaptation Agent which makes it available to the user of the BPMS.

In the following sections, we detail the design of the Adaptation Agent and the Context Provider.

6.6 Strategic Context Provider

In our architecture, strategic information is handled by the *Strategic Context Provider*. Its purpose is to provide an interface through which adapters and the Adaptation Agent can obtain information about the strategic context of the organization. To that end, the Strategic Context Provider is connected to the firm's strategic planning and performance management systems. Such integration is also useful to establish a communication channel between Business managers and IT. The connection of the SA-BPM system with the management systems used by the firm's administrators force the adapters to work in the domain of discussion of the Business people and to use information that is under the managers' control. Thus, adapters cannot be created if strategic goals are not defined for them in the strategic planning tool. Also, adapters cannot use metrics that are not also available to managers in the performance management system.

The strategic context can be split up into three sub-contexts: the *Strategic Planning Context*, the *Business Intelligence Context*, and the *Activities Context*. The first one incorporates the information extracted from the strategic planning tool of the organization. The second, extracts and distributes information from the performance management system. The latter sub-context handles the information that is produced by adapters during their execution. Each one is detailed below.

6.6.1 Strategic Planning Context

The Strategic Planning Context holds the results-chain model, i.e., the current definition of the strategic plans of the organization. It is extracted from the strategic planning application in use by the company.

The following information is provided through the Strategic Planning Context:

1. **strategy definition**: comprise all elements of the results-chain and their description;

2. **performance targets**: the performance indicators, baseline, and target of each strategic element;

3. **priorities**: the priority of each goal;

4. **dependence constraints**: any dependence between goals expressed in the strategic plan. For example, if two goals are complementary to each other, one cannot be canceled without affecting the other.

6.6.2 Business Intelligence Context

The Business Intelligence (BI) Context provides information about the current state of the organization in the pursuit of its goals, through its performance indicators. The term *Business Intelligence* is employed because this module offers not only access to the current value of the performance indicators, but also allows the application of filters, crossjoints, and other operations over the indicator's data.

The following information is provided by the BI Context:

1. **operational data**: comprise the raw data generated by the execution of activities (i.e., the work products);

2. **performance indicators**: indicators that make part of the performance measurement system of the organization;

3. **trend indicators**: indicators that measure the change of an indicator along time;

4. **correlation indicators**: measure the cause-effect relationship between work products and performance indicators.

The BI Context enables the querying of these indicators by the adapters through the MDX (*Multidimensional Expressions*) language [101]. This is a language widely used for querying in BI systems. It organizes data in **cubes**. Each cube defines *dimensions* (e.g., year, region, product type) and *measures* (e.g., revenue, total sales, number of defects). This structure allows for an efficient description of the information desired by the adapter.

If the performance management system of the organization is also a BI system that accepts the MDX language, then the capacity of analysis of the Context Provider is enhanced. MDX is useful to offer more flexibility for adapters, since they can better retrieve the data that is more relevant to the context of the activity being executed. For example, an adapter may be interested in the enterprise's current sales growth. Since the BI context is accessed through the MDX language, this indicator can be sliced and filtered according to the cube's dimensions: year, region, product, etc. If the adapter is interested only in the sales growth for *a certain product* in *a certain period*, it can define these slices in the query and get the precise information it needs.

6.6.3 Activities Context

When they execute, adapters inform the Strategic Context Provider about the context that should be considered by the process participants when performing their job. The Context Provider stores an *activity context* for each instance of activity that is being adapted. The

Adaptation Agent, in turn, adds to the user interface all contextual information that have been collected by the adapters, allowing the user to take better decisions.

The context of an activity instance is composed of:

1. **identification**: the id of the instance in the BPM engine;
2. **recommendations**: a list of recommendations inserted by different adapters. Each recommendation stores also the identification of the adapter that computed it;
3. **strategic links**: references to the strategic goals of the adapters that offered the recommendations stored.

The strategic recommendation is a key component of the activity context. It contains the *interpretation* of the strategic context in the scope of the activity that is being performed. Each recommendation has a *dimension* attribute that informs the user about which concern of the operation the recommendation addresses. This attribute is specific for the activity to be performed. Examples of dimensions are “customer”, “branch”, “department”, “product”, and “supplier”. Within the dimension, the recommendation determines which *members* of the dimension the recommendation is intended for. For example, if the recommendation is applicable only for certain customers within a list, the recommendation’s dimension will be “customer” and the members attribute will enumerate the customers that the user should take special care of. Examples of members of the “department” dimension are “finance department”, “HR department”, etc.

The Adaptation Agent retrieves this information to construct the contextual information that is displayed to the user during the execution of the process. When the activity is concluded, the Adaptation Agent informs the Context Provider about this event. The Context Provider, then, logs the activity context from the run-time memory into a permanent storage. These loggings are of fundamental importance. They allow an *a posteriori* analysis of the strategic interventions performed by the SA-BPM system into the process. On the basis of such information, the managers can identify problems with the application of the strategy (for example, recommendations that are not being followed by the employees), or problems with the effectiveness of the adapters (recommendations that were followed but did not have the expected impact in the firm’s performance).

Information about the work products generated by processes can also be used in the performance management system of the company. This means that it may also be available to adapters when they execute, which could improve their recommendations based on the history of their own previous decisions.

6.7 Strategic Adaptation Agent

The adaptation process is coordinated by the *Strategic Adaptation Agent*. This entity is responsible for recognizing the links between adapters and business processes and invoking the execution of adapters when demanded. The agent also collects data from the process instance and populates the adapters’ internal variables.

The definition of an adapter includes the definition of which work products it generates and which activity(ies) of which business process(es) it affects. The Agent stores a collection of adapters for each business process and starts monitoring the process engine. When an activity instance that is affected by an adapter is *ready* to execute, the Agent performs the necessary steps to execute the adapter in the context of the process instance. These are defined by the following algorithm.

1. change the state of the activity from *ready* to a *suspended* state (the names of these states may vary depending on the business process engine used, but most engines store an internal state that expresses that an activity is "ready" to be executed and another state that expresses that it is "suspended", "on hold", or "blocked");
2. search the registry for the adapters that are linked to the activity and trigger their execution;
3. once all adapters have concluded their process, collect the recommendations stored by them in the Context Provider;
4. set up the activity context to be displayed to the user:
   (a) group recommendations by content, dimension, and members;
   (b) for each recommendation, extract the definition of the strategic goals that justify it;
   (c) retrieve the values of the performance indicators that are linked to the adapters executed;
5. set the state of the activity back to *ready*;
6. when the user initiates the activity, display all contextual information to him/her;
7. wait for the conclusion of the activity;
8. when the activity is concluded, inform the Context Provider about the conclusion of the activity.

The Adaptation Agent's algorithm must be adapted to the constraints imposed by the underlying process engine. The more flexible is the engine, the better its support for the adaptation process. Chapter 7 describes how we implemented the adaptation mechanism in the Bonita BPM's process engine.

6.8 Work Product Conflicts

Sometimes, two or more strategic actions determine conflicting recommendations for the operations that are to be performed by the employee. In such situations, the system must be able to determine which option offers more value to the organization.

The decision for which work product is more important to the organization in a given situation must be taken under the strategic perspective. To support user's decision making and to solve conflicts, the system needs to weight the priorities of the organization and select the option that fits better in the current context. An important aspect of this weighting method is that it should not only consider the relative priorities of each strategic goal, but also the current performance of the organization in the pursuit of those goals.

To perform this task, we propose the use of the *Analytic Hierarchy Process* (AHP) [98,99]. This is a multiple-criteria decision making method that has been extensively used to support decision making in business contexts [114]. One of the key features of this method is its ability to capture subjective judgments of several stakeholders. This is an important feature when we talk about strategic matters, because it enables us to better capture the managers' perception of the organizational environment.

The AHP method consists in creating a decision hierarchy that will lead the stakeholder to compare and prioritize relevant aspects related to the problem, ranking criteria and subcriteria until, finally, finding a ranking for the alternative actions.

Definition 6.31 (Analytic Hierarchy)**.** *An* analytic hierarchy *is a tree defined by $H = \langle C_H, L_H$, where:*

- *C_H is the non-empty set of criteria, which are the nodes of the tree. There is a special criterion $g \in C_H$ which is the* goal *and corresponds to the root of the tree. There is a set of criteria $A_H = \{a_1, \ldots, a_N\} \subset C_H$ which is the set of* alternatives *and corresponds to the leaves of the tree;*
- *$L_H : C_H \to \mathbb{N}$ is a function that defines the* layer *of each criterion $c \in C_H$, such that:*
  - *$L_H(g) = 1$;*
  - *$\forall a_i \in A_H : L_H(a_i) = M$, where M is the total number of layers;*
  - *$\forall c \in C_H : c \neq g \wedge c \notin A_H \Rightarrow 1 < L_H(c) < M$.*
- *the edges of the tree are the set $\{\ (c_1, c_2) \in C_H \times C_H \mid L_H(c_1) > L_H(c_2)\ \}$.*

Table 6.1 The fundamental scale

Intensify of Importance	Definition
1	Equally preferred
2	Equally to moderately
3	Moderately preferred
4	Moderately to strongly
5	Strongly preferred
6	Strongly to very strongly
7	Very strongly preferred
8	Very strongly to extremely
9	Extremely Important

The comparisons between criteria and alternatives are made pairwise through binary comparison matrices and through the so called *fundamental scale* of absolute numbers [99]. The fundamental scale assigns to each alternative a number that represents its relative importance against other alternatives with respect to certain criterion. The scale is presented in Table 6.1.

Within the AHP method, one must follow seven steps to compute the rankings of each alternative, as follows:

1. State the problem;
2. Identify the criteria that influence the behavior;
3. Structure the problem in a hierarchy of L layers constituting the goal (layer 1), criteria (layer 2), sub-criteria (layer $L-1$), and alternatives (layer L);
4. Let T_i be the set of criteria of layer i. For each hierarchical layer $h \in L, \ldots, 2$:
   (a) For each criterion $t \in T_{h-1}$ of the layer above:
      i. Compare each element $s \in T_h$ using the fundamental scale considering criterion t. This produces a *comparison matrix*. The diagonal elements of this matrix are equal to 1;
      ii. Perform calculations to find the maximum *eigenvalue* of the comparison matrix, denoted by λ;
      iii. Determine the consistency of the comparison. This is determined by using the eigenvalue λ, to calculate the consistency index (CI) as follows: $CI = \frac{(\lambda m - n)}{(n-1)}$, where n is the matrix size. Consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate random index in Table 6.2. The value for CR should not exceed 0.10. Otherwise, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.
      iv. If the maximum eigenvalue, CI, and CR are satisfactory then the solution of the comparison is the matrix's eigenvector E_t. This vector determines the weights of each element of the level when compared by criterion t.

   (b) the weighted vectors E_t are joined into a new matrix M_h.
5. Multiply the matrices $M_L \times M_{L-1} \times \ldots \times M_2$;
6. The resulting vector corresponds to the weights (ranks) of the alternatives.

Table 6.2 Random index for different values of n

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,52	0,89	1.11	1.25	1.35	1.40	1.45	1.49

The capacity to check the consistency of the judgments given by the user is an interesting feature of AHP that contributes to the confidence of the method.

An example of hierarchic structure is shown in Fig. 6.11. It exemplifies the application of AHP for web service selection [78]. The leaves of the tree represent the alternatives, in this case, the web services available. The selection criteria are placed in the level above. Examples of criteria are the web service's response time and availability. The top level is the "solution node".

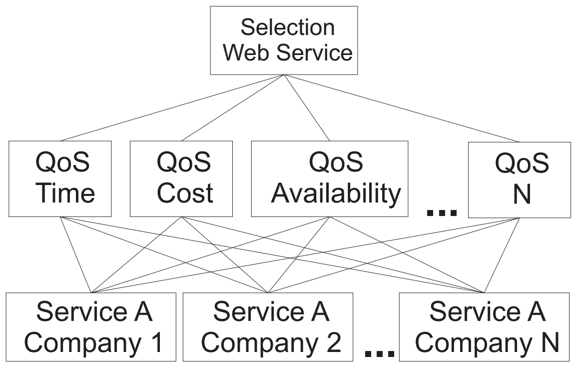

Figure 6.11 AHP structure for web service selection

Each alternative is compared against each other using information about their technical attributes (time, cost, etc.). In the layer above, the managers compare the relative importances of each criterion to the organization's strategy (using the fundamental scale). Thus, they should compare how important response time is compared to cost, how important is cost compared to availability and so on. The AHP method is, then, able to compute preference weights of each alternative considering all this information. The web service that provides higher preference weight is the one selected.

Strategy-aware information systems are concerned with the *strategic* impact of its decisions. So, in our approach, the AHP method is employed to evaluate work product contributions against strategic measures. The objective is to rank recommendations according to the strategic contribution of the *recommended work products*. Fig. 6.12 shows an example of AHP model employed in our approach.

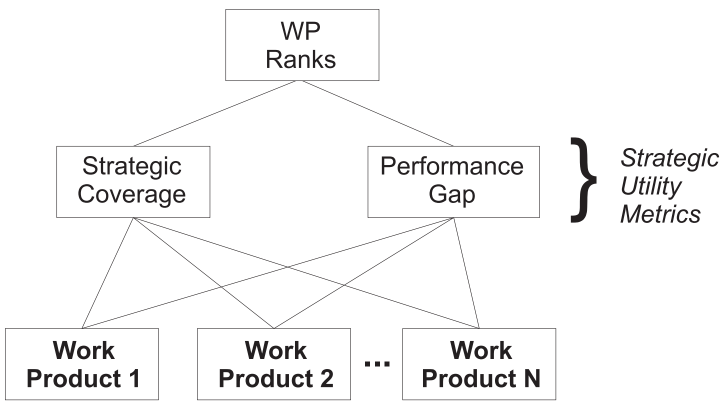

Figure 6.12 AHP structure for work product types ranking

To compare the alternatives, we propose the use of *strategic utility* metrics. The strategic utility metrics are metrics used to measure the contribution of a recommended work product to the company's strategy. In this example, we propose two metrics. However, different metrics could be used as well. The metrics we have used are:

- *strategic coverage*: this metric quantifies the number of strategic goals that are addressed by a work product, taking also their priorities into account;
- *extended performance gap*: this metric quantifies the current state of the company's performance indicators. It reflects a preference for adapters that address goals with higher performance gaps, i.e., which are farther from achievement.

These two criteria reflect two kinds of preferences: (i) firstly, it takes the overall impact of an element over the strategy to define its importance. This is a structural criteria which depends on the definition of the strategy. Elements that affect other elements with high priority are important elements; (ii) secondly, it observes the fact that, once achieved, a goal is not so important as another one that has not been achieved. There is no need to pursue a goal that was already reached. It is more important to catch up on the progress of elements that have been left behind. Thus, it is clear that we should have also a criteria that is dynamic, that depends on the progress of the company in the achievement of its goals. The performance gap is a concept easy to understand by the executives and employees, thus our choice for it.

Definition 6.32 (Analytic Hierarchy for Work Product Ranking)**.** *Let $\Omega = \{\omega_1, \ldots, \omega_n\}$ be a set of work product types. The analytic hierarchy for ranking the work product types in Ω is defined by $H = \langle C_H, L_H \rangle$, where:*

1. $C_H = \Omega \cup \{g, SC, EPG\}$, *where g is the* goal *node, SC is the* strategic coverage *criterion, and PG is the* extended performance gap *criterion;*
2. $L_H(g) = 1$
3. $L_H(SC) = L_H(EPG) = 2$
4. $\forall \omega_i \in \Omega, L_H(\omega_i) = 3.$

Definition 6.33 (Work Product Ranking)**.** *Let t_{SC} and t_{PG} be the weights assigned by the organization to the* strategic coverage *and* extended performance gap *criterion, respectively. The work product rankings is the vector $k = [r_1 r_2 \ldots r_n]$, where r_i is the ranking of the work product ω_i, resulting from the following equation:*

$$\begin{array}{cc} & \begin{array}{cc} SC & PG \end{array} \\ \begin{array}{c} \omega_1 \\ \omega_2 \\ \ldots \\ \omega_n \end{array} & \begin{pmatrix} SC(\omega_1)/T_{SC} & EPG(\omega_1)/T_{PG} \\ SC(\omega_2)/T_{SC} & EPG(\omega_2)/T_{PG} \\ & \\ SC(\omega_n)/T_{SC} & EPG(\omega_n)/T_{PG} \end{pmatrix} \end{array} \times \begin{array}{c} Pref \\ \begin{pmatrix} t_{SC} \\ t_{PG} \end{pmatrix} \end{array} = \begin{array}{c} k \\ \begin{pmatrix} r_1 \\ r_2 \\ \ldots \\ r_n \end{pmatrix} \end{array},$$

where

$$T_{SC} = \sum_{\omega_i \in \Omega} SC(\omega_i)$$

and

$$T_{PG} = \sum_{\omega_i \in \Omega} EPG(\omega_i) \ .$$

6.9 Identifying Problems with Strategies

To achieve strategic flexibility, an organization must be capable of rapidly identifying problems or mistakes in its current strategy. If the identification of problems is delayed, the possiblities of reaction are reduced and the company may be not able to avoid suffering severe losses.

The SA-BPM approach addresses this concern by offering an infrastructure that clarify the relationship between operations and results. Such an infrastructure allows for the use of efficient methods to measure the efficiency and efficacy of a strategy.

We propose two types of analysis that can be used for this purpose. The first one helps a manager to measure the impact of each adapter over the performance of the organization. The second is useful to evaluate the cause-effect relationships described in the results-chain. Both can be used to test the assumptions taken by managers when defining the strategy.

6.9.1 Impact of Work Products Over Performance

Work products are the central point of connection between operations and strategies. It is, thus, important to monitor the correlation that exists between the work products generated by processes and the performance of the organization. This is useful both to identify which is the source of problems as to measure the effects of the adaptation over such problems.

The *Pearson product-moment correlation coefficient* is an useful measure for testing such kinds of hypotheses. It measures linear dependences between two statistical variables. Such measure is adequate for the purpose we apply it here because we are measuring hypotheses of linear dependence (*increasing this will provide that*, *reducing this will leverage that*), which are common in the discourse of business managers. As a tool intended to be easily understandable and applicable by managers, the Pearson correlation is simple yet powerful enough to offer valuable information about the firm's strategic performance.

The Pearson correlation between work products and performance indicators can be measured as following (notice that this is the formula for Pearson correlation applied to the variables defined in this work).

Let $A = \{\langle\omega,\alpha_1\rangle, \langle\omega,\alpha_2\rangle, \ldots, \langle\omega,\alpha_n\rangle\}$ be a set of work products of the type ω, $f_A : [1;n] \to A$ be a function that defines a total order of the products A in the time domain, and $v_A : A \to \mathbb{R}$ be a function that maps each work product into a real value. Let $I = \langle f_I, x_0, x_t\rangle$ be a performance indicator that should be positively affected by ω (i.e., each work product should help the indicator improve from its baseline x_0 to its target x_t value) and Δt be a *time-shift* integer constant. The hypothesis that ω improves I can be tested through the **work product performance correlation**.

Definition 6.34 (Work Product Performance Correlation Coefficient)**.**

$$r_{\omega}^{I} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{v_A(f_A(i)) - \mu_A}{\sigma_A}\right)\left(\frac{f_I(i+\Delta t) - \mu_I}{\sigma_I}\right)$$

where μ_A is the mean sample value of v_A, σ_A is the standard deviation of v_A, μ_I is the mean value of f_I in the domain $[\Delta t + 1; \Delta t + n]$, and σ_I is the standard deviation of f_I in the same domain.

Observe that function v_A is essential to determine how the work product properties are interpreted in this analysis. If work product and performance indicator are correlated, a change in the value of v_A should reflect a change in the performance indicator. So, for example, a sequence of work products of the type "*order delivered*" could be mapped into a function that computes a moving average of the *order processing time* variable. This function can, then, be compared to a performance indicator such as "*average customer complaints*". If on-time deliveries is the company's approach to reduce customer complaints, then the values should be (negatively) correlated. If they are not, then it might be an evidence that this work product does not contributes to the indicator in the manner expected by the managers.

