Agent Assignment for Process Management: Resource Management Support for Skill Intensive Applications of Workflow Technology

Thechnical and Methodological Issues

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M. Ramzan Talib

1. Gutachter: Prof. Dr.-Ing. Stefan Jablonski
2. Gutachter: Prof. Dr. Jorge Cardoso

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DEDICATION

This PhD dissertation is dedicated to my parents for their endless love, prayers, support and encouragement specifically to my late father who taught me the real value of education. This dissertation is also dedicated to my loving wife Sumaira Ramzan, without her ongoing support, inspiration, persistent tolerance and serenity, completion of this dissertation would has been next to impossible. Last but not least, to my four children Reeyyaan, Arshmaan, Furqaan and Etbaan, whose patience is highly appreciated for their amazing waiting and long suffering, I highly appreciate you and your mom for your sacrifices in order for me to complete my PhD.

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ABSTRACT

Managing an organization's resource talent particularly in assigning the right person to the right job at the right time is among the top challenges of today's competitive business environments especially in skill intensive applications of workflow technology since skills of their employees directly affect the business paybacks. Despite that many companies already deal with managing their processes and their human resources, organizations are still feeling the problem of poor resource management. The dilemma is that Workflow Management Systems (WfMSs) support the execution of business process but do only offer static assignment strategies for resources such that an overall poor process performance results. Furthermore, Human Resource Management (HRM) performance evaluation methods lack agility and analytical capabilities that results in poor resource development.

To solve this dilemma of poor resource management, this thesis contributes some technical and methodological supports considering some use case scenarios from a textile industry. It offers Agent Performance Evaluation (APE) Framework and Competency-driven Dynamic Resource Management (CDRM) Methodology to overcome the problem of static assignments and also to support proper resource development. Our APE framework not only evaluates and gives feedbacks of employees' competency profiles but also performs an analysis of employees' competencies for making best use of their talents thus supporting proper resource development. While, our CDRM methodology allocates dynamically only successful employees to their business processes through consistent support of APE framework and thus supports process optimization.

This thesis also contributes a construct in the form of Goal concept and a methodology for continuous resource development in the form of Workflow Lifecycle Support for Continuous Resource Improvement. Defining goals within the process layer, enables organizations to define success criteria of their employees in parallel with all other criteria that influence the performance of an employee within the process. In fact, our APE Framework uses this criteria for evaluating the employees' competency profiles that are latter used by CDRM methodology to allocate only successful employees to their business processes. The Workflow Lifecycle Support for Continuous Resource Improvement aims to define a precise and comprehensive methodology to elaborate a set of basic tasks that are needed to be performed during different phases of the standard workflow lifecycle to achieve continuous resource improvement.

ZUSAMMENFASSUNG

Der richtigen Person zur richtigen Zeit die richtige Aufgabe zuzuweisen gehört zu den größten Herausforderungen im Alltag von Unternehmen, die auf Basis der Fähigkeiten ihrer Mitarbeiter mit anderen Unternehmen konkurrieren. Dies trifft insbesondere dann zu, wenn der Erfolg eines Geschäftsprozesses von den Fähigkeiten der Personen abhängt, welche einzelne Aufgaben dieses Prozesses übernehmen. Obwohl bereits zahlreiche Unternehmen Prozessmanagement und „Human Resource Management“ (HRM) praktizieren, machen viele die Erfahrung, dass das Ressourcenmanagement im Allgemeinen nicht zufriedenstellend ist. Das Dilemma ist, dass zum einen Workflow Management Systeme (WfMSs), welche die Ausführung von Geschäftsprozessen unterstützen sollen, nur die statische Zuweisung von Ressourcen erlauben und dadurch eine ungünstige Performanz des gesamten Prozesses auslösen. Zum anderen lassen die Evaluationsmethoden des HRM Agilität und analytische Möglichkeiten vermissen, so dass die Weiterentwicklung der Ressource ,,Mensch“ im Sinne des Prozesserfolgs nicht gesichert ist.

Um dieses Dilemma des schlechten Ressourcenmanagements zu lösen, steuert diese Arbeit technische und methodische Ansätze bei, die auf Anwendungsfällen der Textilindustrie beruhen. Im Speziellen sind dies ein „Agent Performance Evaluation“ (APE) genanntes Framework sowie eine „Competency-driven Dynamic Resource Management“ (CDRM) genannte Methode, die das Problem der statischen Zuweisung von Ressourcen sowie die Weiterentwicklung von Ressourcen aufgreifen und lösen. Das APE Framework evaluiert nicht nur die Fähigkeiten einzelner Mitarbeiter und gibt zu diesen Feedback, sondern führt zudem Analysen durch, um die Fähigkeiten einzelner Mitarbeiter bestmöglich während der Ausführung eines Geschäftsprozesses zu nutzen und auf diese Weise die Weiterentwicklung zu unterstützen. Die CDRM Methode baut auf diesen Ergebnissen auf und weist dynamisch nur ,,erfolgreiche“ Agenten Prozesse zur Ausführung zu. Das APE Framework und die CDRM Methode bieten damit eine Möglichkeit, Geschäftsprozesse zu optimieren.

Als weitere Beiträge stellt diese Arbeit ein Konstrukt in Form eines Ziel-Konzepts sowie eine Methode für eine kontinuierliche Weiterentwicklung von Ressourcen basierend auf einer Erweiterung des Workflow Lifecycles vor (Workflow Lifecycle Support for Continous Resource Improvement). Die Einführung der Beschreibung von Geschäftszielen in Form von Konstrukten auf Ebene der Prozesse erlaubt Organisationen, Kriterien zur Evaluierung der Leistung einzelner Mitarbeiter parallel zu allen Einflussfaktoren im Prozess darzustellen. Das APE Framework baut auf diesen Metriken auf, um das Erfolgsprofil eines Mitarbeiters zu eruieren. Die Erfolgsprofile aller Mitarbeiter werden dann wiederum im Rahmen der CDRM Methode dazu eingesetzt, Mitarbeitern die Prozesse zuzuweisen, für die ein positives Endergebnis zu erwarten ist. Die Erweiterung des Workflow Lifecycles detailliert eine Menge von einfachen Aktivitäten, die zusammengenommen eine präzise aber gleichzeitig verständliche Methodologie definieren und die in unterschiedlichen Phasen des Workflow Lifecycles angesiedelt sind mit dem Ziel, eine kontinuierliche Weiterentwicklung von Ressourcen zu gewährleisten.