In many cases, the effect of the operations over the performance results are not immediately perceived, but are expected to be observed after some time has elapsed. The time-shift (Δt) applyied to the indicator function is used to take such delay factor into account.

6.9.2 Element Correlation Indicators

Element correlation indicators are a measure of the strength of the cause-effect relationship between elements in the results-chain.

To adequately compute correlation indicators, we need to construct a model of these cause-effect relationships and test it using statistical methods. A cause-effect model captures the managers' assumptions about how each element is expected to contribute to other elements in the results-chain. As such, the models do not need to be an accurate representation of the reality. Rather, it must be an *accurate representation of the manager's view of the reality*. If their perception is unclear or wrong, the cause-effect analysis is an efficient way to identify it. This gives the opportunity to managers for reflecting about their assumptions and possibly implementing changes to the strategy.

The Partial Least Squares Path Model (PLS-PM) [118] method is a suitable technique for investigating cause-effect relationships at the strategic level. According to Rodriguez et al. [95], techniques of Structural Equation Modeling (SEM) such as the PLS-PM are the most suitable to be used to identify relationships between performance indicators. One of the reasons for this is that SEM can be used in most cases, regardless of the characteristics of the data, because it does not assumes that the data is distributed in any particular way.

The model used in the PLS-PM method is called *path diagram*. The path diagram is a graph in which nodes represent variables and arrows represent cause-effect assumptions. Within the set of variables, some are *latent variables*, which represent unobserved phenomena, while others are *manifest variables*, which are the observable effects of the latent variables.

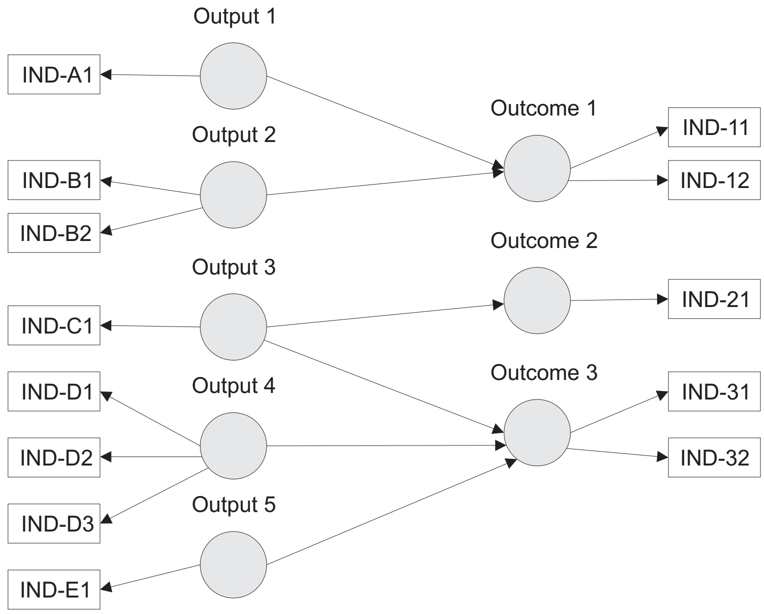

Figure 6.13 Example of a path diagram for a results-chain

Definition 6.35 (Path Diagram)**.** *A* path diagram *is a directed graph* $\langle V, A, t\rangle$*, where*

- V *is a set of nodes representing variables;*
- $A \subseteq V \times V$ *is a set of directed edges or arrows;*
- $t : A \to \{L, M\}$ *is a* type *function that assigns to each node either one of two types:* latent variable *(L) or* manifest variable *(M). Usually, latent variables are depicted as circles while manifest variables are depicted as squares.*

To apply the PLS-PM method, we need a number of observations or samples of the manifest variables. This data is used to compute the *path coefficients* and other statistical measures that explain the relationship between the variables of the diagram.

Fig. 6.13 depicts a path diagram representing output and outcome indicators relationships that can be analyzed through PLS-PM with regard to a given results-chain. Although it is possible to construct such a model for any strategy, the method is more suitable for the use with a results-oriented management approach, since we can construct a direct map from the results-chain to path diagrams, enabling the automatic construction of these models. The mapping is described in the following algorithm:

Definition 6.36 (From Results-Chain to Path Diagram)**.** *A quantitatively managed results-chain* $Q = \langle R, I, \Pi, \mu\rangle$ *with* $R = \langle E, \lambda, C\rangle$ *can be mapped into a path diagram* $\langle V, A, t\rangle$ *through the following steps:*

1. *add a node* p_k *to* V *with type* $t(p_k) = M$ *for each* $p_k \in I$*;*
2. *add a node* e_i *to* V *with type* $t(e_i) = L$ *for each* $e_i \in E$*;*

3. *for each* $(e_1, e_2) \in C$*, add an edge* (e_1, e_2) *to* A*;*

4. *if* $p_k \in \mu(e)$ *for any* $p_k \in I$ *and* $e \in E$*, then* A *has an edge* (e, p_k)*.*

If the strategies are modeled using different approaches, the manual construction of the corresponding path diagrams is required before a PLS-PM analysis can be performed. Such manual process is described by Rodriguez et al. [95].

Through continuous monitoring of correlation indicators, the company can recognize negative situations faster and react more adequately. This is a key ability necessary to improve strategic flexibility. If this information can also be employed to support the adaptation process, for example, for automatically enabling/disabling adapters when problems are recognize or improving the quality of the recommendations computed by adapters, then new levels of adaptability and intelligence can be achieved by the organization.

6.10 Case Study

To demonstrate the feasibility of our approach, we present in this section the implementation of strategy awareness concepts in a *Purchase Supplies* process of a sportswear fashion retailer firm. This case is based on the settings of a real fashion retailer. The owners of this company were receptive to the proposal presented in this work and the strategic interventions described here were partially applied by them. The owners reported that these ideas resulted in noticeable improvement of the store's performance.

This fashion retailer has confronted a problem of excess stock. This has impacted their revenue and impaired their sales growth strategy. Although increased volume purchases are required to support growth, the problem of excess stock has undermined their performance. In this case, it is clear that a strategic change is necessary.

6.10.1 Defining the Strategy

To define their new strategy, the following assumptions were considered by managers:

- a *growing purchase tendency* is reflected in a *growing stock tendency* in the subsequent one or two months;
- to improve performance, the purchase tendency **should decrease** in the next month after a growth in the stock tendency is observed.

These conclusions are supported by the data collected from the sportswear retailer between June/2012 and June/2013. These are presented in Table 6.3. The "*Avg. Purchase Vol.*" column presents the average volume of purchases of five prioritary items that were targeted by this case study. These five items have similar purchase and sale patterns and are those which showed higher excess inventory in 2012. The "*Avg. Inventory*" column presents the average stock of these five items. The "*Purchase Tendency*" is computed as the coefficient of the regression line that fits in purchase data from the last three months. Similarly, the "*Stock Tendency*" is the coefficient of the regression line fitting in stock data from the last three months. Fig. 6.14 plots

Table 6.3 Purchase and Stock Data

Month	**Avg. Purchase Vol.**	**Avg. Inventory**	**Purch. Tendency**	**Stock Tendency**
	μ_p	μ_s	g_p	g_s
Jun/2012	27.8	40		
Jul/2012	19.8	39.4		
Aug/2012	13.6	31.2	3.4	-7.1
Sep/2012	30	39.6	-4.4	5.1
Oct/2012	8.6	34.6	0.1	-2.5
Nov/2012	38.2	58.6	1.7	4.1
Dec/2012	9.8	59.2	9.5	0.6
Jan/2013	19.8	60.6	12.3	-9.2
Feb/2013	0	51.4	1	-4.9
Mar/2013	0	35.6	-3.9	-9.9
Apr/2013	0	24.4	-12.5	0
May/2013	9.4	28.8	-13.5	4.7
Jun/2013	3.6	26.8	-3.4	1.8

the evolution of the two tendency lines in one year. Since the tendencies are computed with data from three months, there is no tendency data for the first two months.

The first of the manager's assumption can be verified by computing the Pearson correlation coefficient between the two tendencies. For this end, we considered that the effect of the purchase pattern over the stock tendency is delayed by two months. Computing the Pearson correlation of purchase tendency data from Aug/2012 to Apr/2013 with respect to stock tendency data from Oct/2012 to Jun/2013 (2-month delay), we find the value of $r = 0.635$. This means that the manager's are quite right in their assumption: there is a significative positive correlation between the stock tendency in a given month and the purchase tendency two months earlier.

Based on this analysis, the strategy of the Sportswear retailer could be designed. The new priority of the retailer was to reduce excess stock, while continuing to be able to fulfill demands, particularly in special dates such as dates near to important sports events (tournament finals) and Christmas. The strategy of the retailer is modeled as a three-level results-chain. The two main strategic outcomes defined for the retailer's strategy are:

- **Outcome 1: reduced excess stock**
  - *Output 1.1: improved quality of the purchase process*

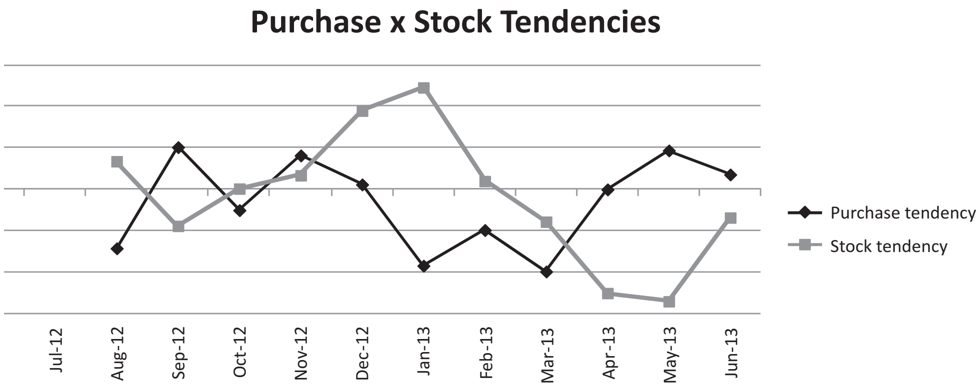

Figure 6.14 Purchase and stock tendencies

- ∗ Action 1.1.1: reduce purchase volumes of products that demonstrate a tendency towards stock growth;

- **Outcome 2: enhanced capacity to fulfill demands**
  - *Output 2.1: improved preparedness to sale in special dates and events*
    - ∗ Action 2.1.1: at special dates, purchased volumes should match historic average sales for that special date.

6.10.2 Implementing an Adaptable Workflow

To implement an adaptable workflow for this case study, we firstly need to determine which work products should be generated to implement the strategic actions. We define the general work product type associated with the strategic actions as being the *purchase order issued*, generated each time a purchase is made. Variables associated with this work product are, “order number”, “items” to be purchased and “purchase volume” of each item. Two constrained work product types are derived from this general type. The constraints are related to the “purchase volume” variable. To implement *Action 1.1.1*, the purchase volume must be lower than the average. We call the constrained work product type corresponding to this constraint as *reduced purchase order issued*. For *Action 2.1.1*, the purchase volume must match the special date’s average. We call this work product type *special date’s purchase order issued*.

These two work product types are connected to the *Purchase Supplies* process. This process contains, among others, two activities in sequence: *Select products* and *Make purchase*. In the first one, the manager navigates through the list of stock items to select the products that he/she intends to purchase. After the products are selected, the *Make purchase* activity requests to the manager the purchase volume of each item. After the *Make purchase* activity, automated activities are executed to send orders to suppliers and so on. The path of the *Purchase Supplies* process that generates both work product types is the two activities sequence: *Select products* $\rightarrow$ *Make purchase*.

Normally, we would redesign the process to include activities and decision rules that implement the sportswear retailer’s strategy. In our approach, we do not change the process, but

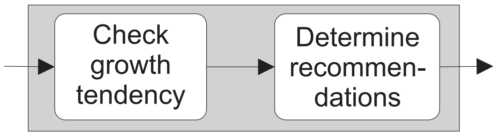

Figure 6.15 Adapter 1 model

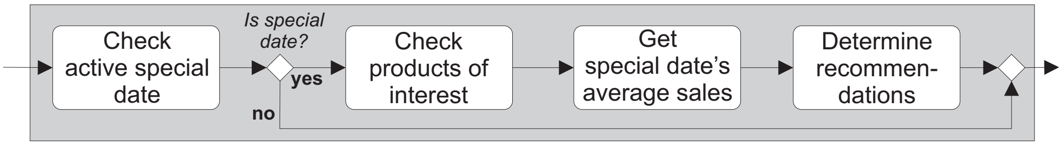

Figure 6.16 Adapter 2 model

left it unchanged. This will be our *core process*. Instead, we design adapters that will include the strategic concerns on this process.

The first task is to create an adapter for each work product type. The first one (Adapter 1) will be responsible for recommending a reduction in the purchase volumes when stocks are growing (Fig. 6.15). To this end, it analyzes the list of purchasing products and queries the *Strategic Context Provider* for their stock tendencies.

The second adapter (Adapter 2) checks whether the current date corresponds to any special date registered in the company's database. If a special date is identified, the system recommends purchase volumes that match the average for that special date (Fig. 6.16). This second adaptation was not fully implemented by the retailer, but it is included here to better illustrate situations were recommendations conflict.

The *Strategic Adaptation Agent* monitors the *Make purchase* activity. When it is ready to be executed, it suspends its execution and triggers the execution of both adapters in parallel. All activities in the adapters are automatic. After their completion, the Context Provider will contain the context of the activity which was computed by them. Both adapters add recommendations regarding the "product" dimension. So, each recommendation address an specific product within the list of products to be purchased.

Next, the Adaptation Agent retrieves the context of the activity and inserts the information into the user interface, to support the manager's decision making. Table 6.4 shows an example of recommendations that may be presented to the user during the execution of the *Make purchase* activity. Observe that there are conflicting recommendations.

Strategic priorities and performance gaps are computed to present a weighted indication to the user. For this example, consider that the first goal's performance has reached 40% of its target, and the second goal's performance has reached 80% of its target. The performance gaps are, respectively, 60% and 20%. Thus, despite the higher priority of the second goal, the urgency to work towards the first goal is evident. To measure how much the recommended work products of Adapter 1 are more important than those of Adapter 2, we apply the AHP method. The decision structure is depicted in Fig. 6.17. The result is displayied in the *ranking* column of the recommendations table (Table 6.4).

Here, we consider *strategic coverage* as important as *performance gap*. This gives weights

Table 6.4 Example of purchase volume recommendations

Dimsension: Product	**Recommendations**	**Strategic Action**	*Rank*
Football T-Shirt Brazil	Due to World Cup event, it is recommended to purchase volumes matching average of 100/month.	At special dates, purchased volumes should match historic average sales for that special date.	0.46
MMA Gloves Red	Reduce purchase volumes due to a tendency to excess stock (growth rate of 8% in stock size).	Reduce purchase volumes of products that demonstrate a tendency towards stock growth.	0.54
Woman's Swimwear VS Basic	Reduce purchase volumes due to a tendency to excess stock (growth rate of 12% in stock size).	Reduce purchase volumes of products that demonstrate a tendency towards stock growth.	0.54
	Due to Spring Break, it is recommended to purchase volumes matching the average of 150/month.	At special dates, purchased volumes should match historic average sales for that special date.	0.46

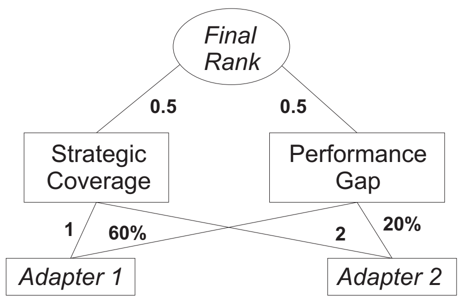

Figure 6.17 AHP structure for ranking recommendations

0.5 for each of these two criterion. Observe that, if a product appears in the recommendations, it means that each adapter has already checked whether the recommendation applies to it or not. The final ranks are calculated as below. The result shows a higher importance for the recommendations of Adapter 1.

$$\begin{array}{c} \\ Adp.1 \\ Adp.2 \end{array} \begin{array}{c} \quad Str.Cov. \qquad\qquad Per.Gap \\ \begin{pmatrix} 1/3 = 0.33 & 0.6/0.8 = 0.75 \\ 2/3 = 0.67 & 0.2/0.8 = 0.25 \end{pmatrix} \end{array} \times \begin{array}{c} \\ S.C. \\ P.G. \end{array} \begin{array}{c} Weights \\ \begin{pmatrix} \quad 0.50 \quad \\ \quad 0.50 \quad \end{pmatrix} \end{array} = \begin{array}{c} Rank \\ \begin{pmatrix} 0.54 \\ 0.46 \end{pmatrix} \end{array}$$

6.10.3 Evaluating the Performance Results

The objective of the adapter implemented in this case study was to ensure that the historic tendency of stock growth was used to decide which purchase volumes should be ordered. The effective intervention of the SA-BPM approach in the retailer should be reflected by a higher correlation between the purchase decisions and the current stock tendency.

The data collected from the retailer corresponds to one year of their operations. The SA-BPM approach was implemented in the last three months, from Apr/2013 to Jun/2013. To evaluate the impact of the SA-BPM in the daily operations of the company, we can compare how the stock tendency in a given month is correlated to the purchase volumes of the next month. To this end, we compared data from the six months before SA-BPM was implemented (Sep/2012 to Mar/2013) against data from the final six months (Dec/2012 to Jun/2013), which is a period affected by the adapter's recommendation.

Before the SA-BPM approach was implemented, the Pearson correlation between stock tendency in a given month and next month's purchase tendency was $r_{before} = -0.416$, meaning that a growing stock tendency had a weak impact in decreasing purchasing tendency. After the addition of the adapter, this number was $r_{after} = -0.801$, meaning that there is, now, a *strong* correlation between the stock tendency and the purchase tendency. When the stock tendency is growing, the purchase tendency decreases.

The data show that the adapter's recommendations actually impacted the organization, influencing the purchase decisions. This is the objective for which the adapter was designed for.

We can now measure the performance of the company regarding the problem of excess inventory. Fig. 6.18 displays the evolution of the excess inventory measure. This measure is computed by the sum of the stocks of the five prioritary products in this study, subtracted by what should be their normal stock levels. The graph shows that, in the last three months, the measure reached values below the past year's minimum. The average excess stock from Jun/2012 to Mar/2013 is 135.1 products, while in the last three months the average value is 43.3 products. However, an earlier tendency of stock reduction can be observed even before the adapter was in place. Therefore, it is not possible to conclusively affirm that the SA-BPM approach was the cause (or the major contributor) of this reduction. A longer observation period would be necessary to adequately measure its influence.

Fig. 6.19 displays the average stock variation along time. The variation is the difference between the stocks of two consecutive months. The graph shows that the average variation of the five prioritary products was reduced in the last three months. This indicates a possible effect of the SA-BPM approach in stabilizing the stock levels. Again, only a longer observation period would conclusively prove this affirmation.

The sportswear retailer's owners reported that their subjective impression is that the new version of the process has really helped them with the issue of excess stock. However, other market and financial constraints have also affected the company's performance in this period, which prevented them from fully experiencing the benefits.

Figure 6.18 Excess Inventory

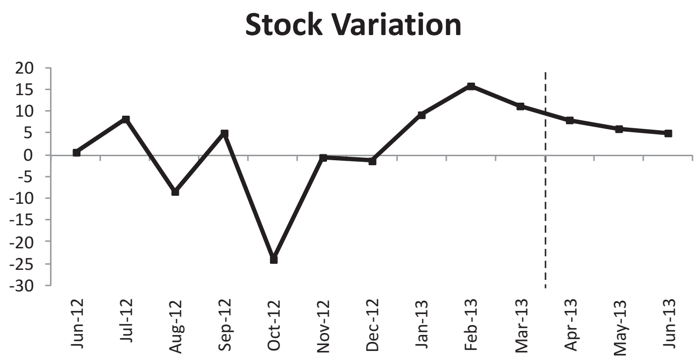

Figure 6.19 Average Stock Variation

6.11 Reflection

The architecture for SA-BPM proposed in this chapter fulfills most requirements to mitigate the effects of uncertainty in an organization. Drawing from the guidelines proposed in Chap. 5, we address several issues raised by environmental uncertainty. Thus, an organization that adopts our SA-BPM approach experiences an improved strategic flexibility and is better supported to deal with changing and turbulent environments. This is illustrated in Fig. 6.20, where we display the elements of the architecture and the guidelines addressed by each one.

The Strategic Context Provider supports guidelines 1, 7, and 8 in the following manner:

- **Guideline 1** - *store strategy models and disseminate goals*: the Context Provider is the central module where strategic goals are stored and from which they are distributed. The SA-BPM architecture assures that these goals will be presented to the user when the activities being performed by them require it;
- **Guideline 7** - *implement statistical methods to confirm or discard hypotheses*: the strategy model stored by the Context Provider can be automatically translated into a path diagram to support statistical correlation analysis (using the PLS-PM method). Moreover,

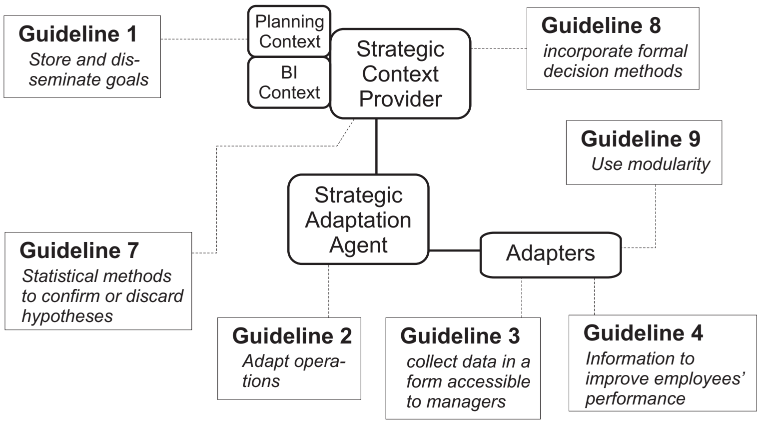

Figure 6.20 Relationship between architecture and uncertainty mitigation guidelines

methods for computing the correlation between work product variables and performance indexes have also been presented;

- **Guideline 8** - *incorporate formal decision methods in business processes*: the AHP decision method is incorporated by the SA-BPM to rank recommendations. This gives objective information to the user about which recommendations have higher priority for the organization at a given time. The Context Provider has all the information to construct the AHP model and compute the rankings.

The Adaptation Agent and the Strategic Adapters support guidelines 2, 3, 4, and 9 as follows:

- **Guideline 2** - *adapt operations to improve alignment*: this is the main purpose of the Adaptation Agent;

- **Guideline 3** - *collect data in a form directly accessible by managers*: the adapters interpret the strategy under the operation's perspective. They "know" exactly how the strategy impacts the operation, and vice-versa. They store this information in the Activities Context, which is logged by the Context Provider for future analysis. The information so computed shows a clear linkage between goals and operations;

- **Guideline 4** - *provide the information necessary to improve employees' performance*: strategic recommendations are computed by adapters and offered to the user to inform them how to contribute to the strategic goals during the execution of their activities;

- **Guideline 9** - *use modularity*: the Adapters comprise a modular solution that allows for the rapid reconfiguration of strategies, reducing costs and time-to-market of strategic changes.

Guideline 10 is indirectly supported due to the integration of strategic planning and performance management systems into the SA-BPM framework. Since developers cannot create adapters without a corresponding strategic action and performance measures, then they need to synchronize what the manager gets from these tools and what the adapters can do.

Guidelines 5 and 6 are not covered by the SA-BPM architecture. To implement them we propose a methodology developed by us to improve strategic flexibility. This methodology is presented in Chap. 8.

6.12 Summary

In this chapter, we introduced the concept of **Strategy-Aware Information Systems** (SAISs) and developed the theoretical foundations and architecture for **Strategy-Aware Business Process Management** (SA-BPM) systems. SA-BPM systems are SAISs specifically designed for BPM. A case study was also presented to evaluate the benefits of SA-BPM.

SA-BPM provides a novel design approach for business processes that reduces the efforts for the maintenance of business processes when strategies change. This argument was demonstrated valid through a metric that measures strategic maintenance efforts for business process models.

Moreover, our architecture for SA-BPM systems is flexible and modular, and is based on design patterns currently in use in the context awareness research field. The architecture is composed of three main elements: the **Strategic Context Provider**, the **Strategic Adaptation Agent**, and the **Strategic Adapters**. The role of the Context Provider is to connect the SA-BPM system with the strategic planning and performance management systems of the company. This enables the communication between management support systems (planning and BI) and BPM systems. The Adaptation Agent, on the other hand, is the entity responsible for adapting the company's BPMS, making it able to execute processes in the SA-BPM approach. Through such an architecture, any regular BPMS can become a SA-BPM system. This can be achieved through the construction of an Adaptation Agent that interacts with the target BPMS to control the creation and updating of process instances.

The following contributions of our approach can be enumerated:

1. it formalizes the concept of strategy and its linkage to BPM;
2. it enables companies to better implement, analyze, and propose strategic changes through an integrated view of business processes and business goals;
3. it helps to reduce the maintenance efforts for business process models through a design approach that improves the capacity to deal with change;
4. it offers methods for a better monitoring of business results through the establishment of analytic metrics that measure the impact of business process activities over results.

Strategic flexibility is essential to enable a sustainable competitive advantage in uncertain and changing environments [38]. Strategy-aware business process management facilitates strategic change and strategic alignment tasks, and implement most guidelines for uncertainty mitigation proposed in this thesis. As such, they provide an adequate infrastructure to support strategic flexibility.

CHAPTER 7

ROSAS: Results-Oriented Strategy Automation System

It's time you realize dear one, that life is short and fleet
So plan today to take the time, to smell the roses sweet.
— (A. P. Hancock, To Smell The Roses Sweet)

7.1 Overview

Strategy-Aware BPM (SA-BPM) systems can offer new capabilities to companies that want to sustain their competitive advantage in turbulent environments. In this chapter, a prototype implementation of an SA-BPM system is presented. The objective is to demonstrate the feasibility of the design proposed in Chap. 6.

The system developed by us is called *ROSAS: Results-Oriented Strategy Automation System*. The BPMS and BI system adopted in the construction of ROSAS are widely known open-source tools that have been in use by large companies worldwide: *Bonita BPM*, from **BonitaSoft** (`www.bonitasoft.org`), and *Pentaho Business Analytics* (BA), from **Pentaho Corporation** (`www.pentaho.com`).

In the following sections, we describe the basic features of the Bonita BPM system, then we explain how ROSAS was constructed and how it integrates to BonitaSoft's BPMS to create an SA-BPM system.

7.2 Bonita Business Process Management System

The business process modeling and execution features in ROSAS are provided by the underlying *Bonita BPM system*. On top of that, we build the "*strategy awareness*" infrastructure, i.e., the architecture for SA-BPM systems described in Chap 6. The Bonita BPM System is an open-source business process automation solution produced by *BonitaSoft*. It offers several useful features that facilitate process design and application integration.

Bonita's *business process modeling interface* supports process modeling in the Business Process Modeling Notation (BPMN). The modeling interface is illustrated in Fig. 7.1.

Bonita also features a *form designer*, in which the process designer can design the screens that are displayed to the end user during the execution of manual activities. A script language is available to the process designer, through which he/she can dynamically manipulate process

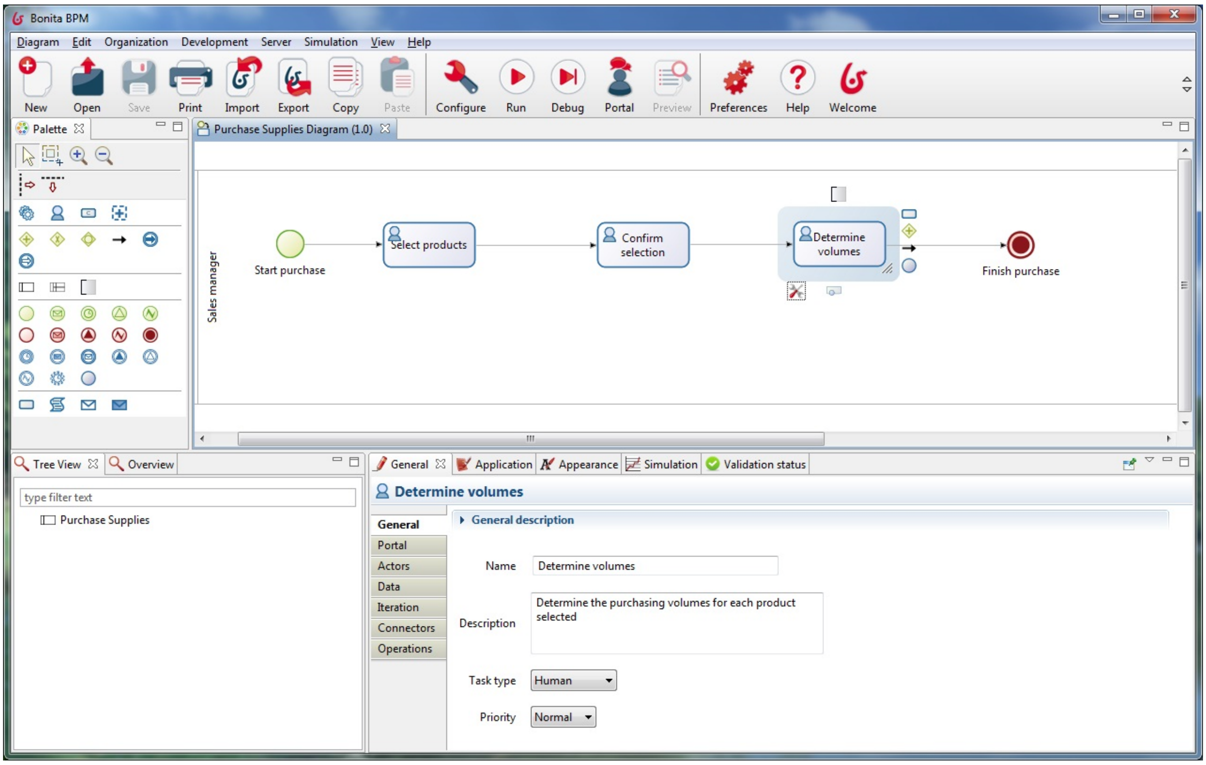

Figure 7.1 Bonita BPM modeling interface

instance data to populate the form's components and process the data inputed by the user. The form designer is illustrated in Fig. 7.2.

Through the so-called *connectors*, Bonita allows the access to external applications, such as databases, web services, e-mail servers, file systems, among others. Custom connectors can also be included in the system. This enhances the range of capabilities of the tool.

The user starts and interacts with process instances through a web interface, called *Bonita Console*. This interface is illustrated in Fig. 7.3. The Console lists all pending tasks that can be executed by the user. Each task corresponds to a pending activity in a business process instance. When the user starts a process or task, the Console presents the forms that were designed by the process modeler. If no form is provided by the modeler, Bonita automatically generates an input form based on the process variables.

The Bonita Console interface is a rich-client web application (RIA) integrated to Bonita's process engine. The Console's web interface is defined internally in a set of web page templates that can be edited by the user. It is possible to assign a different template to each process. By editing these templates, the user can insert new components into the interface, execute scripts, and interact with the default components provided by the Bonita framework. Such flexibility was explored by us to insert into the user interface the ROSAS's components, as will be detailed in next sections.

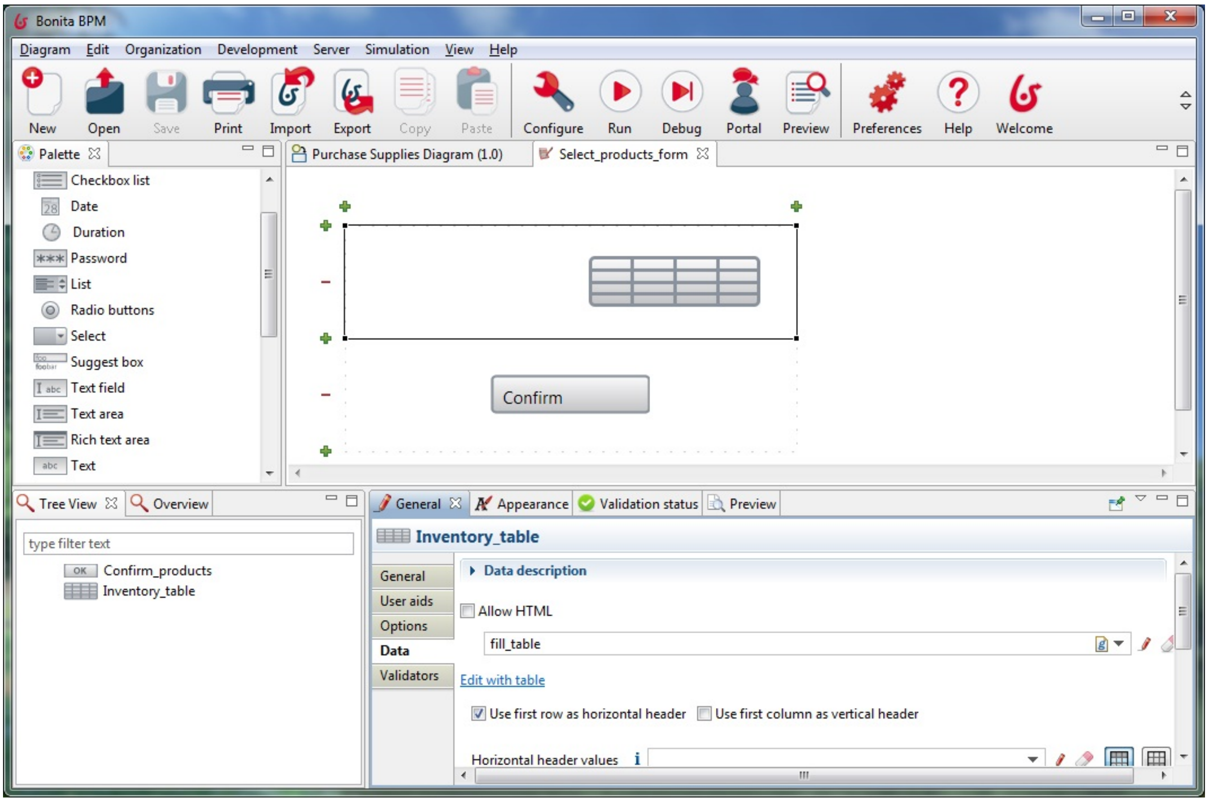

Figure 7.2 Bonita BPM form design interface

7.3 Strategic Planning and Performance Management Systems

ROSAS was constructed according to the concept of a four-level results-chain, incorporating the ROM (results-oriented management) approach. Thus, the strategy model stored by ROSAS' Context Provider is composed of *impacts*, *outcomes*, *outputs*, and *actions*. Each one of these *strategic elements* is associated with performance indicators, for which baseline and target performance values are also defined.

ROSAS does not include a strategic planning tool, since it assumes that the strategic planning tool is an external tool to which it must connect. This connection is made through a database that stores the strategy model that would be designed through such a planning tool. Although ROSAS do not offer features to edit strategies, it includes a visualization tool that displays all strategic elements and the elements to which they contribute (the contribution trace). This visualization is illustrated in Fig. 7.4. The visualization tool is used to disseminate the strategy to employees.

The performance management system supported by ROSAS is Pentaho's BA solution. This tool employs the concept of *On-Line Analytical Processing* (OLAP). In OLAP, data is stored in **cubes**. Each cube is composed basically of dimensions and measures. Consider, for example, that someone wants to know the amount of sales of product X, in country C in the year Y. In OLAP terms, this information is stored in a cube, possibly named "*Sales*", in a location pointed

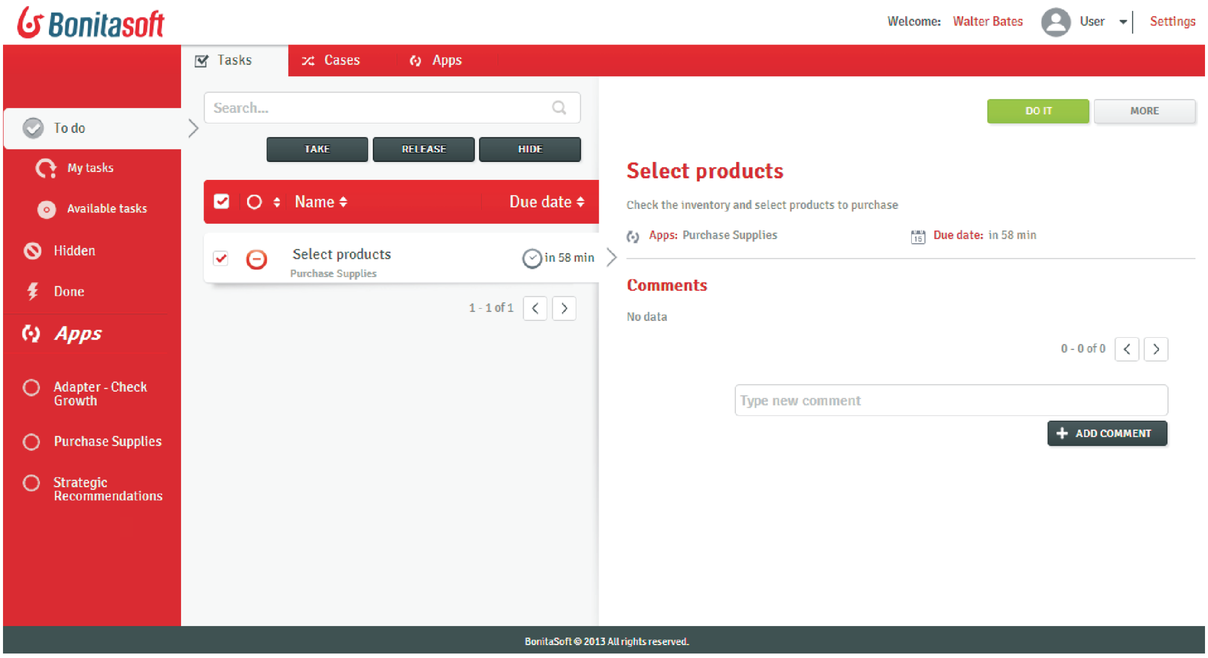

Figure 7.3 Bonita Console: the web-based user interface for Bonita BPM

by the member X of the "*product*" dimension, member C of the "em country" dimension, and member Y of the "*year*" dimension. The value captured could correspond to the "*amount of sales*" measure of this cube.

All indicators recognized by ROSAS must be valid measures from valid cubes stored in the Pentaho BA system. ROSAS' Context Provider communicates with the Pentaho BA system through the MDX (Multidimensional Expressions) language. Any information that can be retrieved by managers through Pentaho can also be obtained through ROSAS' Context Provider, and vice-versa.

7.4 Architecture of ROSAS

This section describes how the SA-BPM architecture is implemented by ROSAS. An overview of ROSAS' architecture is depicted in Fig. 7.5. Observe that ROSAS is composed of the three elements that comprise an SA-BPM system: the Strategic Context Provider, the Strategic Adaptation Agent, and the Adapters. The Context Provider enables the communication of the adapters with the strategy database and with Pentaho. The Adaptation Agent manages the interaction between Adapters and the Bonita BPM process engine.

Each component of ROSAS is described in detail in this section.