CHAPTER 1

INTRODUCTION

Chapter 1: Introduction

This chapter enlightens the foundation of our work by starting with the illustration of the main motivation of the research direction. Our primary research objective is to facilitate competitive business environments – with special focus on skill intensive environments – in managing their process performance specifically for the efficient allocation of resources to their business processes. Workflow technology plays a vital role for an automatic allocation of resources to their business process, thus we will first spotlight on Workflow Management in Section 1.2. Then in Section 1.3, we will elaborate Workflow Resource Management to demonstrate how resources are defined in the organizational model and are automatically assigned to their business processes using assignment strategy. Subsequently, in Section 1.4 we will exclusively focus on primary issues that are outcomes of our comprehensive survey of the literature, an exclusive analysis of competitive business environments and an evaluation of existing frameworks. With respect to these issues, we also drive key requirements which we believe to be essential criteria that influence the effectiveness of the solutions for managing efficient task allocation. Section 1.5 concludes the chapter by defining the main contributions of our solution. Finally, Section 1.6 will present the roadmap that illustrates on how the rest of the thesis is organized.

1.1 Motivation

Nowadays, due to globalization, speed and fierce competition businesses are much more competitive than ever before. Businesses are changing constantly – challenges and opportunities are arising every day. New competitors emerge all over the world while others disappear. In order to survive and remain competitive with the global market it becomes crucial to manage the overall high performance for their business processes.

Workflow is a technology that aims to provide a suitable platform to achieve and sustain the highest level of business process performance. But, despite the long history of well-established workflow technology, and the increasingly recognized relevance of performance management, organizations are still facing the problems of poor process performance. A process can be inefficient due to many reasons:

- Structured weaknesses observed in the process model [Aal04a][Aal05].
- Poor data management for process enactment [Rehm07][Jabl06].
- Poor resource management for the success of business process performance [Son07][Rind07].

Academia and industry have collaborated to reduce and overcome much of these inefficiencies. For example, they developed many process mining algorithms to analyze, diagnose and remove structural weaknesses observed in the process models [Aal04b][Don05]. Also, many data management frameworks were developed for proper data transportation, transformation and integration [Jabl08a][Apat11]. But, notwithstanding with the latest development of workflow technology, less proper attention is given to resource management [Ley09][Ying07][Mueh04a][Moor02].

The organizational resources (i.e. employees, human agents, staff, or people) are the main asset of any organization [Harr05]. They play a vital role for the success of business processes. It is because they serve as the driving force of their business i.e. people do business, not processes. Therefore, they are the key enabler of high business process performance. As a matter of fact, an organization cannot compete or even survive unless their employees successfully produce end results.

Over the last few years, we have witnessed the way the organizational resources are currently being managed in today's competitive business environments. Organizational resources, while they are deployed within an application of workflow technology, are in fact managed dually i.e. the workflow management system (WfMS) as well as the human resource management (HRM) department of the enterprise. Despite this two folded resource management, we have observed organization are still feeling problem of poor resource management.

In the following two subsections, we outline our well identified causes of poor resource management stemming from each dimension individually.

1.1.1 Workflow Resource Management

A Workflow Management System (WfMS) aims to support the modeling, execution, monitoring and overall management of business processes. It also defines the resources required for the execution of these processes as well as manages their automatic assignment for their successful enactment. But our experience with the today's competitive business environments, especially in skill intensive environments like engineering and textile industry, indicates that organizations are still feeling the problem of poor workflow resource management [Jabl09].

We have observed that in most WfMSs, an organizational resource is simply defined as an entity that is initially assigned to a process during process design time. While during process execution, he is then requested to perform the task. We have observed that mostly employees are assigned to processes on the basis of their capabilities and skills usually defined in terms of a "*role*". For example in a textile industry, a **Cutting Process** is assigned to **Cutters** (role; group of employees capable to cut fabric for specific garment) and a **Sewing Process** is assigned to **Sewers** (role; group of employees capable to sew apparel) during process design time. When a process step (e.g. Cutting Process) is executed, its associated role (e.g. **Cutters**) is utilized by a WfMS for automatic task assignment i.e. all employees belonging to that role are informed about the task to perform. One of the eligible employees then claims that piece of work and performs it.

We have realized that organizations are experiencing problems with such type of resource management i.e. utilizing the "role concept". In particular where the assignment of resources to a process is "merely" done through a role concept, their assignment is "static". Their assignments become static due to following four causes:

- Cause-1: Role (e.g. **Cutters**) used for the assignment of employees to a process is determined only once at the introduction of a workflow application (at process design time).
- Cause-2: Employees belonging to that role are not reevaluated by the WfMS to determine who is performing a certain process how well.
- Cause-3: No dynamic feedback about "unsuccessful" employees is given for the forthcoming processes improvement.
- Cause-4: No success definition is observed within the process to figure out unsuccessful employees.

As a consequence, all the employees belonging to that role remain enacting the process even if some of them have poor performance. For example, employees whose cutting faults are beyond the acceptable limit also continuing with their processes. This as a result drags the performance of a business process down. As a matter of fact it is quite possible, especially in skill intensive environments, that employees although having the same capabilities they still achieve different success levels i.e. employees result in different levels (%) of cutting faults while they are cutting different fabrics. It is due to the disparity of their levels of expertise, experiences, attitude, understandings, judgments, opinions, correlation etc.

1.1.2 Human Resource Management

Almost all organizations have a separate Human Resource Management (HRM) department that basically is concerned with overall comprehensive resource management tasks including their recruitment and selection, performance evaluation, training, promotion, termination or layoff, transfer, bonus, compensation. There, evaluators either manually or using a software system basically utilizes different methods and techniques like Balance Scorecard [Kap92], Critical Incidents [Twel11], Graph Rating Scales [Grs11], Forced Distribution [Forc11], Work Standard [Raph11], Management By Objectives (MBO) [Mbo11] etc. to evaluate employees' performance by focusing different aspects like personality, cooperation, dependability, initiative, knowledge, quality of work related to assigned tasks.

To evaluate "the link between an employee and a process" in particular, they use Management By Objective (MBO) technique. According to MBO, employees are assigned task specific "goals" and their performance is evaluated by computing their "competencies". According to MBO, goal is a measurable target that an organization sets up to be achieved by their authorized resources and is used as a yardstick to determine their success of business process performance. For example, the "cutting fault should be less than 2%". This defines a "success criteria" for cutters against which they are evaluated. Moreover, competency is defined as the measure of "achieved success" by an employee towards accomplishing the goal while performing their assigned task.

After analyzing the HRM performance evaluation techniques, methods and tools, we have observed, though the results of such wide-ranging performance evaluation are comprehensive and extremely useful they still suffer two main problems:

- Cause-5: The result of the traditional HRM based performance evaluation is "not agile", especially for a process centric view of employees' performance. Not agile means the result of such evaluation is too late usually done just once a year. As a result, continuous evaluation of the "link between an employee and a process" i.e. who is

performing a certain process how well, either get delayed until the result of general appraisal (a comprehensive task), or is done more-or-less manually (difficult to do). Indeed, agility of the process centric employees' performance evaluation at operational level is becoming very essential for today's competitive business environments, because it provides the companies with the ability to accurately measure employees' performance specific to their process in a timely and accurate fashion. Moreover, it also facilitates organizations to respond the observed employees' deficiency proactively, more precisely and quickly. Since, when it is timely observed that certain employees are not performing well, process centric decisions (either to further allocate them or not, or suggest a training), can be made more efficiently and effectively. Instead of simply waiting for the tardily result of general appraisal which inevitably leads for downsizing or layoff, especially for those employees who were observed inefficient after general appraisal. Thus does not support for continuous resource development.

- Cause-6: The traditional HRM methods do not support "analytical analysis" of employees' performance. Rather, these methods only support "simple evaluation" of employees' performance that is not suitable for continuous resource development. Basically, continuous resource development aims at "intuitively" guiding resources for dynamic performance improvement. Such guidance is not sufficiently supported through simple evaluation e.g. MBO, because simple evaluation just determines the observed status of an employee (either good or awful). However, for continuous resource development it is highly desirable that the result of the performance evaluation mechanism should not just deliver only good or awful status of employees' performance. In contrast to simple evaluation, analytical analysis of employees' performance is more suitable for continuous resource development since, it determines under "what certain conditions" employees are performing "how well", and "what certain improvements" are actually required. Such feedback is creative to sufficiently guide employees and to passably create instill in them for their performance improvement. Thus, through analytical analysis employees can intelligently be guided for their performance improvement.

To exemplify different scenarios of skill intensive applications of competitive business environment, we will use garment production processes of a textile industry [Kml11]. Textile production processes are the best fit examples of skill intensive applications of competitive business environments since, skills of their employees directly affect the production outcomes of their production processes. This motivates production manager to perform process centric analytical analysis of their employees' performance for better resource management.

We aim for its process improvement effort particularly at improving agent assignment strategies i.e. to allocate only successful agents instead of merely eligible agents. For this purpose, we observed its three main production units, namely Apparel, Dyeing and Weaving comprising more than twenty processes and above 730 employees were involved. Thus, through the experience gained from textile industry and after analyzing the workflow' resource management support and also along with HRM performance evaluation methods/techniques, we observed that organizations are suffering a resource management dilemma. The dilemma of resource management is that on one hand, workflow resource management offer only static assignment strategies without supporting any implicit performance evaluation mechanism to determine successful or unsuccessful employees that as consequence leads to poor performance; on the other hand, HRM performance evaluation techniques/methods are firstly, "not agile" and secondly, do not perform analytical analysis thus insufficient support continuous resource development.

Even though process centric analysis of employees performance can be made either manually or using data mining techniques. But our real world experience with textile industry indicates that it is difficult to perform such analysis more or less manually by process supervisor/controller (e.g. cutting supervisor). Moreover, even when such analysis is made manually, the quality of such analysis heavily depends upon the experience and analytical skills of the person that perform it (i.e. process supervisor or even HR personal). He cannot perform such deep analysis "manually" as opposed to data mining techniques – ultimately used for knowledge discovery and decision making. Therefore, utilizing data mining techniques within WfMS to perform process centric analytical evaluation of employees' performance is the better choice.

Workflow technology has proved to be an ideal candidate for managing business processes according to organizational needs since it focuses on aligning all aspects of an organization to promote business effectiveness and efficiency. It also helps to integrate different technologies to support continuous process improvement. Therefore, to overcome the dilemma of resource management, it is a suitable platform for the

1. introduction of a performance evaluation mechanism within the process layer as an auxiliary application of WfMS to support "agility for process centric employees' performance evaluation", and the
2. integration of data mining techniques within the process layer to perform process centric analytical analysis of employees' performance to support "continuous resource development".

Though, most of the existing workflow frameworks have endeavored to develop Performance Evaluation Frameworks like IBM WebSphere [Web07], Global 360 enterprise BPM suite

[Glob06], Tibco iProcess Suite [Tib06] etc. They use simple Key Performance Indicators (KPIs) in their monitoring model for tracing business process performance and efficiency. Their monitoring models only issue alerts when KPI values deviate from predefined target values but do not allow for pro-active feedback. KPIs in general are good for measuring the current process performance but they are unable to detect the causes of the problem because they do not establish a link between the process outcome and an employee who is performing it. Thus, a KPI alone does not allow for resource management.

Presently, due to the lack of process centric analytical employees' performance evaluation mechanism, process supervisors are performing such analysis "manually" which ultimately places extra burden for them which results excessive time delay. Therefore, In order to cope with the resource management dilemma in a well-organized and transparent manner, there is need for a performance evaluation mechanism within the process layer in order to support agility for process centric resource decisions management. Furthermore, it can also perform process centric analytical analysis of employees' performance to support continuous resource development.

Now we conclude our motivation section in Table 1.1. It presents the summary of our well identified causes of poor resource management stemming from both domains i.e. Workflow Resource Management as well as HRM Resource Management.

Problem Description						
Main Problem →	Poor Resource Performance					
Solutions →	WfMS Resource Management				HRM Resource Management	
Sub Problem →	Defined once (Cause-1)	No reevaluation (Cause-2)	No feedback (Cause-3)	No success definition (Cause-4)	No agility (Cause-5)	No analytical analysis (Cause-6)

Table 1.1: Causes of poor resource management

However, to grasp the problem definition more convincingly, basic understanding of some fundamental concepts is important. In the following two sections, we give a short overview on

Workflow Management and Workflow Resource Management. However, familiar readers may skip these sections to directly precede Section 1.4.