7.4.1 Strategic Context Provider

ROSAS' Strategic Context Provider is the module responsible for storing and distributing the strategy model, performance data, and context information. This is done through a web in-

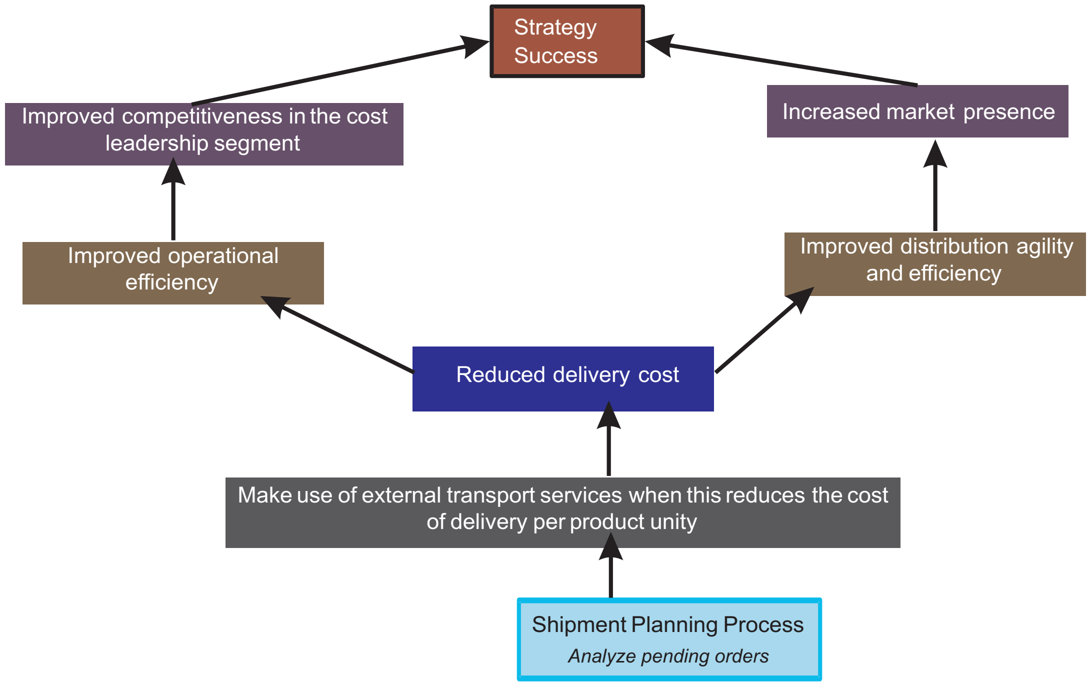

Figure 7.4 Visualization of a contribution trace in ROSAS

terface. The other modules of ROSAS retrieve context data through the HTTP protocol. The information is transfered between the Context Provider and other modules using the JavaScript Object Notation (JSON) format. A JSON message describes an object in plain text, using a notation that can be interpreted by the Javascript and other script languages. ROSAS' Context Provider recognizes the following types of objects:

- **Context Event**: an object that updates information about the context of an activity instance. The Context Event object can describe three types of events:
  - *Recommendation*: a recommendation computed by an adapter, which refers to certain dimension (such as customer, order, product) and dimension's member;
  - *Information*: arbitrary, unstructured, information to be displayed to the user;
  - *Completion*: informs the conclusion of an activity instance and transports the values of all variables of the process instance after the conclusion of the activity.
- **Context Request**: retrieves all context information for a particular activity instance, including performance measures;
- **Indicator Request**: retrieves the value of a performance indicator, possibly applying filters to its dimensions. This request can result in an array of values, for example, with the evolution of the indicator along time;
- **Adapters Request**: retrieves the list of adapters registered in the system;

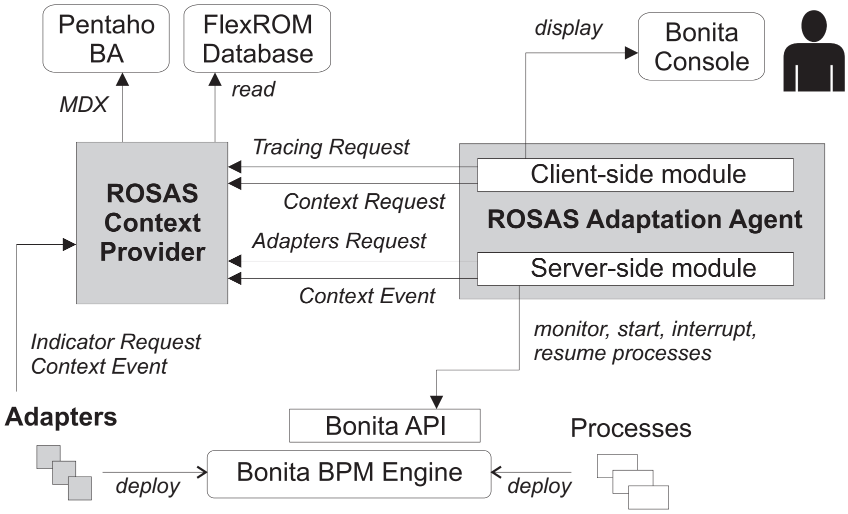

Figure 7.5 Architecture of ROSAS

- **Tracing Request**: retrieves a trace of the contributions of all strategic elements of the strategy or of all elements that are linked to an activity instance.

To retrieve performance data, ROSAS' Context Provider captures the information about the *cubes* stored in the Pentaho BA system and uses the MDX language to extract the indicators desired. To allow this, each indicator is described by a cube and a measure from the cube (e.g., "*amount of sales*" from the "*Sales*" cube). This allows ROSAS to construct the MDX expression required to retrieve the performance data. If adapters require data from specific slices of the cube, they issue an *Indicator Request* defining the dimensions that are required. The request object is then converted to an MDX expression by the Context Provider.

Besides collecting and distributing the context information to other modules of ROSAS, the Context Provider also has the task of logging the information about all activities that were concluded to allow for future audition. This task is performed when the *Completion Event* is received.

7.4.2 Adapters Construction

Adapters are developed using the Bonita process modeler, just like any other process model. Fig. 7.6 shows an example of adapter process model designed in Bonita. To retrieve and store context information, the adapters can use the connectors provided by Bonita to query the Context Provider using HTTP GET and POST methods. Each adapter defines its target process' name and version, and the activity inside the process that triggers its execution.

In order to ROSAS to recognize the adapters, they need to be registered in the Context Provider. The Adaptation Agent access the context to check which adapters should be executed in the context of a given process instance and to figure out which strategic elements each adapter is associated with.

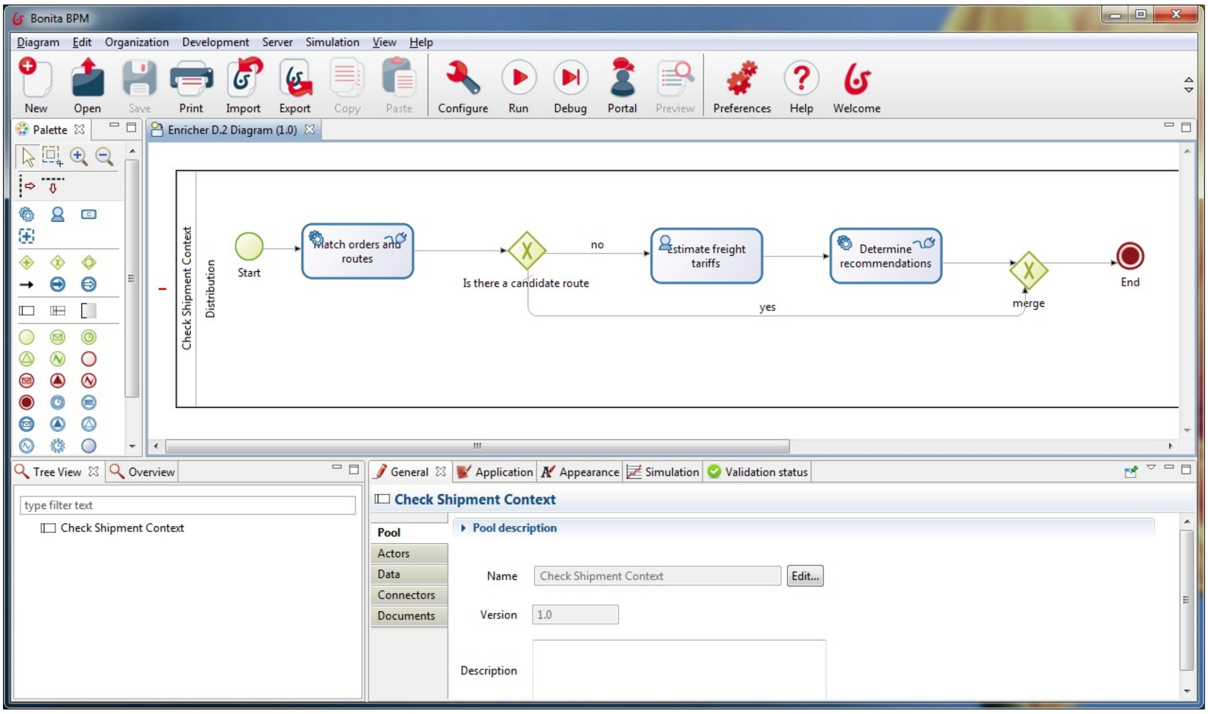

Figure 7.6 Example of an adapter in Bonita

7.4.3 Strategic Adaptation Agent

ROSAS' Adaptation Agent is divided in two parts: a server module and a client module. The server module monitors and controls the Bonita BPM engine. The client module executes at the client side to retrieve information about the activity's context and present this information to the user. Since Bonita's user interacts with the engine through a web page, the client side Agent runs in the user's browser.

The connection of the Adaptation Agent to the BPM engine occurs in the server side through the Bonita API (*Application Programming Interface*). This API is provided by the Bonita BPM system to allow external applications to have access to the engine. Through it, ROSAS can log into the system, retrieve the list of available processes, retrieve the list of running process instances and activity instances, start processes, execute activities, and even deploy new process models. All operations that can be performed by the user in the Bonita Console can also be executed by ROSAS through the Bonita API.

The Adaptation Agent performs adaptations at run-time, according to the following algorithm. An overview of this mechanism is depicted in Fig. 7.7.

1. when a new instance of the activity is created in the *ready* state, the monitoring component changes its state to *interrupted*. This is a state internal to the Bonita engine that prevents the user from executing the activity;

2. next, all adapters that have that activity as target are started. When doing this, ROSAS sets the values of each adapter's process variables to the same values of the variables of

the interrupted instance. Thus, each adapter has access to the variables of the original process being executed;

3. the running adapters may store strategic recommendations in the Context Provider's storage area;

4. once *all* adapters have completed, the agent *recovers* the interrupted activity and sets it again to the *ready* state. The user can then continue the execution of the process;

5. when the user access the activity's entry form on Bonita Console (using a web browser), the client module inquiries the Context Provider to look for context information. Any information found is inserted in a component added to Bonita Console that display this information to the user;

6. as soon as the activity is completed, the Adaptation Agent informs the Context Provider about the completion of the activity, which concludes the adaptation.

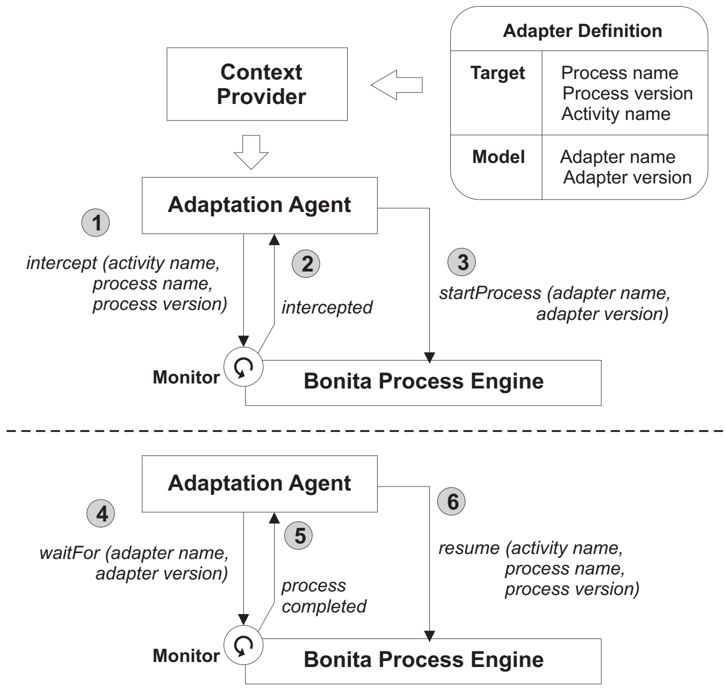

Figure 7.7 Sketch of the adaptation mechanism (server-side only)

The client module of the Adaptation Agent is implemented in an alternative HTML template for the Bonita Console. This alternative template adds to the web interface the ROSAS component, which displays strategic information. The HTML template is merged with the Bonita Console web interface and adds both visual elements and scripts to Bonita's web page (Javascript). The scripts communicate with ROSAS' Context Provider using the HTTP protocol. Thus, the client-side Adaptation Agent is a collection of HTML templates and javascript programs that run in the user's browser to communicate with the server and adapt the user interface. The following information is displayed to the user when he/she executes the activity:

- **strategic recommendations**: all recommendations computed by adapters;
- **strategic links**: the strategic elements that justify the recommendations displayed. This component provides a link for the visualization of the results-chain, which shows how that recommendation is contributing to outputs, outcomes, and impacts of the strategic plan;
- **performance indicators**: the performance indicators that measure the performance of the operations being executed by the user, along with its current measure and the strategic target.

An example of screen displayed to the user with this information is shown in Fig. 7.8.

Figure 7.8 ROSAS panel displaying context information in the Bonita Console interface

7.5 Summary

This chapter described ROSAS, our prototype implementation of an SA-BPM system. ROSAS is a solution that is built upon two professional enterprise systems: Bonita BPM and Pentaho Business Analytics. Both are widely known systems that have been employed by several large organizations: Bonita has been used by *accenture*, *DirecTV*, and *Xerox*; Pentaho has been used by *Lufthansa*, *Strato*, and *Mozilla*.

ROSAS integrates these existing systems, transforming then into a SA-BPM solution. To this end, ROSAS provides a Strategic Context Provider that collects information from Pentaho and deliver it to strategic adapters. The Adaptation Agent coordinates adapters and interacts with Bonita BPM to perform the necessary adaptations at run-time. In this chapter, we discussed the technical details of this mechanism.

Although the concept of SA-BPM systems is richer than what ROSAS is able to perform, this prototype is sufficiently complete to demonstrate the feasibility of the architecture proposed in this thesis.

PART III

Transferring Technology to Business

CHAPTER 8
Methodology for Strategy Management in Uncertain Environments

Now, the general who wins a battle makes many calculations in his temple, where the battle is fought. The general who loses a battle makes but few calculations beforehand. Thus, many calculations lead to victory, and few calculations to defeat: how much more no calculation at all! It is by attention to this point that I can foresee who is likely to win or lose.
— (Sun-Tzu, The Art of War)

8.1 Overview

It is a consensus among information systems researchers that technology alone does not determines the success of an organization [33, 86]. It is of prominent importance that the organization develops the capacity to employ IT in the "right way" [33, 91, 120]. Moreover, strategic flexibility, the core subject of this thesis, requires not only resources that can be adapted and reconfigured [110], but also a strategy management methodology that is dynamic and open to change [38, 106].

To fully exploit the benefits of the SA-BPM concepts proposed in this thesis, a *flexible* strategy management methodology is important. Despite SA-BPM technology facilitates the process of change, a bureaucratic planning culture may completly undermine its benefits.

We introduce in this chapter a new methodology for strategic management that integrates with SA-BPM to improve the strategic flexibility of the organization. The methodology is called *Flexible Results-Oriented Management* or **FlexROM**. It is inspired by the Results-Oriented Management (ROM) style [102] and by literature findings on the subject of strategic planning in uncertain environments (see Chap. 2).

8.2 FlexROM: Flexible Results-Oriented Management

A flexible strategy management methodology is one in which plans are not fixed, but may evolve and change to respond to environmental necessities [104, 106]. Management research literature shows that decentralized decision making and incremental planning are two major characteristics of flexible management [6, 12, 40, 106]. However, empirical works also identified that formal plans composed of goals and performance targets are not abandoned by organizations, even in unstable environments [6, 12]. On the contrary, these instruments have shown an important role in improving strategic focus and long-term benefits [119].

FlexROM, the Flexible Results-Oriented Management methodology, is a methodology proposed by us to implement these directions and foster the benefits achieved through SA-BPM.

FlexROM is built on top of the ROM methodology and employes the concept of a results-chain of four levels: impacts, outcomes, outputs, and actions. Then, it expands the concepts of ROM and introduces the notion of incremental planning and decentralized decision making. The principles adopted by FlexROM are the following.

- *Impacts and outcomes that are good today, may not be as good tomorrow.* Changes in the market and economic environments may affect the long-term goals of the company and may require large changes in its strategic plans. Even if the environmental conditions do not change, the company may gain more experience to improve its strategical focus;
- *Functional managers are the best to decide what their functional unit can do.* Quick responses to market changes require people that are well informed about the company's operations. Functional managers are the first to know when the operations of their unit are not working as expected and can react more quickly to these events.
- *Managers' assumptions must be continuously under verification.* The assumptions taken by the managers when making strategic choices may turn out to be wrong, due to the uncertainty of the environment. Continuous verification avoids biased assumptions and overconfident attitudes;
- *One may decide to change the outputs to be produced, yet stay committed to the current outcomes.* Outputs and outcomes are not tightly coupled, in the sense that the same outcome can be produced by different outputs.
- *Performance targets and continuous performance assessment improves organizational focus.* Working towards clear performance targets ensures an overall organizational integration and focus. It is also a mechanism to drive operational optimization and employee engagement.

Since FlexROM proposes the continuous improvement of the strategy, the continuous adaptation of operations is also required. The SA-BPM approach is employed to translate strategic requirements into operations. Each cycle of strategic assessment and improvement also demands a cycle of improvement and updating of business processes. Thus, the FlexROM methodology can be defined by the combination of two lifecycles: the *Managers' Cycle* and the System *Developers' Cycle*.

8.2.1 The Managers' Cycle

At the managers' level, the FlexROM methodology defines two main roles:

- **top manager**: corresponds to the company's CEO, the corporate board of directors, and top-level managers that directly respond to them;

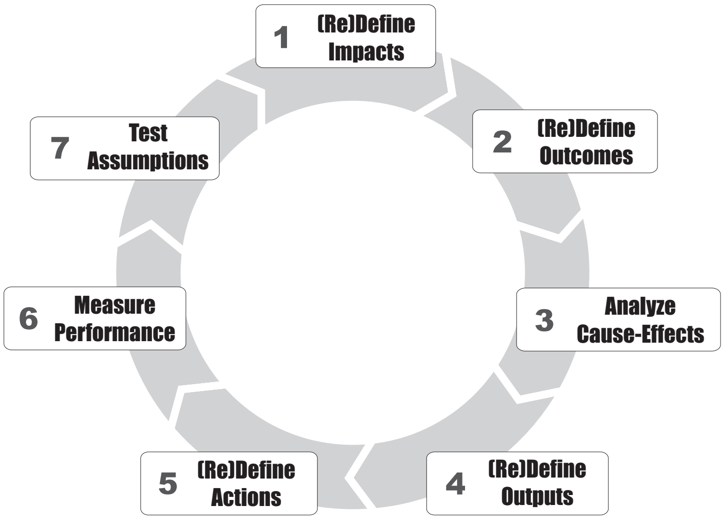

Figure 8.1 FlexROM Managers' Cycle

- **functional manager**: a manager that is responsible for an organizational unit, such as a department or a division.

The FlexROM Managers' Cycle is represented in Fig. 8.1. The steps in this cycle will be described in more detail at this point.

1. **(Re)Define Impacts** - taking into account the current company's context, determine if its long-term vision (i.e., expected impacts) is still valid and attainable. If not, new impacts or changes to current impacts must be defined. This is an activity performed by top managers.
2. **(Re)Define Outcomes** - determine which outcomes should be generated to produce the impacts; discuss the effectiveness of current outcomes and their capacity to produce the results expected. Top managers should involve relevant stakeholders in this discussion.
3. **Analyze Cause-Effects** - study the company's operations and identify cause-effect relationships that connect operations and their business outcomes (e.g., identify production problems that have as outcome an increased number of customer complaints).
4. **(Re)Define Outputs** - analyze the relationship between a unit's outputs and the strategic outcomes proposed. Change or improve each output's definition when necessary. Functional managers should be granted autonomy to determine the outputs of their functional unit.
5. **Define Actions** - evaluate current actions being taken by the organization and determine which actions can deliver the outputs proposed. Acquire the resources and competences necessary to perform these actions. This is a responsability of functional managers.
6. **Measure Progress** - progress is measured at two levels:

(a) Efficiency of Production - analyze the performance indicators associated to the production of the **outputs**. The following question should be investigated: *Is the company producing the expected outputs within the time and budget constraints?*

(b) Results - analyze the strategy's results, which are expressed by the outcome and impact *indicators*. The following question should be investigated: *Is the company moving forward toward its goals?*

7. **Test Assumptions** - analyze the degree of correlation between the outputs produced and the outcomes being achieved. The goal is to objectively find an answer to the question: *Are the outputs really producing the expected strategic results?*

This cycle reflects a combination of formal, incremental, and generative planning approaches [8, 12]. Impacts and outcomes define the goals. Such goals are incrementally improved at each cycle. In turn, functional managers have the autonomy to decide which outputs their unit will produce to achieve the outcomes established by top managers. Thus, top managers are focused mostly on performance monitoring (phases 1, 2, 6, and 7). Steps 6 and 7 must also be performed by functional managers to continually improve their operations.