1.2 Workflow Management

The spirit of workflow management is to facilitate organizations conducting their business processes according their needs and specifications. The formal concept of a workflow has existed for a long time and has drawn enormous attention in the research and development communities of databases and information systems. It has roots from manufacturing, office automation, software process management, and transaction processing systems [Bau80]. It concerns to provide automated support and coordination of business processes by aligning of all aspects of an organization to promote business effectiveness and efficiency while striving for innovation, flexibility through the integration of new technologies to support continuous processes improvement [Jab96]. For continuous process improvement and supervision of business processes, it also provides process improvement theories e.g. workflow lifecycle, that groups different stages of workflow basing on their functionality into different phases like Analysis, Design, Implementation, Enactment, Monitoring and Evaluation to achieve success of business process performance [Broc10].

Basically, a WfMS is a software system that automates processes and manages the flow of work between workflow participants (i.e. resources) according to the formal specification of business processes, called workflow. A workflow (or workflow model) defines process steps, their order, under which conditions and when they will be carried out, by whom (resources i.e. human agents) within an organization, with which tools (i.e. applications), and define the flow of data within these process steps [Jab96]. It consists of a modeling component for the creation of workflow models; a workflow engine that creates workflow instances from the workflow models and executes them; and also administrative components that comprises set of methods, techniques and tools that helps organization for continuous supervision and improvement of their processes [Card09].

Also, while modeling a business process, the Business Process Modeling Language (BPML) plays a very important role. It provides basic constructs (i.e. available by the language) to integrate many types of information into a process model. Therefore, selection of a particular BPML to adequately describe a business process for specific domain is essential. Because, required constructs may not be available for the specific language since today BPMLs differ in the extent to which their constructs highlights different information associated with them [Jabl08b][Jabl09b]. Furthermore, the Meta Model of a BPML is a comprehensive model that defines the modeling language itself, comprising all of its basic elements required for

expressing a process model. However, flexibility of the meta model for the extension of a new construct is important especially when required modeling constructs are not available beforehand.

Essentially, we differentiate between the term “process” and a “workflow” in [Jabl96]. A process is an abstract description and therefore cannot be executed whereas a workflow it is “somehow” derived from a process and in contrast it is executable. However in this thesis, since we mostly focus on the execution and evaluation aspects for performance management, we want to take them synonymous.

However, when a workflow is executed in a workflow application system, the main task of WfMS is to coordinate all aspects of a process. A WfMS has to take care that all process steps are executed in the right order, consuming and producing the right data, applying the right applications, and the most important to select the right agents.

We follow an innovative approach for the “selection of qualified agents” in contrast to traditional approaches. Traditionally, agents belonging to a certain role are considered as all right and eligible to execute a certain process [Bus95]. In contrast, we consider only those agents as qualified agents, who are executing the process “successfully”. Therefore, for the selection of right agents (i.e. only successful agents), we introduce business intelligence for proper workflow resource management.

1.3 Workflow Resource Management

Business process automation requires the specification of a process model as well as the specification of the organizational resources involved in the execution of these processes. During process design phase, the process designer designs both: the structure of the processes to be automated within the process model, as well as the description of the resources involved in the execution of these processes within the organizational model. Whereas, the link between these two models is defined through the “assignment policy”. An assignment policy describe the agent selection criteria: “who will execute a certain process step?” [Bus95]. However, during the execution of a certain process step, a workflow engine utilizes the corresponding assignment policy and retrieves the list of eligible agents from the organizational model through a policy resolution mechanism [Buss95].

We observed, in the workflow context, resources are traditionally being treated as if they were cogs in a machine – usually defined in the organizational model and simply utilized through assignment policy. WfMSs have no concerns about:

1. How successfully are they performing their process?
2. What certain improvements do they need?

3. How can they be guided for their continuous improvement?

Moreover, as described within the reference model of the Workflow Management Coalition [WfMC10], management of the resource information also lies within the responsibility of a WfMS, that basically reflects the fact that a WfMS not only needs to provide a mechanism just to define organizational resources involved in the execution of business processes but it must provide the mechanism for their continuous improvement [Mueh04b].

Although some of the frameworks e.g. BPEL Process Manager V.10.1.2 (Oracle) [Mul05] and iPlanet 6.0 (SUN) [Sun03], have developed some resource management facilities as an auxiliary application for their WfMS to support better resource management. For example, they utilize workflow execution history for resource allocation just on the basis of "more executions; more experience" and or "quick execution time" – but, without focusing on "success of business process performance" aspect of employees.

1.3.1 Organizational Model

Basically, an organizational model is used to describe the "society of employees" in an enterprise involved for the execution of their business processes. It is described in terms of organizational elements and organizational relationships. An organizational element basically abstracts employees' collection at certain organizational level [Bus95]. Usually, these elements are **Agents** (i.e. employees in an organization), **Roles** (i.e. group of employees having similar capabilities), **Groups** (i.e. members of certain project), **Departments** (i.e. group of people performing tasks of similar objective) etc. Whereas the organizational relationship describes how different organizational elements are interrelated or associated with each other while they are performing their tasks [Jabl96]. For example, **play**, **member of**, **belongs to** etc, are used to describe: "who **play** what role", "who are the **member of** certain groups", "who **belongs to** which department" etc.

An organizational model is instantiated from an organizational meta model that provides the foundation for defining certain organizational elements and their interrelationships depending on their availability in the meta model [Buss95]. Mostly, WfMSs have their specific organizational meta model that is used to instantiate particular organizational model for the enterprise under consideration. For example, Staffware [Sta02] has a relatively simple meta model to define only users, groups and role in the organizational model whereas COSA [Tran03] has a rather richer meta model to define users, groups and groups hierarchies, role and role hierarchies, capabilities and more types of organizational relationships.

In our workflow resource management approach we use the organizational meta model [Buss95] shown in Figure 1.1 because it is more general, expressive, flexible, and extendable than the organizational models of commonly used WfMSs e.g. Staffware [Staf02], WebSphere [Web03], FLOWer [Flo04] and COSA [Tran03]. It allows the definition of all types of organizational elements and relationships that are required while modeling any particular enterprise. Instead of having fixed list of organizational elements and relationships from a certain meta model, it allows to define any organizational element by simply instantiating **Object** type, and any relationship by instantiating **Relationship** type. According to an object oriented meta model, object type describes the organizational elements like agent, role, department, group etc, whereas relationship type describes the possible association or dependency between the derived organizational elements. Thus, this object oriented organizational meta model allows enterprises to implement their own organizational model according to their need without being limited to a presumed set of model elements and or relationships.

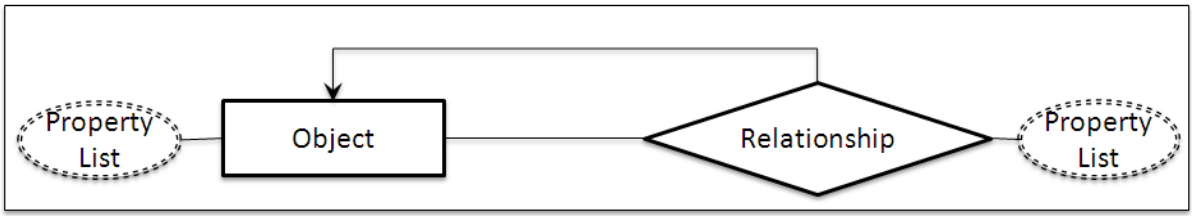

Figure 1.1: Organizational meta model

As an example, the organizational model of an Apparel Division of a textile industry that is mainly concerns for the production of different apparels is shown in Figure 1.2 (a short view). In the apparel division, the Garment Production Process is the main process typically concerns with skill intensive manpower and is generally consists of sub processes like Marker Making, Cutting, Sewing, Washing, Button and Rivets Attachment, Trimming, Pressing etc. The organizational model is created from the organizational model by first instantiating the object type (e.g. **Agents**, **Roles**, **Department** etc) and the relationship type (e.g. **Play**) whereas **Property List** describes characteristics of their corresponding object type and relationship type in terms of attribute of their corresponding database tables accordingly. Then this model is further populated through concrete instantiation of individual objects and relationships. For example, “Ali” and “Amir” are the instances of organizational object **Agents**; “Cutters” and “Sewers” are the instances of organizational object “**Roles**”; whereas “Ali” **Play** “Cutters” is the instantiation of organizational the relationship **Play**.

Agents

Agent	Description	--
Amir	--	--
Rehman	--	--
Saqib	--	--
Tahir	--	--
Naveed	--	--
Shahid	--	--
--	--	--

Roles

Role	Description	--
Cutters	--	--
Sewers	--	--
Washer	--	--
Attacher	--	--
Trimmer	--	--
Presser	--	--
--	--	--

Play

Agent	Role	--
Amir	Cutters	--
Rehman	Cutters	--
Saqib	Cutters	--
Tahir	Cutters	--
Naila	Attacher	--
Arif	Trimmers	--
--	--	--

Groups

Groups	Description	--
Winners	--	--
--	--	--

--	--	
--	--	
--	--	

Departments

Department	Description	--
Production	--	--
--	--	--

Figure 1.2: An organizational model of an apparel division

1.3.2 Assignment Policy

In order to execute a certain process, different WfMSs offer various ways or manners for the selection of appropriate agents from the organizational database, based on the criteria defined by assignment policies. In a real world enterprise, a process can be assigned to an agent directly (e.g. Amir), or to a role (i.e. on the basis of capability like **Cutters**), or to a group (e.g. agent working on the same project) or in terms of organizational relationships among employees (e.g. ManagerOf(Ali) can sign Ali's leave application). Additional constraints like **Delegation** (e.g. if a user is not available, process should be allocated to an alternate user), **Binding of Duties** (e.g. customer complaint should be handled by an employee who actually sold the product) and **Separation of Duties** (employee should not approve his/her own leave) are also required.

Basically, an assignment policy specifies the eligible agents: "who should execute the process". This eligibility is defined in terms of agent selection criteria that the user must meet to proceed for process execution. This criteria is mostly described in terms of entities or relationships defined in the organizational model in order to select subset of agents out of an

organizational database [Buss95]. Assignment policies are defined during process design time. While during process execution, a workflow engine automatically evaluates the assignment policy through a policy resolution mechanism which determines eligible agents who are further continued with their process execution.

```
ASSIGNMENT_POLICY
    WORKFLOW                    ProductionProcess.Cutting
    OPERATION                   Execute()
    AGENT_SELECTION             Agents Play Cutters
    RUNTIME_CONSTRAINTS         WithinDays(2)
    SYNCHRONIZATION             1
    NOTIFICATION                Worklist
END_ASSIGNMENT_POLICY
```

Figure 1.3: An assignment policy for cutting process

Traditionally, an assignment policy does not have any notion regarding employees achieved success i.e. competency. For example, for the Cutting Process, AGENT_SELECTION clause of traditional assignment policy (Figure 1.3) merely restricts “agents who plays cutters role” can execute cutting process. As a result, all cutters are allowed to perform cutting, without focusing on “how successfully they are performing their job”.

1.4 Identified Issues

Despite large effort in research and industry organizations are feeling problems in efficient resource management. Based on our real world experiences in different application domains, especially skill intensive environments (e.g. textile industry), we have identified different issues and in view of these issues we have also derived key requirements. In fact, these requirements can serve as the major criteria to compare the evaluation of various aspects of the state of the art of WfMSs along with their support for resource management.

We not only strongly believe but also the prototype implementation of our solution in the above mentioned application domain has convincingly demonstrated that the accomplishment of these requirements in fact facilitates an organization in managing their resources proficiently. In this section we will spotlight on the identified issues and enlist derived key requirements.

Issue 1: *Lack of BPMLs expressiveness*

Today, there is a lot of business process modeling languages (BPMLs) that express different perspectives (e.g. functional, informational, behavioral, operational and organizational etc) of a process. To adequately describe a business process, many forms of information related to these perspectives must be integrated into process models. Different constructs are made available by BPML to integrate different information regarding many aspects of different perspectives of a process. But, despite the availability of many BPMLs, presently BPMLs lack to model "***success criteria***" for a process against which all of its authorized agents are evaluated. But as a matter of fact, today in almost every organization, particularly skill intensive environments, administration defines "criteria" for their employees to access their business process performance, specific to their assigned tasks. This success criteria actually helps them in measuring employees performance in terms of different success levels. Though, it exists even in the process theory yet not still incorporated in workflow implementation. Therefore, in order to support proper resource management and to overwhelm the lack of success definition (Cause-1) there is an eminent need for **a construct** in workflow modeling composition, so that it can add a "success criteria" ultimately required for measuring certain level of agents' success of business process performance and serve as a yardstick to evaluate agents' performance appropriately.