Functional autonomy is a characteristic that is strongly correlated with organizational agility and flexibility [6]. However, without proper coordination and integration mechanisms, this characteristic may be harmful to the company [119]. In this regard, the FlexROM methodology proposes two mechanisms to support the communication between top-level and functional-level managers: alignment constraints and business intelligence. The alignment constraints define coordination requirements and dependencies between outcomes. Functional managers must define their actions in conformance with these requirements. The business intelligence, on the other hand, comprises a collection of data mining and analysis methods that can be used to measure the efficiency of functional managers' actions.

Figure 8.2 presents a graphical overview of the communication between top-level and functional-level managers in the FlexROM methodology. Here, the results-chain is split into two parts: in the upper part are the top managers concerns: impacts and outcomes; in the bottom part are the functional managers concerns: outputs and actions. The alignment constraints and business intelligence "forces" act as communication channels between these two parts. Through these channels, concerns from the top managers reach the functional managers. Moreover, in the reverse direction, functional managers communicate to the top managers their achievements and requests. This synergy provides flexibility to functional managers while keeping top executives in track of what outputs are being produced and their corresponding influence in the company's goals.

As an additional control mechanism, the definition of 'outputs' can be tied to the budget control process of the firm. Thus, functional managers would be required to define outputs and efficiency measures to their own activities in order to receive the financial support necessary to execute them. This ensures a coherent application of the framework in all units and enables top managers to evaluate the investments made and the corresponding results achieved.

The Managers' Cycle ensures the continuous review of strategies and their performance. The Developers' cycle ensures that the strategic directions will be fastly implemented in the SA-BPM system.

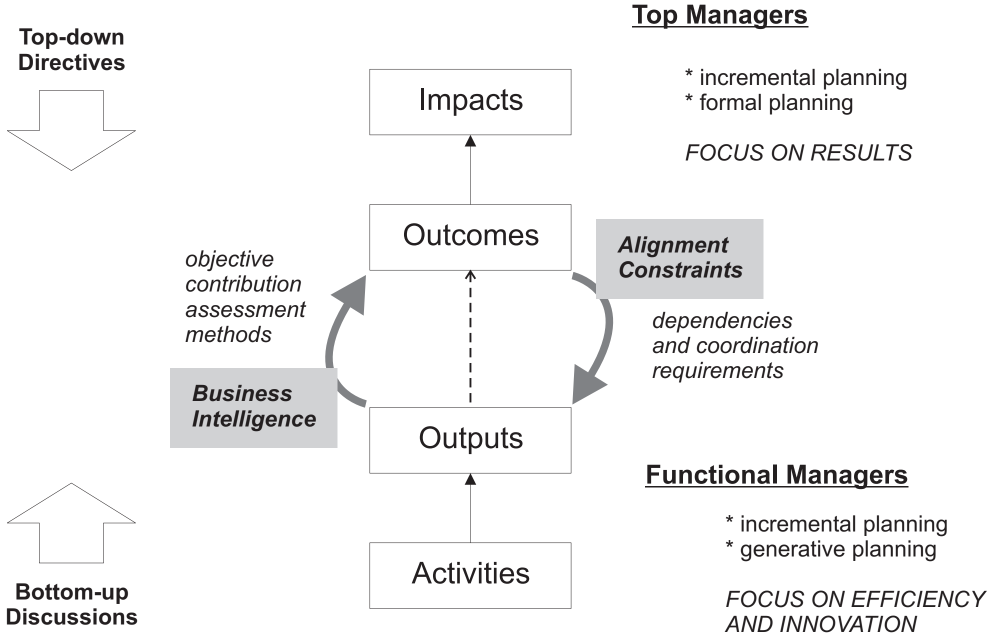

Figure 8.2 Communication between top-level and functional-level managers

8.2.2 The Developers' Cycle

While managers' functions are focused on monitoring and continually updating strategies in response to environmental changes, the role of developers is to implement the strategic changes in the business process portfolio of the firm. The system developers have the task of translating business demands into software applications.

The FlexROM Developers' Cycle defines what are the main tasks performed by a firm's IT unit when strategies are changed. This cycle involves three roles:

- **business analyst**: responsible for analyzing the company's strategic actions and identifying which work products should be generated and which processes are connected to them;
- **database analyst**: responsible for designing data schemes and queries to enable the computation of performance indicators. The database analyst also analyzes the work products and define how they are stored in the company's databases for future analysis;
- **business process developer**: responsible for designing adapters that help generate the work products and strategic recommendations necessary to implement the actions proposed by the functional managers.

The FlexROM Developers' Cycle is represented in Fig. 8.3. It is composed of the following steps:

1. **Analyze Actions and Determine Work Products** - determine which work products correspond to each action, how they must be generated, and which recommendations should be given to employees in each situation;

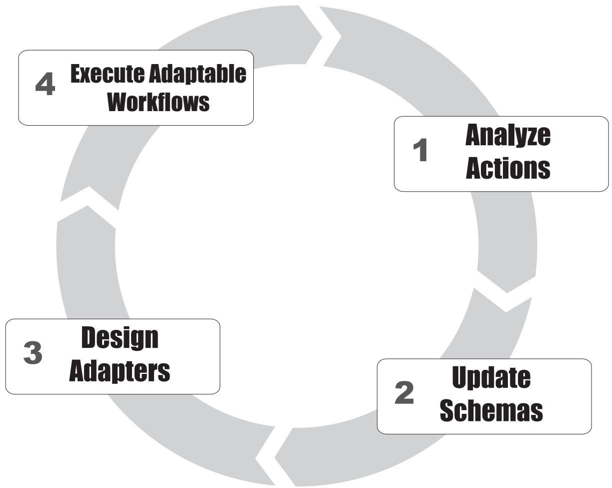

Figure 8.3 FlexROM Developers' Cycle

2. **Update Database Schemas and Queries** - design schemas and queries to support the computation of performance indicators and other information necessary to implement adapters and to measure the performance of the strategy;

3. **Design and Test Adapters** - design, develop, and test adapters;

4. **Deploy, Execute, and Monitor Adaptable Workflows** - deploy adapters and connect adapters to processes, enabling the execution of adaptable workflows. Monitor the execution of adaptable workflows.

The developers' tasks are supported by the SA-BPM System. For example, in ROSAS, the database analyst defines and cofigures database schemas and performance indicators in the Pentaho platform. Once new indicators or new data schemas are inserted into Pentaho, they are immediately available both to managers and software developers.

The business process developers, in turn, construct adapters using the Bonita BPM Modeling interface. Through Bonita, they can write scripts that communicate with ROSAS' Context Provider to get information about the strategy and the performance of the company. The information retrieved from these sources is used to determine decisions during process enactment.

It is the task of the Business analyst to define the requirements for the adapters and to specify the information that should be handled by the database analyst. The SA-BPM approach proposes the use of the concept of work product types to support the role of the analyst. Thus, the analyst firstly identifies which work products fulfill the strategic needs of the organization. Then, he/she identifies which business processes are connected to those work products. ROSAS can also generate the trace of contribution of these processes to inform the Business analyst about which strategic actions are currently implemented by the SA-BPM system.

The Developers' Cycle is triggered by changes in the strategy, but is also an independent cycle of continuous monitoring and improvement of software systems that support the current strategy of the organization.

8.3 Pursuit and Evolution of a Results-Chain Along Time

Until now, our discussion about SA-BPM concepts has focused on models about the current strategy of the firm. The results-chain, formally introduced in Chap. 6, is defined as a static structure. However, our major interest is on strategies that are frequently changing.

To adequately model the scenario in which the FlexROM methodology is applied, we need to expand our definitions and represent the evolution of a results-chain along time. We approach this subject now.

The pursuit of a results-chain is the act of start executing the corresponding strategy in an organization and managing its execution.

A *pursuing results-chain* has **states** associated with its elements, which may change along time. The state of an element is a dynamic property that interprets the definition of an element from the point of view of its execution. An example of state is the *achieved* state, which means that the objectives proposed by the element have been achieved. This property only makes sense when we consider the results-chain in its dynamic nature, as a collection of objectives and goals that are being pursued by the firm.

Moreover, in each moment t, a performance indicator $p_k = \langle f_k, x_{k0}, x_{kt} \rangle$ has a determined **value**, given by $f_k(t)$. As performance indicators measure the progress of the strategy at a certain point in time, when we deal with a dynamic environment, these indicators must assume actual values in each point in time. This situation is formally defined as follows.

Definition 8.1 (Pursuing Results-Chain)**.** *A pursuing results-chain is a tuple* $\langle Q, S_t, \chi \rangle$*, where*

- $Q = \langle R, I, \Pi, \mu \rangle$ *is a quantitatively managed results-chain, with* $R = \langle E, \lambda, C \rangle$*;*
- $J = \{\texttt{proposed}, \texttt{pursued}, \texttt{halted}, \texttt{abandoned}, \texttt{achieved}, \texttt{underreview}\}$ *is a set of states;*
- $S_t : E \to J$ *is a state function, which assigns a state to each element in a certain point in time;*
- χ *is a set of LTL constraints that determines the allowed transitions between states.*

The meaning of each state is described as follows:

- *proposed*: the element is part of the results-chain, but the organization has not authorized its implementation yet;
- *pursued*: the element is implemented but its performance targets have not been reached;
- *halted*: the element was implemented, but the organization decided to stop pursuing it for a determinate period or until a certain condition is met;
- *abandoned*: the element is not part of the results-chain anymore and actions proposed to pursue it must be abandoned;

- *under review*: the element is implemented, but the organization is reviewing its definition or has not fully implemented it yet. Its performance indicators or targets may change in the future. That is not different from halted in conceptual terms. However, it has a different purpose in practical terms when these states are changed dynamically. This is because the system can itself, automatically, set an element to this state to tell everyone that it is incoherent and should be reviewed (this will be described in sections to follow). Halted elements, on the other hand, are elements arbitrarily halted by managers due to temporary conditions of the environment;

- *achieved*: the element was implemented and all of its performance targets have been reached.

We call **execution trace** of a *pursuing results-chain* a sequence of results-chain states $\sigma = [s_1, s_2, \ldots]$. Each s_i is determined by a state function S_i and the values $f_k(i)$ of the performance indicators $p_k \in I$. For $i = 0$, all performance indicators are at their baseline values ($\forall p_k \in I : f_k(0) = x_{k0}$) and the state function S_0 maps all elements to the "`proposed`" state.

The set χ of constraints contains domain constraints (governing all strategies) and specific purpose constraints (applyied to a particular strategy). A *valid execution trace* of a pursuing results-chain is a trace that complies to the constraints defined in χ.

The domain constraints for any results-chain are defined such that only transitions that comply to the state diagram depicted in Fig. 8.4 are allowed. The domain constraints also define the rules that govern how the states of two linked elements correlate. These rules are defined as follows:

Let $R = \langle E, \lambda, C \rangle$ be a results-chain. The following statements must be true for any state function S_t to be considered **valid**:

$\forall (e_1, e_2) \in C :$

- $S_t(e_1) = \texttt{pursued} \Rightarrow \neg(S_t(e_2) = \texttt{proposed})$
- $S_t(e_2) = \texttt{halted} \Rightarrow \neg(S_t(e_1) = \texttt{proposed})$
- $S_t(e_2) = \texttt{halted} \Rightarrow \neg(S_t(e_1) = \texttt{pursued})$
- $S_t(e_2) = \texttt{underreview} \Rightarrow \neg(S_t(e_1) = \texttt{pursued})$
- $S_t(e_2) = \texttt{abandoned} \Rightarrow \neg(S_t(e_1) = \texttt{proposed})$
- $S_t(e_2) = \texttt{abandoned} \Rightarrow \neg(S_t(e_1) = \texttt{pursued})$

The specific purpose constraints express the dependence requirements and alignment constraints between elements. We introduce a number of useful templates for specific purpose constraints in Sec. 8.3.1

If the state function of a pursued results-chain does not complies with the constraints, then the state function is called **invalid**. To make an invalid state function become valid, the organization must take actions to change the state of one of the elements that are violating the constraints. For example, if the element e_1 in the state "`pursued`" contributes to e_2, which is "`halted`", then changing e_1 to the state "`under review`" makes the state function valid (if no other relationship violate the constraints). This means that the organization is evaluating the element e_1 and deciding whether it will also be halted or abandoned. Thus, the "`under review`" state is used as an alert that the element should be under review and may not be pursued at the moment.

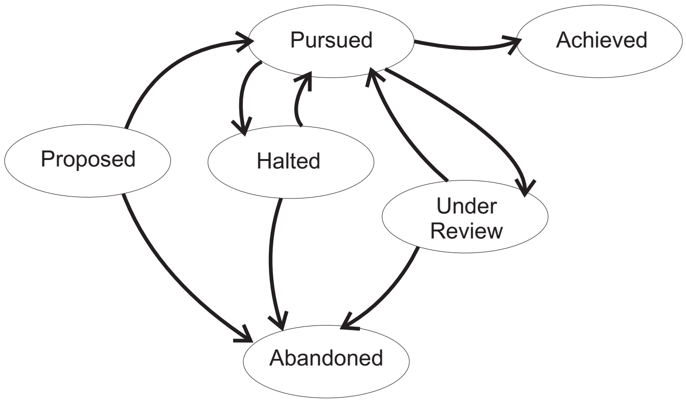

Figure 8.4 Allowed transitions between results states

Table 8.1 Valid states of linked elements ($e_1 \to e_2$)

$(e_1, e_2) \in C$	$S_t(e_1)$					
$S_t(e_2)$	proposed	pursued	achieved	halted	u. review	abandoned
proposed	✓	*change* e_2	✓	✓	✓	✓
pursued	✓	✓	✓	✓	✓	✓
achieved	✓	✓	✓	✓	✓	✓
halted	*change* e_1	*change* e_1	✓	✓	✓	✓
u. review	✓	*change* e_1	✓	✓	✓	✓
abandoned	*change* e_1	*change* e_1	✓	✓	✓	✓

Table 8.1 shows the relationships between the possible states of two linked elements in a results-chain. A checkmark (✓) is placed in each valid combination. A system can automatically change the states of some elements to make the state valid or ask for an action from managers to manually change the states of these elements.

8.3.1 Alignment Constraints

Alignment constraints can be determined by both top managers and functional managers to describe the coordination and integration requirements of the operations and projects conducted by the organization. Top managers should usually define relationships only at the impact and outcome levels, while functional managers may define relationships at the output and activity levels. However, the interdependencies defined at the top manager's level may also be reflected in interdependencies between outputs and between activities, at the functional level.

Firstly, we should clearly define the concept of "interdependency" that we adopt in our context. Two strategic elements e_1 and e_2 are interdependent if any of the following conditions is true:

- **precondition:** the firm is not able to start working on e_1 while e_2 has not been achieved;
- **execution condition:** changes that impact e_1 (delaying, canceling, or changing its scope or targets) require adjustments to the operations that pursue e_2.

This notion of interdependency is inspired by findings from project portfolio management literature [57]. To provide an operational semantics for the interdependencies described above and to allow

Table 8.2 Alignment constraints: precondition types

Relationship	**Definition**	**Operationalization**
Precondition		
Dependence (A,B)	A must be (at least) partially achieved before B is pursued.	Before creating activities that pursue B, specific performance indicators associated with A must have reached certain target values.
	E.g.: *Outcome "Increased R&D investments" (B)* depends *on the achievement of "Increased cash flow" (A).* **E.g.:** *"Improved brand recognition" (B)* relies on *the achievement of* at least 50% of *"Reduced customer complaints" (A).*	
Conditional sequence (A,B)	B is expected to start after the achievement of A, but only if the environment at that time agrees to specific conditions.	Before creating activities that pursue B, all performance indicators of A must have reached their target values and, furthermore, certain conditions must hold.
	E.g.: *Outcome "Increased offshore market share" (B)* will only be pursued after *"Improved brand recognition" (A) is achieved and only if the % of brand awareness in international markets* is higher than 20%.	

its systematic implementation as an information system, we propose the relationship types described in Table 8.2 (precondition types) and Table 8.3 (execution condition types). These relationship types are proposed on the basis of our experience with strategic planning and project management, but having the two conditions for "interdependency" as a basis for their definition. Examples are provided to demonstrate their practical occurrence in real settings.

When formally describing alignment constraints, Linear Temporal Logic (LTL) [50] appears as an adequate framework for defining time-dependent relationships between events. LTL has been used, for example, to model constraints in declarative business process models [88, 94]. In this area, it allows the modeler to define partial order relations between a process' activities. These relations determine if the execution of an activity is *enabled* or *disabled* at each moment. To our purpose, we can use LTL to define relationships between the states of two or more elements.

The set of well-formed LTL formulae can be inductively defined as follows:

Table 8.3 Alignment constraints: execution condition types

Relationship	**Definition**	**Operationalization**
Execution Condition		
Exploitation (A,B)	*A* exploits some results provided by *B*, if *B* is achieved.	If specific performance indicators of *B* reach certain target values, the operations of *A* must be adjusted to exploit the benefits obtained through *B*.
	E.g.: *If "Reduced communication costs" (B) is achieved, then tighten the target deadlines for outcome "Improved customer service" (A).*	
Threatening (A,B)	If *A* is delayed, canceled or has its scope or quality reduced, *B* must be adjusted.	Operations that pursue *B* must be reviewed when the performance indicators of *A* reflect the negative effects that may threaten *B*.
	E.g.: *Review outcome "Increased product diversification" (B) if "Reduced distribution costs" (A) does not reach 50% of achievement within next one year.*	
Cooperation (A,B)	*A* and *B* are pursued together and with cooperation of the managers responsible for *A* and for *B*.	The progress of *A* and *B* as measured by their performance indicators should be positively correlated.
	E.g.: *Simultaneously pursue "Improved productivity" (A) and "Improved employee happiness" (B).*	

Given a finite set of propositions P.

- every member of P is a formula;
- if ϕ and ψ are formulas, then so are $\neg\phi$, $\phi \wedge \psi$, $\phi \vee \psi$, $\phi \rightarrow \psi$, $\mathbf{G}\ \phi$, $\mathbf{F}\ \phi$, $\mathbf{X}\ \phi$, $\phi\ \mathbf{U}\ \psi$, $\phi\ \mathbf{R}\ \psi$ and $\phi\ \mathbf{W}\ \psi$.

The semantics of operators $\neg$, $\rightarrow$, $\wedge$ and $\vee$ is the same as in classical first-order logic, while temporal operators have a special semantics:

Let a trace σ be a sequence of states $[s_1, s_2, \ldots]$.

- Globally ($\mathbf{G}\psi$): specifies that ψ holds at every state s_i in the trace (*always*);
- Eventually ($\mathbf{F}\psi$): specifies that ψ holds at least once in the trace;
- Next ($\mathbf{X}\psi$): specifies that ψ holds in the next state s_{i+1} of the trace;
- Until ($\psi\mathbf{U}\theta$): specifies that there is a position in the trace where θ holds and ψ holds in all preceding positions in the trace;
- Weak until ($\psi\mathbf{W}\theta$) is similar to operator Until ($\mathbf{U}$), but it does not require that θ eventually becomes true.

We can formally define each relationship type by using LTL constraints, as follows. Consider the execution trace $\sigma = [s_1, s_2, \ldots]$.