Requirement 1: *BPMLs need to model 'success criteria' ultimately required to determine certain level of agents' success of business process performance*

Issue 2: *Missing support for an agent performance evaluation mechanism*

Our analysis over state of the art WfMSs indicates there is "something missing" for the process centric agent performance evaluation mechanism which is ultimately required for continuous resource improvement. Currently, to the best of our knowledge, almost all WfMSs assign agents to their business processes during process design time (Cause-1) by simply assuming that they will execute it successfully. But as a matter of fact, it is neither reevaluated (Cause-2) to observe how successfully certain processes are actually being performed by their authorized agents nor is feedback into future assignments (Cause-3). Due to this vital fact, unsuccessful agents remain with their processes. This situation is very awful for business point of view because it inevitably drags the performance of a business process down. Therefore, in order to improve the success of business process performance (in general) and to provide support for the continuous resource management (in particular), there is a prominent need for an

agent performance evaluation mechanism within the process layer to support agility (Cause-5) and analytical analysis (Cause-6) for continuous resource development. Thus, this analytical performance evaluation mechanism must be able to answer the following:

1. To determine whether all employees are performing a certain process almost equally well.
2. If a certain process is being performed differently by different employees, THEN it can also determine: whether certain employees are performing the process differently under certain different conditions.
3. If it is observed that certain employees are performing a certain process differently under certain different conditions (Cause-5) THEN it can determine:
    a. Firstly, what are those conditions where their expertises are outstanding?
    b. Secondly, who are performing a certain process how well and what those certain conditions are where certain employees are performing the process well.
4. Does it provide effective feedback (Cause-3) to WfMS to improve its forthcoming process assignments? Objective is to put employees' talent to the best use i.e. so as, when a certain process concerning to certain situation (i.e. condition) is ready for execution, WfMS can first identify that certain situation for the process ready for execution and can then allocate it only those employees who were observed successful, for that specific condition – more intelligently (Cause-5, Cause-6).
5. Does it provide feedback to resource about: under what certain situations what certain improvements they actually required for their continuous improvement towards better resource development (Cause-5, Cause-6)?

Requirement 2: *Need for a process centric analytical agent performance evaluation mechanism for continuous resource improvement*

Issue 3: *Missing process lifecycle support for continuous resource improvements*

As a matter of fact, several process improvement theories (e.g. Six Sigma, Total Quality Management, Business Process Reengineering and Leans Systems) exist that guide for continuous process improvement. These theories describe different activities in aligned with different phases of workflow. For example standard process lifecycle differentiate different phases like Analysis, Design, Implementation, Execution and Evaluation in

order to provide sufficient methodological guidance for continuous "process" improvement. But these theories, especially for proper resource management, do not provide sufficient guidance for continuous "resource improvement". Because, they simply explain only "resources utilization" through static assignment (Causes-1,2,3,4) in their different phases but do not specify explicitly any methodological guidance about: who will perform what task in each different phases of standard workflow lifecycle to provide proper support for "continuous resource improvement" (Causes-5,6). Therefore, to provide appropriate detail for continuous resource improvement within process lifecycle there is a need to specify explicitly different set of tasks along with their performers <<who performs what>> in each different phase of the lifecycle.

Requirement 3: *Need for a lifecycle support for continuous resource improvement*

Issue 4: *Insufficiency of work allocation mechanism*

In competitive business environments, especially skill intensive environments, employees' work history plays an important role. Based on their work history, an organization decides either to allocate or to revoke a certain process from certain employees. In order to improve success of business process performance, work history enables organizations to "continuously identify and allocate only successful employees" to their business processes. A WfMS is a software system that aims for overall management of business processes. It also manages the flow of work among workflow participants. It offers different ways or mechanisms to allocate work item to workflow participants. But, real world applications of workflow, however, demand that existing task assignment mechanisms/methodologies are not sufficient to cope with their overall requirements because currently they are defined only once (Cause-1) and do not have the ability to allocate work items to agents on the basis of "history of their success of business process performance" dynamically. Existing task allocation mechanisms do not focus the agents' work history towards business success because currently history is neither evaluated nor incorporated into future assignments. Consequently, as a result, unsuccessful agents also continue with their processes that ultimately result poor business process performance. Therefore, in order to improve success of business process performance, today's competitive business enterprises demand "***an ability to allocate***" work item to those participants who have credible history of *success of business process performance* i.e. only successful agents continuously remain enacting the processes. Furthermore, this allocation mechanism must be sufficiently expressive so that "agents' history of success of business process

performance" can be defined explicitly within ***agents' selection criteria*** of an assignment policy during process design time – while, assignment policy is being defined.

Requirement 4: *WfMS needs for a mechanism to allocate work item to resources on the basis of their history of achieved business success*

1.5 Contributions

The thesis presents efficient solutions for proper resource management towards achieving success of business process performance. Our following contributions overcome the drawbacks and limitations of the existing WfMSs and facilitate the skill intensive competitive business environments by accomplishing all the derived requirements in a well structured and transparent manner. Figure 1.4 demonstrates our main contributions and solutions by aligning them with our well identified issues and key requirements.