- **dependence** (e_1,e_2): $\chi = \neg(S_i(e_2) = \texttt{pursued})\mathbf{W}\phi$, where ϕ is an expression over the performance measures $\mu(e_1)$;
- **conditional sequence** (e_1,e_2): $\chi = \neg(S_i(e_2) = \texttt{pursued})\mathbf{W}(\phi \wedge (S_i(e_1) = \texttt{achieved}))$, ϕ is an expression over performance measures in I;
- **exploitation** (e_1,e_2): $\chi = \mathbf{G}(\phi \Rightarrow (S_i(e_1) = \texttt{underreview}))$, where ϕ is an expression over the performance measures $\mu(e_2)$;
- **threatening** (e_1,e_2): $\chi = \mathbf{G}(\phi \Rightarrow (S_i(e_2) = \texttt{underreview}))$, where ϕ is an expression over the performance measures $\mu(e_1)$;
- **cooperation** (e_1,e_2): $\chi = \mathbf{G}(\phi \Rightarrow ((S_i(e_1) = \texttt{underreview}) \wedge (S_i(e_2) = \texttt{underreview})))$, where $\phi = \phi_1 \vee \phi_2$ is an expression in which ϕ_1 is defined over the performance measures $\mu(e_1)$ and ϕ_2 is defined over the performance measures $\mu(e_2)$.

If the manager uses these pre-defined relationship types, there is no need for the direct use of the LTL language. Relationships expressed at a high-level (e.g., "only pursue *improved brand recognition (A)* when *reduced complaints (B)* achieves 50% of achievement") can be translated into LTL expressions (e.g., $\chi = \neg(S_i(A) = \text{pursued})\mathbf{W}$ *MonthlyNumComplaints(i) < 100*).

An information system that aims to verify the alignment constraints could act in the following manner.

Initially, all results are in the state "`proposed`". Performance measures may have arbitrary initial values. The system stores the set of all constraints. When either the performance value of some measure is changed or when the state of a result is changed, the system computes the new states of the elements. The sequence of states is stored as a trace, which can be verified against the alignment constraints. If any constraint is violated, the system issues an error message informing which constraints were violated. If the problem is fixed (e.g., by starting the review of a result that should be in the "`under review`" state), then the system updates the current state to the correct state of the result (e.g., to "`under review`") and erases the state that violated the constraints. This enables the verification to proceed with a correct trace.

The system should also verify cyclic dependencies, which cause deadlock. Such dependencies can be described in a directed graph in which results are represented by vertexes and dependence relationships as arcs pointing from an element to the element it depends on. A cycle in this graph, considering the directions of the arcs, means a deadlock.

8.3.2 Effect of Alignment Constraints Over Adaptable Workflows

The semantics of the alignment constraints (χ) defined for a pursuing results-chain $\langle Q, S_t, \chi \rangle$ can be extended to the level of strategic adapters. Since each adapter models the business process paths to generate a certain work product, the state of the elements associated with this product may affect the adapter's behavior.

The general rule is that an adapter cannot include activities or present recommendations to an user for elements that are in the "`proposed`", "`halted`", or "`abandoned`" states. These are objectives that should not be under consideration for the user's decision making. Recommendations associated with elements that are "`pursued`", on the other hand, are always presented to the user.

The situation where an element is "`under review`" or "`achieved`" demands further attention. "`under review`" means that something is about to change, but does not means that the the company should stop executing the corresponding actions right at the moment. The same applies to the "`achieved`" state, which means that the targets have already been reached. In these two cases, it is necessary to consider the requirements of the specific situation.

For example, consider an action defined as "reduce profit margin", which contributes to the output "reduced prices", linked to "increased sales". When the target sales performance is reached, should adapters that reduce profit margin be still executing? Probably not, because such action is likely to be intended to be temporary. On the other hand, an action that defines to "purchase larger volumes of supplies at once to reduce costs", linked to the same output, possibly could remain in execution despite the target to increase sales has been reached. A similar reasoning can be used for the "`under review`" state. If the "reduce profit margin" action is under review, then it may be the case that the company wants to immediately stop executing this action until the review process is finished.

To model the effect of alignment constraints over adapters, we firstly define the states in which an adapter may be:

- **active** - all elements associated with the adapter are in the "`pursued`" state;
- **obsolete** - all elements associated are in the "`achieved`" state;
- **under review** - there is at least one element associated with the adapter that is not in the "`pursued`" state and at least another one that is;
- **inactive** - all elements associated with the adapter are either "`halted`" or "`abandoned`".

Consider a complete results-chain R in which the base level is composed of work products. Consider that this results-chain is pursued and its current state is defined by the function S_t.

Definition 8.2 (Active Adapter). *An adapter S is* active *if it is connected to a set Ω_S of work products and* $\forall \omega \in \Omega_S, \forall e \in \tau(\omega, R) : S_t(e) = \texttt{pursued}$.

Definition 8.3 (Obsolete Adapter). *An adapter S is* obsolete *if it is connected to a set Ω_S of work products and* $\forall \omega \in \Omega_S, \forall e \in \tau(\omega, R) : S_t(e) = \texttt{achieved}$.

Definition 8.4 (Adapter Under Review). *An adapter S is* under review *if it is connected to a set Ω_S of work products and* $\exists \omega \in \Omega_S, \exists e_1, e_2 \in \tau(\omega, R) : S_t(e_1) = \texttt{pursued} \wedge \neg S_t(e_2) = \texttt{pursued}$.

Definition 8.5 (Inactive Adapter). *An adapter S is* inactive *if it is connected to a set Ω_S of work products and* $\forall \omega \in \Omega_S, \forall e \in \tau(\omega, R) : S_t(e) = \texttt{halted} \vee S_t(e) = \texttt{abandoned}$.

An adapter is *never* executed if it is *inactive*. Adapters that are *active* are always executed. Obsolete adapters can continue to be active. Their deactivation must be handled by the organization in the next FlexROM cycle. For example, if all targets are achieved and the company wants to continue pursuing a certain outcome, then the managers could determine new performance targets for that outcome. This would make the element go back to the state "pursued" instead of "achieved". Observe that this is also important to inform employees about what they are seeking after. In case the obsolete adapter is not necessary anymore, then it should be undeployed from the SA-BPM system.

To illustrate these two situations, think in an adapter that is designed to meet a goal of cutting costs down by 10%. When the company reaches this goal, it may be the case that they want to keep the adapter active. It will, however, have a lower chance of being recommended when compared to other (conflicting) goals that are farther from achievement (for example, a goal to increase production speed, which may conflict with cost reductions at some point). If the managers want to push cost reductions, they need to put new reduction targets for the strategic elements associated with the adapter.

Adapters that are *under review* must be analyzed by the business analyst during the Developers' Cycle. This is because the work products to be generated by the process may require changes. Changes to the definition of the corresponding action, at the Managers' Cycle, may also be necessary. The situation of the adapter after this review cycle must be clear. Either the elements have changed their states or the adapter is disconnected from the elements. Observe that the *under review* state means that elements associated with the adapter are invalid. Thus, an action is required by the developers.

It is the task of the Strategic Context Provider to inform the Adaptation Agent about each of these states and is the task of the Adaptation Agent to select adapters accordingly. The employee should be informed about recommendations that come from obsolete adapters or from adapters under review. The more informed the employees are, the better can be their decisions.

8.4 Summary

This chapter described our proposal of a flexible strategic planning and management methodology, called FlexROM. This methodology was constructed on the basis of existing good practices in the management literature and was tailored to exploit the benefits provided by SA-BPM technology.

FlexROM features can be summarized as follows:

- it describes a strategy management process that explicitly account for the necessity of changing, characteristic of complex and uncertain environments;
- it adopts decentralized decision-making as a mean to improve strategic flexibility;

- it defines both a managers' lifecycle and a developers' lifecycle, which act in synchrony to keep business and IT connected;
- it defines a formal model for expressing alignment constraints, which help integrating diverse organizational functions in a flexible manner;
- it defines a method for continually and objectively assessing the effectiveness of the strategy, allowing for the rapid identification of threats.

It is worth notice that the adoption of FlexROM fulfills the requirements to support *Guideline 5* of our mitigation guidelines, which recommends that the system stores and communicate the interdependencies between strategic goals (Chapter 5). This also enables *Guideline 6*, but this guideline is not implemented in our work.

It is important to remark that FlexROM is not the unique management methodology that could be used in conjunction with SA-BPM systems. However, it is a methodology constructed to maximize the benefits of SA-BPM. The extensive analysis of the literature presented in Chap. 2 demonstrates that the elements present in other management methodologies in use by successful organizations are in agreement with the design of the FlexROM methodology.

CHAPTER 9

An Application Scenario

If you realize that all things change, there is nothing you will try to hold on to. If you are not afraid of dying, there is nothing you cannot achieve.

— (Lao Tzu, Tao Te Ching)

9.1 Overview

In this chapter, we describe a business case that demonstrates the application of the concepts and tools proposed in this thesis. Although this case is fictitious, it is based on reports and documents from real companies, as a mean to ensure higher proximity with the scenarios of real companies. The objective of this chapter is to provide a more practical view of this work's contributions, its benefits, and area of application.

To evaluate the benefits of the approach, a simulation of this application scenario was constructed. The simulation results are described in this chapter and show a positive gain from the use of SA-BPM technology.

9.2 The Fictitious Luggage Manufacturer

The Fictitious Luggage Manufacturer (FLM) is a small industry that manufactures luggage, backpacks, and travel accessories. The main differential of FLM is the design of its products, customized with themes from its State's most well known tourist attractions. Although their luggage are not known to be the best in class, they have a wide variety of stylized designs that are well recognized by the citizens of its hometown and neighborhoods. Their primary clients are large department stores in its State.

Unfortunately for FLM, its backpack segment has demonstrated a systematic drop in sales for the past two years, since the entry of new competitors in the market. FLM's debits have increased in this period and cash flow reduced. The moment was crucial for a change in the company.

9.3 The New CEO and The New Ideas

FLM hired a new Chief Executive Officer (CEO) to promote changes in its business and to recover the company from their current financial crisis.

The first decision of the new CEO was to shut down its backpack segment. Its manufacturing machines should be sold and the staff redistributed to other functions. By abandoning the backpack product line, marketing and production administration would be made simpler, since the variety of products is reduced. Furthermore, improvements could be made to the plant, making it simpler and more efficient.

This could make the production of luggages less costly. With a more efficient production line, the company would be able to compete with better prices in the market. Besides, the cash generated from the sales of the old machines would be used to pay most of the company's debits and to modernize the manufacturing plant.

The second decision of the new CEO was to start working closer with small resellers. Although large department stores were still in the plans of the company, the new focus would be small stores. This could improve cash flow and reduce inventory turns. The company would also have more presence in small cities and better attend demands from stores next to tourist attractions.

Finally, the CEO decided to implement the **Flexible Results-Oriented Management** (FlexROM) approach and to deploy *strategy-aware* business processes. The CEO's intention is to improve the strategic flexibility of the firm. The functional managers would now have improved autonomy in their unit and the company would continuously pursue new market opportunities and become more agile and efficient.

9.4 The New Strategic Plan

A four-year strategic plan was designed by the new CEO. Using the FlexROM approach, this plan was firstly designed as a top-level results-chain (*impacts* and *outcomes*). Performance indicators and performance targets were assigned to each of these results.

The elements of the top-level results-chain are described in Table 9.1. Although other goals could be also specified, we will limit the scope of this study to the elements described.

In the FlexROM methodology, each functional unit defines the *activities* and *outputs* that will be produced to reach the expected outcomes of the organization. This case will describe how the strategies of the Distribution and the Finance departments are implemented.

The new strategy proposed by the CEO is highly related to the way products are distributed by FLM to its resellers. The Distribution manager decided that, to improve the delivery agility and to reach smaller resellers, they should reduce truck sizes and reduce the requirements for minimum volume purchases. The manager's calculus showed that a "divide-and-conquer" approach would be more economic than sending a few large trucks for all deliveries. Since small resellers usually purchase smaller volumes, it would require more time until a large truck is filled up to its full capacity (Full Trailer Load). Besides, the routes would be more complex. This could increase the delivery time. It is the manager's *hypothesis* that exchanging current large trucks for smaller ones would make the delivery process more efficient, regarding the new small resellers market focus.

However, when the volume of sales is high and when big purchases are made, larger trucks are the best option for shipment. In this case, the manager decided that external carriers would be contracted for those shipments.

These changes proposed by the Distribution manager have impact in the shipment *processes*, which will be described soon.

The Production manager, in coordination with the Distribution manager, observed that they could reduce the *purchase order to cash cycle time* (which is the time it takes from the moment of the order purchase until its full payment). If the Production department could accelerate the processing of late orders, the average processing time could be reduced. For example, in certain cases, the purchase order is delayed due to issues of the Finance department. However, the Distribution is not aware of these delays and process the orders in a first-come-first-served policy. The managers determined that they should improve the coordination between the departments, so that, at each step of the order processing, each department is aware of which orders are experiencing more processing delays. As a result, a department

Table 9.1 FLM results-chain with top-level results (2013-2016)

Result	Indicators	Department	Priority
Impact 1: increased market presence	*Number of resellers*. **Baseline**: 40. **Target**: 120.	Sales	*High*
• **Outcome 1.1**: improved distribution agility and efficiency	*Average cost of delivery per product unity*. **Baseline**: \$6. **Target**: \$1.	Logistics	*High*
Impact 2: improved financial stability	*Debit to Capital Ratio*. **Baseline**: 0.8. **Target**: 0.4.	Finance	*Normal*
• **Outcome 2.1**: increased cash flow	*Free Cash Flow (FCF)*. **Baseline**: \$30,000. **Target**: \$60,000.	Finance	*High*
Impact 3: improved competitiveness in the cost leadership segment	*Market share*. **Baseline**: 8%. **Target**: 20%.	Global	*Normal*
• **Outcome 3.1**: improved operational efficiency	*Purchase order to cash cycle time*. **Baseline**: 30 days. **Target**: 10 days.	Production, Distribution, and Management	*Normal*

could prioritize problematic orders when they arrive at their unit, reducing the overall processing time.

For his own department, the Distribution manager decided that orders would be shipped in order of priority, and not in the first-come-first-served policy. This also has impact in the shipment processes.

These are the first strategic decisions to be put in practice by FLM. The functional-level elements of the results-chain are summarized in Table 9.2

The managers also defined one dependence constraint between the strategic elements defined:

- **Dependence** - Output 3.1.1 *depends on* Output 3.1.2 having reached at least 60% of achievement. It is not possible to compute order priorities until at least more than half of its processing time is being monitored.

9.5 Redesigning the Shipment Planning Process

The strategic choices of the functional managers require changes to the company's shipment processes (among others). As the CEO decided to employ the concept of SA-BPM, the company's processes should now exhibit a clear separation between core functions and strategic requirements. Moreover, the execution should be made in a strategy-aware fashion, which means that the strategic context must be taken into consideration to determine control flow and decisions. In this section, we describe how SA-BPM for FLM was implemented with the use of **ROSAS**, the prototype SA-BPM developed in this thesis. Later on, we show how strategic changes are simplified due to this approach.

There are two main processes that support the distribution of goods in FLM. The *Order Shipment* process and the *Shipment Planning* process. The first one defines the processing steps of an order from the authorization for shipment until its full payment. The second one defines the steps necessary to arrange the shipment of the products.

The *Order Shipment* process is illustrated in Fig. 9.1. It starts when the Distribution department *authorizes the shipment of goods*. At this point, the department performs the steps necessary for billing and issuing the payment invoice corresponding to that order. Then, shipment arrangements are performed. For that sake, the staff analyzes the currently assigned routes and trucks to determine whether the package fits in the schedule of trucks already appointed. If not, a new shipment arrangement must be performed. This is the point where the *Shipment Planning* process is called for. This process is illustrated in Fig. 9.2. The analysis may also reveal the necessity to hire a carrier for the shipment. In such a case, the contract arrangements are made by the Logistics department, before the process can proceed. Insurance procedures are also performed at this moment. It should be remarked that freight tariffs for external carriers are paid in advance. So, the freight invoice must be payed before the order is shipped.

Once the shipment is appointed, the Distribution department updates the task list of the Warehouse. This list informs the Warehouse about which products must be separated from the inventory, which packages are assigned to which carriers, and when the delivery is appointed to depart. At the appointed time, the Warehouse loads the truck and dispatch the shipment. The staff informs the system whether the orders have been actually shipped in the expected time.

Once loaded, the truck is authorized to leave the fabric. When it returns, the receipts are processed by the Warehouse. If no problem is identified, the order goes to the Accounting department, which will proceed with its processing until the payment is done. Shipping problems may require the canceling of the order and invoice or may trigger a re-shipment.

Both the *Order Shipment* and the *Shipment Planning* processes described correspond to the core versions of the company's processes. Although they are very important for the strategic objectives of the enterprise, there is no mean to ensure that they are contemplating any strategic requirement. From an

Table 9.2 FLM results-chain for functional-level results (Distribution)

Result	Indicators	Department	Contributes to
Output 1.1.1: reduced delivery cost	*Total cost of deliveries per day*. **Baseline**: $900. **Target**: $700.	Distribution	**Outcome 1.1, Outcome 3.1**
• **Action D.1**: renew the fleet of trucks, exchanging large trucks with smaller trucks	*Number of new trucks*. **Baseline**: 0. **Target**: 30.	Distribution	**Output 1.1.1**
• **Action D.2**: make use of external transport services when it is advantageous to the company	*Average cost of delivery per product unity*. **Baseline**: $3. **Target**: $2.	Distribution	**Output 1.1.1**
Output 3.1.1: improved capacity to handle delayed orders	*Average order processing time*. **Baseline**: 3 days. **Target**: 1 day.	Distribution	**Outcome 3.1**
• **Action D.3**: deliver orders according to a priority policy that favors delayed orders	*Percentage of orders delivered that exceeded 2 days processing time*. **Baseline**: 50%. **Target**: 10%.	Distribution	**Output 3.1.1**
Output 3.1.2: improved capacity to identify delays in order processing	*Percentage of departments monitoring the order processing time* . **Baseline**: 0%. **Target**: 100%.	Global	**Outcome 3.1**
• **Action G.1**: develop the capacity to monitor the time spent by the order in each processing step	*Percentage of processing steps that are monitored.* **Baseline**: 0%. **Target**: 100%.	Global	**Output 3.1.2**

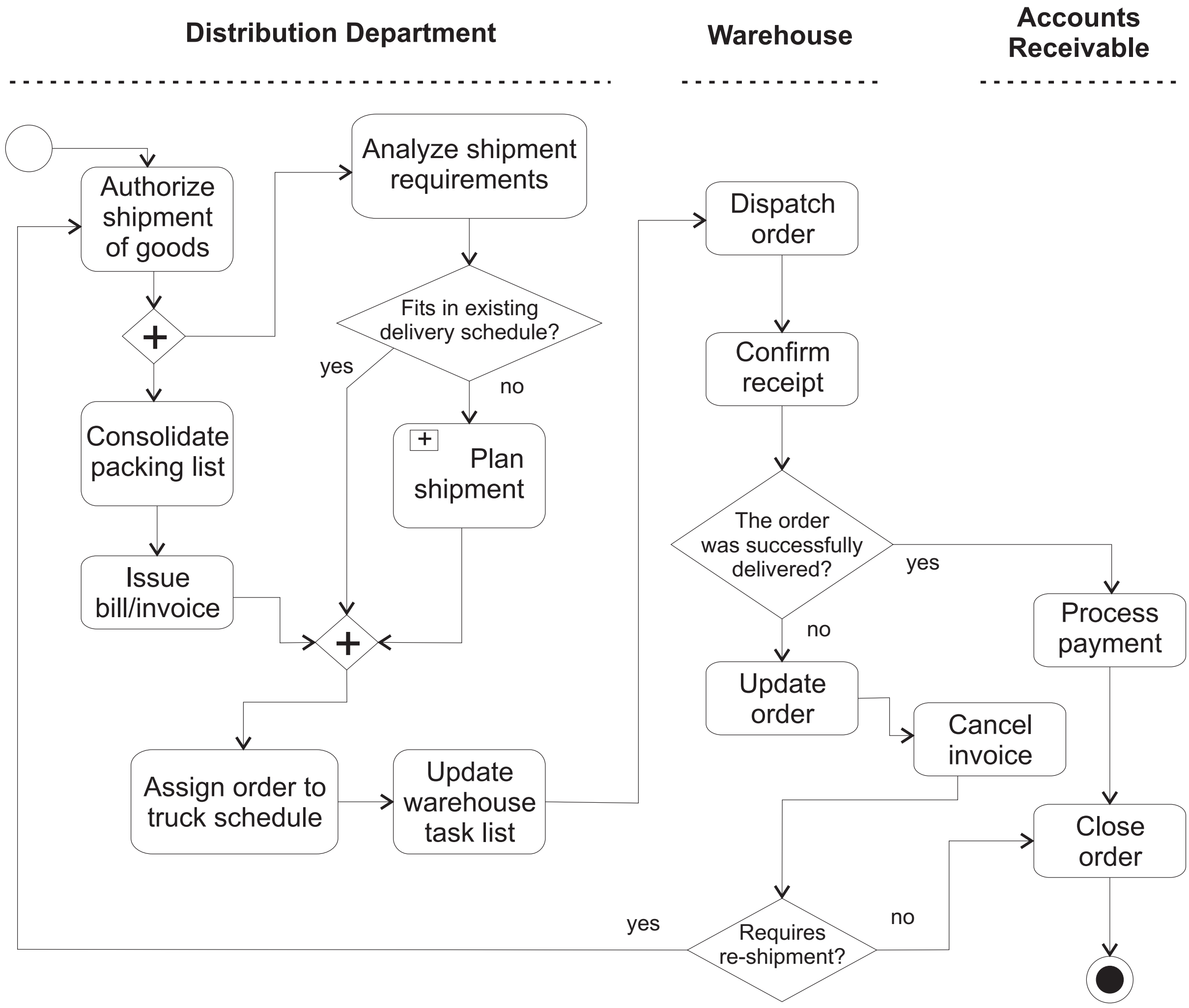

Figure 9.1 Order Shipment

operational point-of-view, there is no need to make any changes to these processes. However, there are strategic concerns that are not under consideration. Using SA-BPM terminology, some work products that should be generated by these processes are missing.

The following work products can be associated with the actions defined in FLM's strategy:

- *small truck aquired*: this is the work product type related to Action D.1 (renew fleet, exchanging larger trucks with smaller ones). This work product has no connections with the shipment processes (i.e., the processes do not generate it). We assume that this output has already been achieved;
- *external carrier contracted*: this work product type, related to Action D.2, has a constraint - it only contributes to the action when the freight tariff affords a cost per product delivered lower than when using the company's fleet;
- *order delivered*: this work product type is related to Action D.3 and is also constrained. It only contributes to the action when the delivered order's processing time is not smaller than other

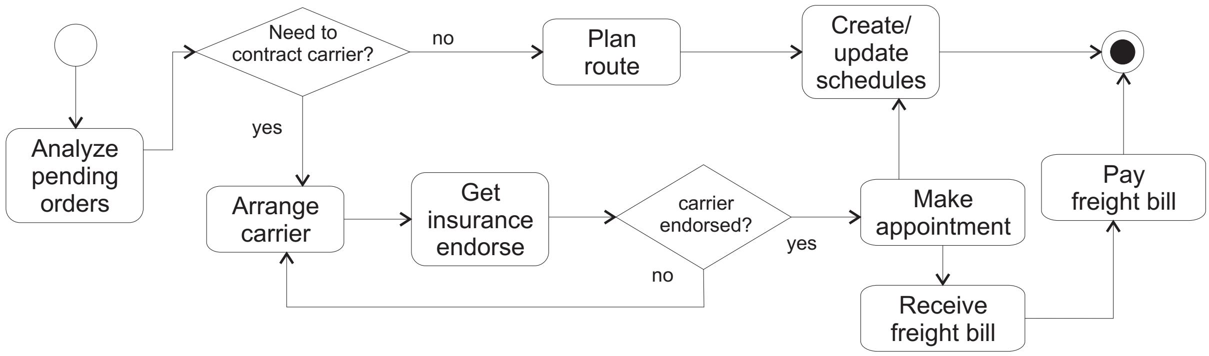

Figure 9.2 Shipment Planning

orders in queue;

- *processing step monitored*: this is the work product type associated with Action G.1.

To make the processes adequately generate these work products, we do not make changes to its core design. Instead, we design *adapters*.

9.5.1 Adapter D.2 - Choose Shipment Method

The first adapter is dedicated to recommend the right shipment method depending on the volume of packages, current performance, and current route schedules. This adapter corresponds to *Action D.2* of the Distribution department's strategy. Its objective is to reduce the *cost of delivery per product*. To this end, it introduces steps to estimate shipment costs **before** the *Analyze pending orders* activity of the *Shipment Planning* process is executed.

FLM's Logistics plans truck routes in the following manner. The routes are grouped in areas. A single truck deliver products to all retailers in a certain area. A route optimization software is also used to reduce the costs of delivery in each area. Such software uses information about the company's fleet capacity, fuel costs, time restrictions, package volumes, and stop addresses.

When the volume of pending orders increase, trucks will need to be sent two or three times to the same area. To avoid this, external carriers are contracted. Since external carriers are not part of the company's fleet, they can't be included in the route planning software. In fact, FLM does not control the routes of external carriers. The company simply pays a freight tariff that is charged by the carrier.

The *Analyze pending orders* activity's purpose is to check whether current pending orders can be delivered in a truck of the company's own fleet. The employee must verify: 1) whether there are trucks available; 2) whether the packages fit in a single truck; and 3) whether there are trucks currently appointed to deliver to the same area. The employee than determines whether the orders can be sent by a truck already appointed to depart or if a new appointment must be scheduled.

The strategic requirement of *Action D.2* is that the cost of delivery per product is reduced. The adapter's objective is, thus, to inform the user about the estimated costs of his/her choice and recommend the option that has lower cost.

This adapter's process model is illustrated in Fig. 9.3. At run-time, the Strategic Adaptation Agent intercepts the execution of the *Analyze pending orders* activity. When the activity is *ready* to be executed, the Agent disables this task and starts Adapter D.2's process. This adapter's process can be summarized as follows:

Figure 9.3 Adapter D.2 model

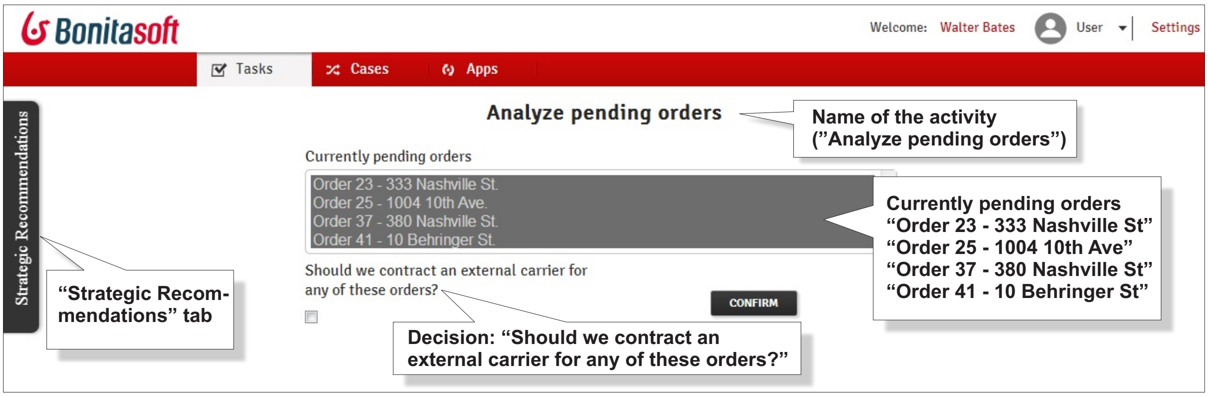

Figure 9.4 "Analyze pending orders" input form

1. if the sum of all pending orders to an area exceeds the capacity of a single truck, it is possible that an external carrier for that orders would be less costly than sending two (or more) trucks to the same area;
2. request the user to estimate freight tariffs for the areas that are candidate for external carriers (the user may need to contact several freight forwarders or independent carriers at this point);
3. make recommendation on the basis of the cost per product measure;
4. inform the recommendations to the Context Provider.

After the conclusion of the adapter, the employee can perform the *Analyze pending orders* activity. The screen presented to the user is depicted in Fig. 9.4. The ballons describe the elements presented on this screen. In the "Strategic Recommendations" tab, ROSAS's displays to the user all context information that affect his/her decision. An example of screen with the recommendations displayed is shown in Fig. 9.5. The retractable slide panel shows a recommendation for a single order or for a group of orders, along with the strategic action that justifies the recommendation (in this case, the definition of Action D.2 of FLM's strategy). The performance indicators affected are also displayed to the user, with their current and target values. The user can also click on a link displayed in the panel to see the trace of all strategic elements that are impacted by his/her decision (outputs, outcomes, and impacts). The trace for the *Analyze pending orders* activity is shown in Fig. 9.6 and corresponds to a partial results-chain containing the elements associated with the work product type *external carrier contracted*.

The role of the adaptation is to ensure that the right work products will be generated in the process instance. Thus, independently of the method employed to make the decision, the task of the adapter is to make the process participant *aware* of the strategic necessities of that decision, so to influence his/her choices. In Sec. 9.7 we simulate this scenario to show the benefits of this approach. In Sec. 9.6, we demonstrate how such approach also improves the efficiency of strategic changes.

Figure 9.5 Context information for "Analyze pending orders"

After the completion of the *Analyze pending orders*, ROSAS' Context Provider logs the context of the activity and the values of the process variables, which correspond to its work products. Some of the informations logged are:

- the ID of the process instance;
- the user that executed the activity;
- the list of pending orders;
- the value of the *cost of delivery per product* indicator at the moment;
- whether recommendations were presented to the user and whether such recommendations, if any, indicated that the user should contract a carrier or not (the recommended work product);
- the value of the *boolean* variable "*contract carrier*", which contains the decision of the user (which will be compared to the recommended value).

This information is very useful to support the analysis of the strategy. For example, by the end of the month, the manager can compute the actual cost of delivery and the method employed for their shipment (company's fleet or carriers) and compare this information to the system's recommendations for each case. Then, the manager can analyze data such as:

- the rate of recommendations' acceptance: a lower rate may imply that recommendations were not considered relevant by the employees;
- the cost products' deliveries: the manager can compare the costs when the recommendations were accepted to the costs when not, and observe if the recommendations are really positively affecting the measure;

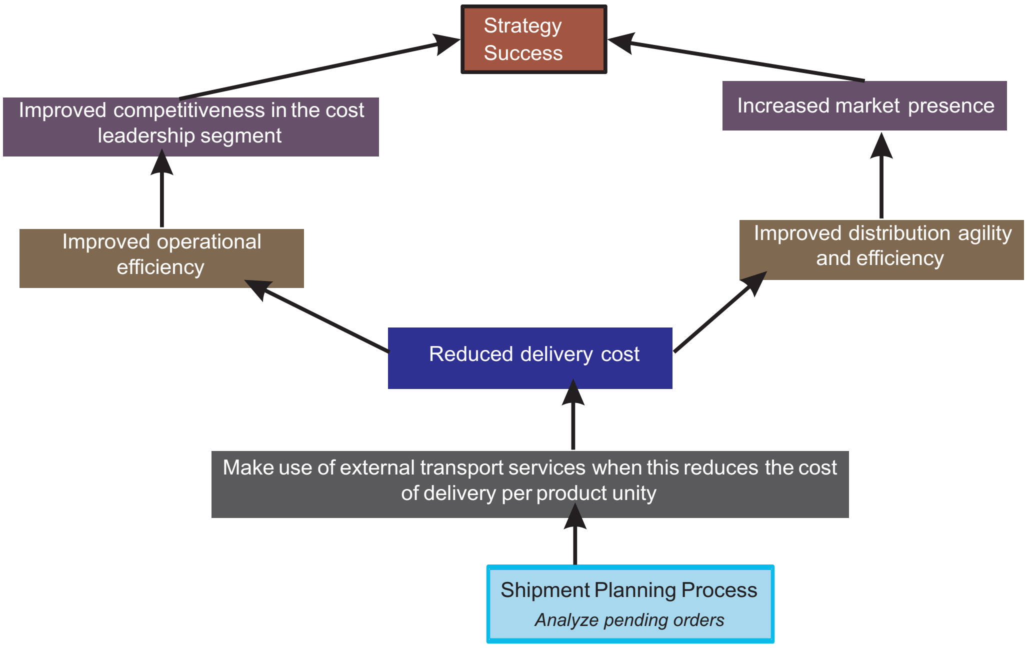

Figure 9.6 Contribution trace of the “Analyze pending orders” activity

- the ratio of instances where the recommended work product requires to contract a carrier compared to those which do not. If this ratio is high, it is an indication that the strategy to reduce costs with smaller trucks may not be adequate for the company (since this is rarely recommended).

9.5.2 Adapter D.3 - Order Priorities

The next adapter responds to *Action D.3*. This adapter is executed at multiple points and affects both processes. Its objective is to assign priorities to each order, depending on the amount of time already spent by the company processing it. Then, the adapter informs the user about these priorities at the moments this information is important.

The algorithm is simple, the adapter gets the list of pending orders (orders that are not assigned to a shipping schedule yet) and sum up their processing time up to this point. Then, it computes the ratio of the order's processing time related to this sum. More formally, let we have N orders, indexed by $i = 1, 2, \ldots, N$. The priority of the ith order is given by:

$$\texttt{priority}_i = \frac{\texttt{time} - \texttt{processing} - \texttt{order}(i)}{\sum_{k=1}^{N} \texttt{time} - \texttt{processing} - \texttt{order}(k)}$$

The result is the order's priority. The higher the portion of the order in the overall sum of processing times, the higher is its priority. The adapter is inserted at three points:

- at the *Assign order to truck schedule* activity of the *Order Shipment* process;
- at the *Plan route* activity of the *Shipment Planning* process; and
- at the *Make appointment* activity of the *Shipment Planning* process.

In either case, what the adapter does is to recommend the user to schedule the shipment appointments according to the given priorities. The orders with higher priorities should be delivered first.

The user may, then, hold the execution of the current process instance and switch to other instances of higher priority. Or, perhaps, try to adjust the schedule so to put items with low priority only in trucks that are not close to their full capacity yet, while preferring to put high priority items on trucks that are close to their full capacity and, thus, able to depart sooner.

In either case, the user is informed about the strategic objectives that he/she should be pursuing in the execution of their job. In this case, to reduce the order processing time.

After the completion of the adapted activity, ROSAS' Context Provider stores the context and variables of the process, which includes its processing time up to the moment, the priorities of each pending order, and the variables that show which decision was taken by the staff.

An example of analysis that can be made by the manager is the following. Consider that the employees are always postponing the schedule of orders that have lower priorities. Although this may improve the processing time of high priority orders, this may negatively affect the orders that had lower priorities. The data stored by ROSAS allows the manager to observe the variation in the processing time and priority of the order in each step of execution. He or she can, then, identify if orders that exhibited initially lower priorities were delayed too much, so that they were only scheduled when they reached higher priorities.

Such analysis may reveal if the strategy is being effective or if there is a necessity to improve the priority assignment algorithm.

9.6 The Finance Department Joins In

The results-chain is not complete yet, since no action was proposed by the Finance department. To address the strategic requirements of the company, the Finance department analyzed the operations of the organization during a few weeks.

What the Finance department observed was a number of cash disbursements made to pay freight tariffs that were impacting the cash flow of the company. Since freight tariffs are payed in advance, the organization was committing financial resources that could be used elsewhere. The manager decided that the use of external carriers should be constrained in periods of low cash flow. Their *hypothesis* is that the possible higher delivery costs would be compensated, due to the larger flexibility to deal with *accounts payable* when compared to advance freight tariffs.

The Finance department defined the strategic activities described on Table 9.3. They communicated their decision to the Distribution department. Together, these departments updated the dependence relationships in the strategy and included the following new relationship:

- **Precedence** - Outcome 1.1 (improved distribution agility) *relies on* Outcome 2.1 (increased cash flow);

- **Threatening** - Output 2.1.1 (avoid cash disbursements) *must be reviewed if* Output 1.1.1 (reduced delivery time) *does not reach 20% of achievement by the end of the year*.

The first dependence relationship makes clear that the achievement of Outcome 1.1 relies on the wealthy of the company's free cash flow. This is because contracting carriers require a margin of free cash flow to work properly. The second relationship communicates a threatening dependence. If the activities of the Finance department impair the progress of the Distribution department, then these activities should be reviewed within the specified timeframe.

Table 9.3 FLM results-chain for functional-level results (Finance)

Result	Indicators	Department	Contributes to
Output 2.1.1: avoid cash disbursements when free cash flow is low	*Percentage of cash disbursements avoided.* **Baseline**: 0%. **Target**: 50%.	Finance	**Outcome 2.1**
• **Action F.1**: when free cash flow is low, prefer trucks from the company's fleet over external carriers	*Percentage of company's cash committed to pay freight tariffs.* **Baseline**: 25%. **Target**: 10%.	Logistics	**Output 2.1.1**

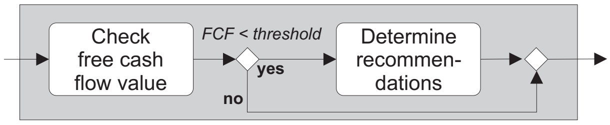

Figure 9.7 Adapter F-1

It is worthy to remark that, since the Finance department is autonomous on its approach to the company's strategic goals, it can design and redesign its strategic initiatives (actions and outputs) without communicating top managers. Although the shipment processes cross several boundaries within the organization, the Finance department does not need to request a redesign of the entire business process. They can simply deploy adapters that include in the process the tasks they need.

The infrastructure for SA-BPM keeps track of all strategic adaptations in place. Thus, any manager is able to identify which adapters are affecting the processes or activities of their interest. They can also identify what are the expected results of each adaptation. Thus, even without the intervention of top managers, the functional managers can identify relationships between their activities and formalize their dependence or coordination requirements among each other.

9.6.1 Adapter F.1 - Avoid External Carriers

To implement their strategic directives (Action F.1), the Finance department proposes an adapter that, depending on current measures of free cash flow, recommends the Distribution department to do not contract external carriers. The adapter's model is illustrated in Fig. 9.7.

Observe that this adapter **conflicts** with the Adapter D.2, which may recommend contracting carriers at the same time that Adapter F.1 recommends not to contract. This conflict is handled by ROSAS. The Adaptation Agent consolidates all recommendations, displaying to the user a weighted set of recommendations. The priority of each recommendation is computed by the Strategic Context Provider, through the application of the AHP method as illustrated below.

Consider that the outcomes to which the Adapter D.2 contributes have reached 55% of achievement, while those of Adapter F.1 have reached 30%. Their performance gaps are, respectively, 45% and 70%.

The *strategic coverage* of D.2 is the sum of the weights of the results it contributes to. We assign

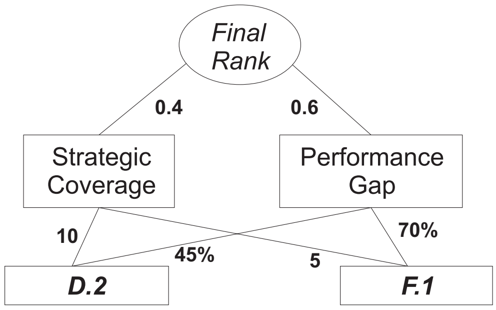

Figure 9.8 AHP model for the resolution of conflicts between recommendations

the following values to the priorities of the results: *Low*=1, *Normal*=2, *High*=3. Thus, according to Table 9.1, if we sum up the priorities of the elements: Outcome 1.1 (High=3), Impact 1 (High=3), Outcome 3.1 (Normal=2), and Impact 3 (Normal=2), we get adapter D.2's strategic coverage value of 10. Adapter F.1 has strategic coverage 5, which is the sum of priorities of Outcome 2.1 (High=3) and Impact 2 (Normal=2).

Finally, consider that FLM's priority is on reducing performance gap. They give weight 0.40 to strategic coverage and 0.6 to performance gap. The resulting AHP model is illustrated in Fig. 9.8.