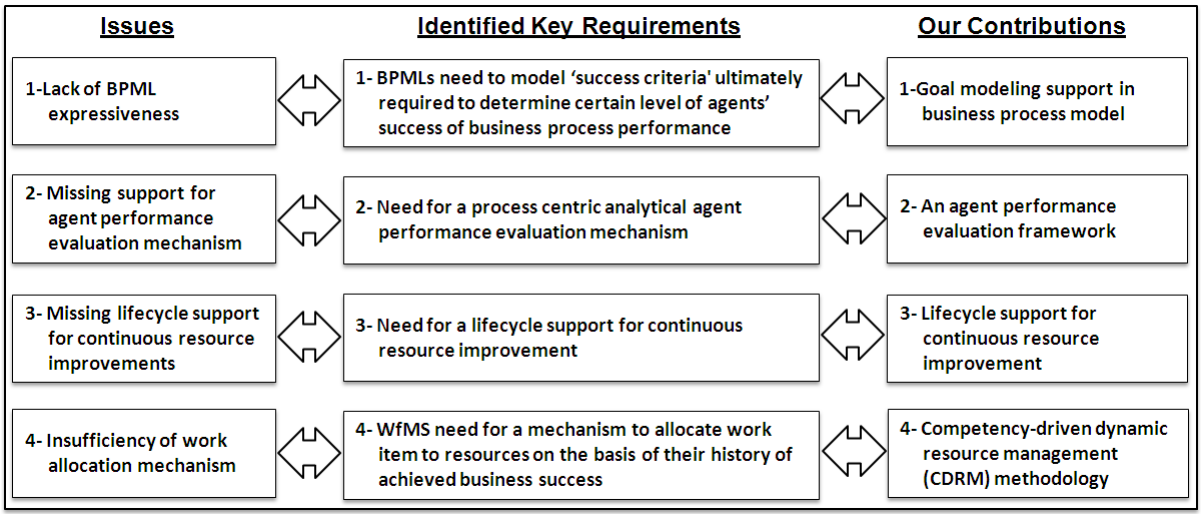

Figure 1.4: Alignment of identified issues, key requirements and our contributions

Thus we make the following technical contributions:

Contribution 1: *Goal modeling support in business process model*

We model goal in the process model that defines "what success is and how to measure it". Basically for a process, a goal defines a measurable target to be achieved by all of its authorized agents. To be successful, achievement of the goal is essential for all of its authorized agents. In fact, we define the goal in such a way that a software system can use it as a "formula" in determining how successfully employees are performing a certain process. Actually through goal definition, success of the business process is defined in terms of different success levels. Further, each success level is assigned different priorities to rank each certain level in the group. Therefore, goal definition enables performance evaluation system to determine: Up to what certain success level, certain process is actually being performed by their authorized agents by utilizing the priorities associated with each different success level. Thus a goal serves as a "yardstick" for measuring certain level of employees' performance – only. However, neither it actually evaluates nor does responsible to evaluate the performance – itself.

Moreover, through our approach of goal modeling, context of the process is also incorporated within the goal model. This context definition basically helps in integrating more domain relevant knowledge e.g. influencing factors that may however maneuver employees' performance towards achieving their best level of success of business process performance. Thus, our goal modeling provides sufficient support for defining a complete performance measurement infrastructure. Therefore, this performance measurement infrastructure can be used as a yardstick towards performing process centric analytical analysis of employees' performance.

*This contribution is explained in Chapter 3.

Contribution 2: *An agent performance evaluation framework*

We have developed an Agent Performance Evaluation (APE) Framework that aims to evaluate agent performance specific to their process. It uses workflow execution history integrated with application data as a "*data source*" about the previously executed workflow instances and goal definition as a "*yardstick*" to compute agent competency profiles. Basically, agent competency profiles are computed specific to each agent who has executed the process in the history with the objective to determine "who is performing a certain process how well".

Moreover, it also has the ability to perform analytical analysis of agents' performance as it comprises different methods from data mining technology that carry out process centric analytical evaluation of agents' performance and to compute their competency profiles. These data mining methods utilize the CONTEXT of the process from goal definition to perform such analytical analysis. These methods basically have the ability to determine whether different scenarios (patterns) of a process do exist where predominant agent expertise are observed. If such scenarios are observable then data mining methods determine how each particular agent is performing a certain process how well and under what certain scenarios i.e. agent competency profiles are determined specific to their scenarios (i.e. conditions) of expertise. Otherwise, simple agent competency profiles are determined i.e. "who is performing a certain process how well".

APE Framework then feeds these competency profiles back into an organizational database. Again, process CONTEXT that is a part of goal definition, also helps framework in selecting the appropriate Organizational Element/Relationship from the organizational database in order to perform appropriate feedback. Through APE Framework, when organizational database is consistently upgraded with agent competency profiles, it supports WfMS for successful agent selection for its forthcoming process allocation, because organizational database is a data source wherefrom agents are selected by a WfMS through policy resolution for forthcoming process allocations. Thus, APE Framework provides support for continuous resource management.

*This contribution is explained in Chapter 4.

Contribution 3: Lifecycle support for continuous resource improvement

We have developed a process lifecycle model with its ultimate objective to elucidate how to perform continuous resource improvement along different phases of standard workflow lifecycle. In our lifecycle model, we basically link resource to process through "goal" concept. It is based on the notion: when a goal is achieved the agent is successful and remains with the process. Otherwise before proceeding for subsequent process enactments, the agent is suggested for further learning and training for his specific skill improvement. We therefore consider a goal not as an add-on to the normal lifecycle but instead as an integral part of it thus it is influencing every phase of the lifecycle.

Thus, through this link, we outline different tasks related to a **process**, **resource** and **goal** that need to be performed in each different phase. Particularly, goal relevant

tasks like *Goals Analysis, Goal Design, Goal Relevant Data Store Creation, Goal Relevant Data Store Maintenance, Goal Evaluation* and *Goal Feedback* are defined precisely as an integral part of standard workflow lifecycle, by explaining and aligning them with the set of specific tasks pertaining to process and resource, in each phase – thoroughly. Moreover, all these tasks are explained along with their performers i.e. who are responsible to perform each different task. Explicit duties of different domain experts like process engineer, business expert, data experts etc, are clearly defined. Therefore, our lifecycle explains explicitly: who will perform what task and when (in which phase), to provide sufficient detail for continuous resource improvement within workflow life cycle.

*This contribution is explained in Chapter 5.

Contribution 4: Competency-driven dynamic resource management methodology

In order to improve success of business process performance (in general) and to support continuous resource improvement (in particular), we have developed a methodology for the allocation of resource to business process on the basis of "history of agents' success of business process performance". In fact, our methodology is built on the notion of our **success demand-and-supply model**. This success demand-and-supply model basically explicates: "what success level is basically demanded from employees", that is defined through the goal concept; and "what success level is actually being provided by them", that is defined through competency. Thus through the visibility of goal and competency in the process layer allowing mismatches to be identified and continually adjusted – provides an ideal support for continuous resource improvement. In our Competency-driven Dynamic Resource Management (CDRM) Methodology, assignment policy is defined **i**n terms of required competency as demanded by goal definition, as an additional constraint for its *Agent Selection* clause. Our methodology is also supported by a performance evaluation mechanism that utilizes "goal definition as a yardstick" and "workflow execution history as a data source" to continuously evaluate and consistently update agents' competency profiles into the organizational database – a data source wherefrom a WfMS selects agents through policy resolution mechanism. As a result, when a workflow execution engine resolves the policy, it retrieves the list of only those agents who have good history of success of business process performance – thus allowing only successful employees remain enacting the process.