The final ranks, then, are calculated as follows. Observe that, despite its wider strategic coverage, Adapter D.2 is not the preferred adapter, as the company is not exhibiting progress towards the improvement of its cash flow. The ranks are close, because the recommendations of D.2 have a quite high priority to the company.

$$
\begin{array}{c} \\ D.2 \\ F.1 \end{array}
\begin{array}{c} \begin{array}{cc} \quad Str.Cov. \quad & \quad Per.Gap \quad \end{array} \\ \begin{pmatrix} 10/15 = 0.67 & 0.45/1.15 = 0.319 \\ 5/15 = 0.33 & 0.7/1.15 = 0.681 \end{pmatrix} \end{array}
\times
\begin{array}{c} \\ SC \\ EPG \end{array}
\begin{array}{c} Weights \\ \begin{pmatrix} 0.4 \\ 0.6 \end{pmatrix} \end{array}
=
\begin{array}{c} Rank \\ \begin{pmatrix} 0.459 \\ 0.541 \end{pmatrix} \end{array}
$$

Such approach to the resolution of conflicts brings several benefits:

1. each strategic concern can be modeled, inserted, and updated independently of others. This enhances the autonomy of the departments;

2. the user is aware of all concerns. The system does not hide from him/her the aspects of the decision. Instead, it shows a weighted list which indicates the most relevant aspects in that moment;

3. the user is informed about which goals he/she should pursue and can observe how its decisions affect the company's performance in the medium/long-term.

With the advent of this adapter, the process flow is not changed from the point of view of the user. What changes is the recommendations presented to him/her by ROSAS. Figure 9.9 shows the Bonita Console with the new recommendations being presented. The user can see the recommendations of each adapter, the justification for each one, and the performance indicators affected.

The information provided by this adapter (in the logs produced by the Context Provider) allows the manager to check, for example, whether there is a correlation between periods of low free cash flow and a decrease in the use of external carriers. The manager can also compare the information from this adapter and other adapters that are connected to the same action (in our case, the Adapter D.2). This may reveal particular patterns of decision that make the user decide to contract the carrier regardless of the

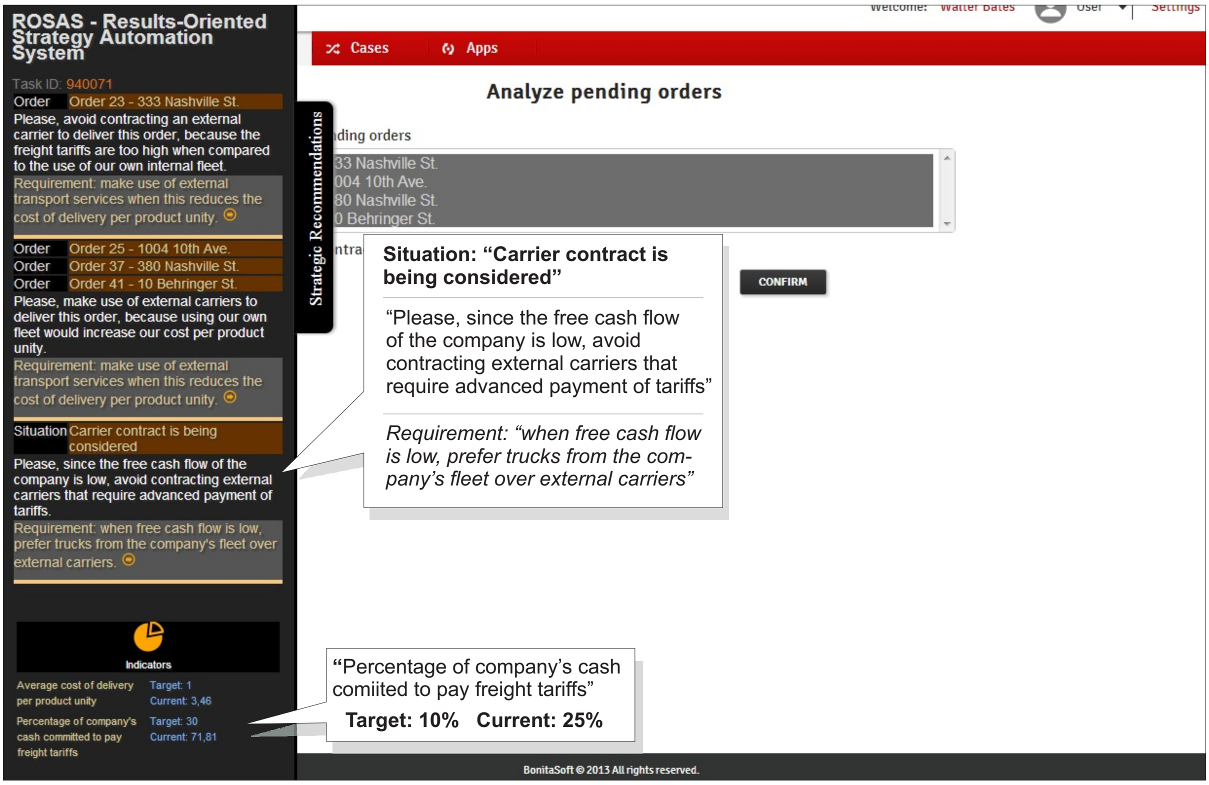

Figure 9.9 Context information including Finance's strategy and indicators

recommendation of the Finance department. If the user's decision shows to be unjustified, the Finance department can identify such pattern.

9.7 Simulation of the Scenario

To evaluate the gains from the SA-BPM approach in the FLM's new strategy, we performed a simulation of the scenario.

The scenario was set up with the following settings:

- **shipment areas**: The city was divided in four "shipment areas". Each area corresponds to the area covered by one truck in a single trip;
- **truck fleet**: FLM has a fleet of 6 trucks, each with a load capacity of 20 items. Regardless of the area, a truck expends one hour in average and exactly $50 dollars to perform the delivery over the area;
- **order dispatch**: orders are grouped by area. When the number of items for an area reaches 20 items, one of the available trucks is loaded and dispatched to the area;
- **carriers**: a carrier covers all four areas in a single trip. Its load capacity is 60 items. There are both cheap and expensive carriers in the market. A cheap carrier costs exactly $100 dollars, while an expensive carrier costs exactly $300 dollars. A carrier is always available when needed, but, at certain moments, cheap carriers are not available;

Table 9.4 Cost per Product Delivered (cpp)

	Max. Load	Cost	cpp
Fleet's truck	20	\$50	\$2.50
Cheap carrier	60	\$100	\$1.67
Expensive carrier	60	\$300	\$5.00

- **carrier assignment rule**: when the sum of pending orders for all areas reaches 60 items, a carrier is contracted to deliver these orders.

The following statistical information was employed:

- **order arrival**: 266 items are ordered per day. The arrival was modeled as a Poisson process with a 33.3 arrival rate (hourly). A day is considered to span 8 work-hours. Items can be ordered by retailers in any of the four areas. The distribution of items among areas is uniform. Hence, any item has equal probability to have been ordered from each of the four areas;
- **carrier prices**: carrier prices change periodically from cheap to expensive. At any time, there is a 50% chance that a cheap carrier is available;
- **shipment time**: the time necessary for a truck to ship all items in its area has an exponential distribution with mean equal to 1 hour.

The scenario was modeled using Generalized Stochastic Petri Nets (GSPN) [71].

Two setups were simulated: a setup with *no adapter* and a setup where the *shipment cost adapter* (D.2) was active. The presence of the adapter determines the carrier assignment rule. When the adapter is active, the employees avoid contracting expensive carriers, regardless of the number of orders pending. These orders are delivered by the company's fleet until the carrier price drops.

Observe that the adapter makes its recommendation based on an estimation of the carrier prices. This estimation may, however, be wrong. A delay between the decision moment and the actual contract of the carrier may provoke the raise of the price in the meantime. Thus, even when the adapter is active, it may occur that expensive carriers are contracted.

9.7.1 Results

The GSPN was simulated using the TimeNet tool [37] with a 99% confidence level and 5% of error tolerance. The following metrics where computed:

- *Throughput – u*: the throughput of the GSPN in terms of items delivered per day. The throughput is split in three flows:
  - u_{fleet}: items delivered through the company's trucks;
  - u_{chp}: items delivered by cheap carriers;
  - u_{expen}: items delivered by expensive carriers;
- *Number of Deliveries – d*: the number of deliveries per day. It is computed from the throughput on the basis of how many items are shipped at once in each delivery. It is split in:

Table 9.5 Setup 1 - No adapter. 99% confidence; 5% error.

Values per day	**Fleet**	**Chp. carrier**	**Expen. carrier**	*Total*
Items delivered (u)	123.2	86.4	86.4	296
Number of deliveries (d)	6.16	1.44	1.44	9.04
Deliveries cost (c)	\$308	\$144	\$432	\$884

Table 9.6 Setup 2 - Adapter D.2. 99% confidence; 5% error.

Values per day	**Fleet**	**Chp. carrier**	**Expen. carrier**	*Total*
Items delivered (u)	228.8	48.0	19.2	296
Number of deliveries (d)	11.44	0.80	0.32	12.56
Deliveries cost (c)	\$308	\$80	\$96	\$748

  - d_{fleet}: number of fleet's trucks deliveries;
  - d_{chp}: number of cheap carriers deliveries;
  - d_{expen}: number of expensive carriers deliveries;
- *Deliveries Cost* – c: the daily costs of delivery, computed from the delivery cost of each shipment method and the number of deliveries per day. It is similarly split in three costs, for each shipment method.

The results of the simulations are presented in Tables 9.5 (setup 1) and Table 9.6 (setup 2). Observe that, without the adapter, the carrier option is adopted more frequently, with only 123 items in a day being delivered with the company's fleet, while 173 items are delivered through carriers. Observe, also in setup 1, that both cheap and expensive carriers are contracted with the same chances, regardless of their price. The total cost for the company is of \$884 per day in this setup.

In the setup 2, the use of the company's fleet raises. A number of 229 items are delivered per day with the fleet's trucks, while only 67 are delivered by way of carriers. As a result, the fleet's trucks make much more deliveries in a single day (aprox. 2 deliveries per truck for a total of 11 deliveries). It can be observed that, when carriers are contracted, most of the time cheap carriers are contracted. Expensive carriers are contracted when the prices change between the time the recommendation is computed and the moment the carrier is actually contracted. At the end of the day, the FLM expends \$748 with deliveries.

The performance indicator targeted by Adapter D.2 is the *average cost of delivery per product*, which we denote by $cpp_{(AVG)}$. This indicator can be computed through the Eq. 9.1.

$$AVG(cpp) = \frac{u_{fleet}\ cpp_{fleet} + u_{chp}\ cpp_{chp} + u_{expen}\ cpp_{expen}}{u_{fleet} + u_{chp} + u_{expen}} \tag{9.1}$$

Through Eq. 9.1 we can compute the average costs of each setup as being:
Setup 1 (no adapters):

$$AVG(cpp)_1 = \$2.99$$

Setup 2 (Adapter D.2 active):

$$AVG(cpp)_2 = \$2.53$$

It can be observed a gain of 15% in performance when the Adapter D.2 is active (setup 2). The use of carriers was also reduced by 50% (corresponding to the probability of a cheap carrier to be available). Considering a 20-day business month, the monthly economy for the company was of $2720 dollars.

These results demonstrate that Adapter D.2's recommendations can successfully improve the performance of FLM in the pursuit of the strategic goals targeted by it (i.e., the reduction in delivery costs). They also suggest that such positive benefits can be experienced by other companies through the application of the SA-BPM approach proposed in this work.

9.8 The Process of Change

In this application scenario we demonstrated not only the role of adapters as tools for strategic implementation, but also as tools to generate audit information.

The analysis of the data generated by adapters (and, possibly, further sources of information) may reveal issues regarding the effectiveness or efficiency of the initiatives proposed by a department. The SA-BPM technology helps in the earlier identification of such issues. The managers are empowered to better analyze the relationship between their strategic interventions in the processes, the operations that were actually performed by the employees, and the results obtained. All these benefits are obtained through the integration of business process management, strategic planning, and business intelligence.

When a change is needed, the SA-BPM infrastructure permits the manager to trace the impacts of these changes on activities, adapters, and processes. Since there are clear links between: processes and adapters; adapters and activities; and activities and strategic goals – then any change in strategies or processes can be traced back and forth to the elements that are affected.

As an example, consider that the corporate managers change the strategy in such a way that small resellers ceases to be the focus of the company. Such a drastic change can be traced down to the process level by constructing the *reverse trace* of the changing element:

- change **Impact 1**: increased market presence;
  - change **Outcome 1.1**: improved distribution efficiency;
    - change *Output 1.1.1*: reduced delivery cost (Distribution department);
    - change Action D.1: renew fleet of trucks, exchanging large trucks with smaller trucks;
    - change Action D.2: make use of external transportation services when larger deliveries are needed;
      - affect the *Shipment Planning* process (Adapter D.2);
    - due to a threatening relationship, review *Output 2.1.1*: avoid cash disbursements when free cash flow is low;
    - review Action F.1: prefer trucks from the company's fleet over external carriers;
      - affect the *Shipment Planning* process (Adapter F.1).

Such traceability is of essential value to improve the strategic flexibility of organizations. It enables a more clear and coordinated process of change and improves the efficiency of the overall change process. Furthermore, if needed, all adapters affected can be immediately disabled. The system will automatically stop making the adaptations that were taking place. As soon as new initiatives are defined, their adapters can be modeled and deployed, offering renewed recommendations to the users. This process can be asynchronous, it does not need an overall redesign of the process, since each department can develop and deploy adapters independently. However, ROSAS also supports the coordination between managers, since it shows clearly where their activities combine or interfere with each other.

9.9 Summary

This chapter described an application scenario that aim to demonstrate the practical usefulness of the concepts proposed in this thesis. The FlexROM management methodology was applied to construct a strategy and the ROSAS was used to implement *adaptable workflows*.

A simulation of this scenario was performed to measure the benefits of SA-BPM to this fictitious organization. The simulation results showed a 15% gain in performance when the process participants follow the recommendations computed by adapters.

As the scenario demonstrated, strategic alignment and change are more efficient when SA-BPM technology is employed by the organization.

CHAPTER 10
Conclusions

It is necessary to develop a strategy that utilizes all the physical conditions and elements that are directly at hand. The best strategy relies upon an unlimited set of responses.
— (Morihei Ueshiba, Founder of Aikidō)

The central subject of this thesis is the use of information technology to improve a firm's strategic flexibility. Companies in complex and uncertain environments need means to adapt their strategies and operations quickly in response to unexpected situations. It is our contention that current IT-based solutions do not fulfill the necessities of these companies. A review of the literature on both business (Chap. 2) and IT (Chap. 4) research fields showed that there are several issues still unsolved.

This thesis proposes the concept and tool support for Strategy-Aware Business Process Management (SA-BPM). The objective of SA-BPM is to close a gap that separates strategy management and business process management subjects. SA-BPM helps companies to overcome a number of difficulties that surge due to this gap:

- *unclear linkages between business processes and strategic goals*, which makes achieving and maintaining the alignment between processes and strategies more difficult;
- *the difficulty in disseminating strategic change thorough the organization*, which reduces the agility to react to unforeseen changes;
- *the difficulty in measuring the contribution of each activity performed by the organization to the achievement of the strategic goals*, which makes it more difficult to identify and address internal weaknesses;
- *the inefficient communication channel between business and IT*, which increases the efforts necessary to identify the requirements for new or changed business processes.

The features provided by SA-BPM systems, which can be constructed on the basis of the theory presented in this thesis, help solving these problems because they:

1. **provide conceptual basis and tool support to *identify and disseminate* the linkage between a business process and the organization's goals**. The concepts of *results-chain* and *work products* are proposed to model both strategies and the linkages between the products generated by business processes and these strategies. On the basis of this model, several features can be developed. For example, it allows the identification of which processes are impacted by the change of a certain strategic element. It also allows for the construction of models for statistical analysis of the contribution of each activity to the performance of the organization. This information is readily

available to all individuals in the organization, improving their *awareness* about the performance of the organization and their own contribution to it;

2. **provide a *modular* infrastructure that *reduces the maintenance efforts* for updating business processes due to strategic changes**. The concept of adaptable workflows, that are composed of a core process model and a varying number of adapters, help decompose processes in a way that makes easier the task of implementing strategic changes. Adapters can be changed, added, and removed from the system, automatically making changes to the adaptable workflow. We quantitatively demonstrated through a metric of maintenance effort that the *strategic* maintenance of adaptable workflows is less costly than that of ordinary workflows;

3. **provide conceptual basis and tool support to *improve the alignment* between an employee's decision choices and the strategic directives of the company**. Through the concept of *recommendations*, adapters apply decision making methods and inform users about how their decision options affect the strategic performance of the company. The methods proposed also allow for measuring the impact of these recommendations over the performance of the firm. For example, in a case study described on Chap. 6, we were able to measure how the recommendations affected the decisions of employees. Prior to the implementation of SA-BPM, there was a weak correlation between strategic concerns and employees decisions. After it, a strong correlation was obtained, giving evidences that the recommendations effectively improved the strategic alignment of the company. A simulated scenario was also presented. The simulation showed evidences that recommendations can successfully improve the performance of the organization.;

4. **provide conceptual basis and tool support to objectively *assess the performance of the organization* and to *measure the business processes' contribution* to its strategic goals**. The FlexROM methodology proposed includes a management step in which the efficiency of the organization is assessed and managers' assumptions are tested. Two main tools are offered to support these tasks. The first one is the automatic mapping from strategy models to path diagrams, which allow the analysis of strategies through the Partial Least Squares method. A second tool is the analysis of correlation between work products generated by business processes and the performance indicators they should help improve. This is accomplished through Pearson correlation analysis, on the basis of the concepts of work products and recommended work products.

Our analysis of the literature also produced two additional contributions. The first one is a *causal model* to explain how the uncertainty of the environment affects internal factors in the organization resulting in the decline of its performance. The second one is a set of *guidelines* on how information technology can help reduce these effects, making the company more apt to deal with environmental uncertainty.

Finally, the FlexROM methodology is also an important contribution of this work. It shows how SA-BPM technology can be applied in practice with a flexible strategy management approach. FlexROM implements the concepts of incremental strategic planning and fulfills several requirements for strategic flexibility mentioned in the literature, such as decentralized decision making and continuous performance assessment.

The contributions enumerated here meet the objectives proposed for this thesis, which were to:

- improve the capacity to identify which operations contribute to each strategic goal and to monitor their performance on that task;

- reduce the efforts required to implement strategic changes;

- improve the employees' awareness about how the firm's strategic goals affect their operations and decision choices.

10.1 Limitations and Future Work

We can recognize some limitations in the work here proposed. The drawback of allowing systems, and business processes in particular, to dynamically change their behavior is the detriment of the capacity to monitor and audit its performance.

It becomes more difficult, for example, to track all processing steps of an order when the process is changed by several adaptations. However, this is an issue also shared by related approaches to business process flexibility. It is still an open question how can we get better control of flexible business processes. The *process mining* research field may offer the best answers for this question. As long as the tools store sufficient information, process mining and data warehouse techniques can be employed with high chances of success.

Another open issue left by this work is how to perform adequate exception handling. If an adapter fails during its execution, should the system stop the process execution? Should it ignore the adaptation and continue from the point before the adaptation started? Such questions were not approached by this work, but are important aspects to be researched in future work.

It is also necessary to conduct more studies on the approach employed by us to adapt business processes. We opted for a very simple adaptation approach in which activities are inserted in a running process. The reason for our choice is that our objective is to allow for the independent maintenance of adapters. An adapter can be inserted or removed from the workflow without interference on other adapters or on the core process. This improves the agility to update strategic concerns, which is our main objective. Further work should analyze how these limitations in the adaptation approach impact the capacity of designers to implement adaptable workflows. Such a study could reveal some design patterns that could help process developers in the design of adaptable workflows, or could inspire a new adaptation approach that presents a better balance between flexibility and expressive power. An example of future directions for this research is the analysis of its relationship with related work on Aspect-Oriented Programming (AOP). Some works have already taken this subject in the context of BPM [21] and may reveal opportunities for integrating new features to our approach.

Finally, more evaluations need to be undertaken to identify the settings in which the contributions of this thesis can be better explored. The case study and the fictitious scenario described here did not cover all aspects encompassed by our approach, due to their relative simplicity. The major benefits of SA-BPM may be obtained when both business processes and strategies are more complex than those shown in these examples. Evaluations in the real settings of large enterprises can show new directions for the advancement of the SA-BPM approach.

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