*This contribution is explained in Chapter 6.

Thus the significant difference between the traditional WfMS' resource management approach and our innovative resource management approach can clearly be seen by comparing Figure 1.5 with Figure 1.6.

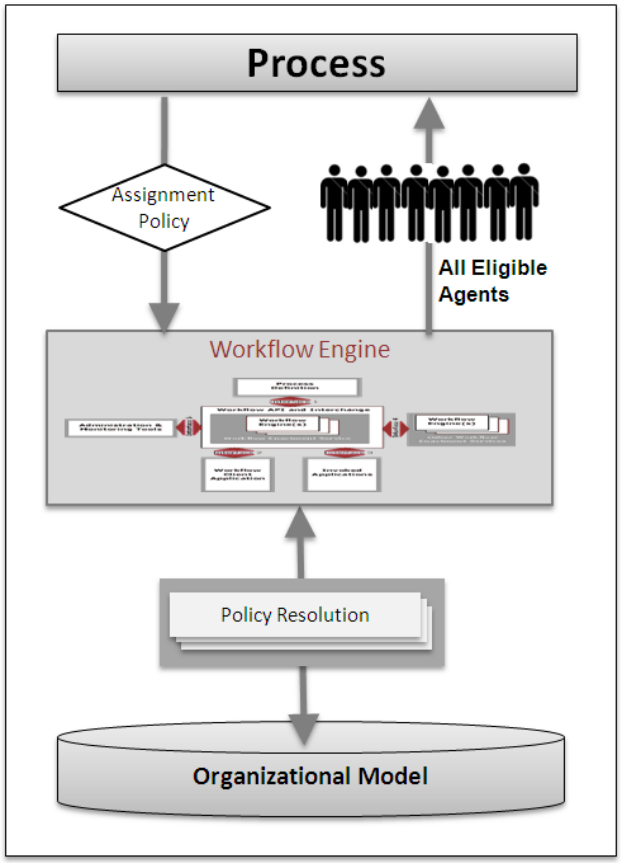

Figure 1.5: Traditional resource management approach

As shown in Figure 1.5, there is no dynamic feedback to assignment policy and organizational model. Since, a WfMS traditionally offers only static assignment strategies at process design time. Also, competency profiles are neither evaluated nor incorporated into organizational model. Due to that consequence, WfMS selects all eligible agents (through policy resolution) even if some of them are not performing the process well. Therefore, it might results in poor business process performance.

However, through our approach, resources are managed dynamically because continuous evaluation and feedback is provided to assignment policy and organizational model in a cyclic form as shown in Figure 1.6. Further to select only successful employees, assignment policy is defined in terms of required competency (i.e. Competency Driven Assignment Policy

(Chapter 6)); and then the APE Framework learns and updates agent competency profiles into the organizational database – consistently (Chapter 4), by using goal definition from process repository "as success criteria" and "workflow execution history as data source"; therefore during process execution, when policy is resolved, a WfMS selects only successful employees from the competency driven organizational database (Chapter 6).

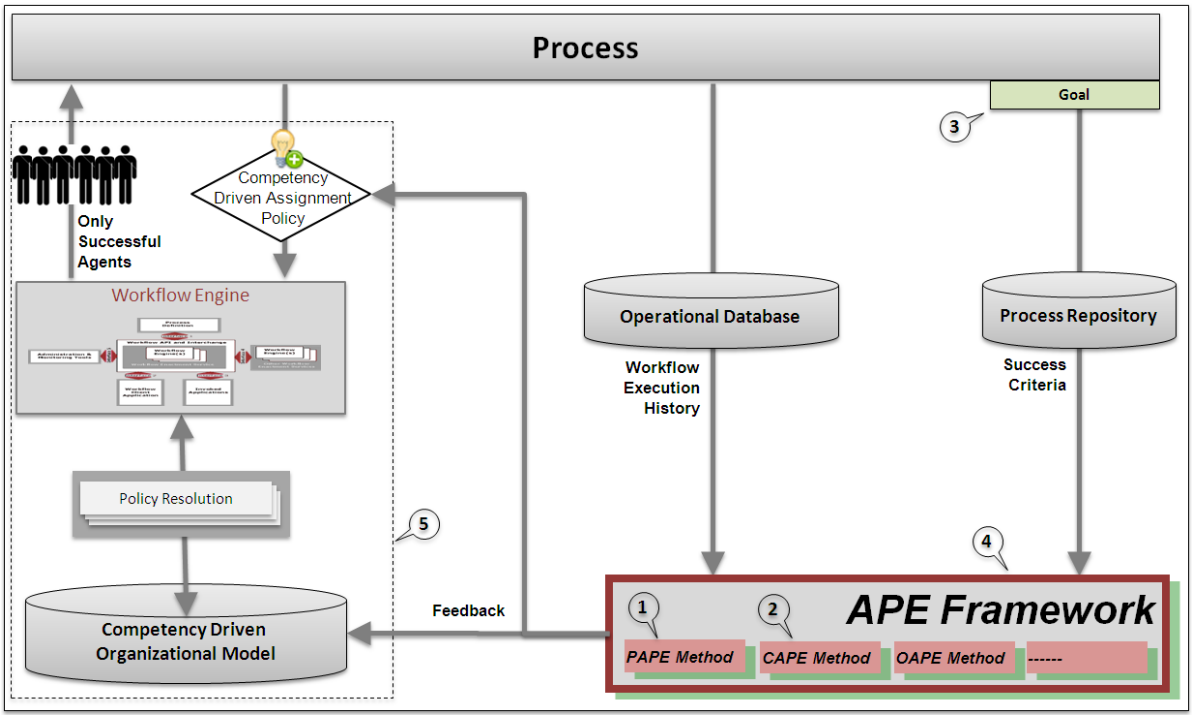

Figure 1.6: Our innovative resource management methodological model

The thesis has resulted in several scientific technical contributions thoroughly focusing the topic of "**Agent Assignment for Process Management"**. Furthermore, to give the structural clarity about the detailed contribution in view with the specific component of our general methodological model (Figure 1.6), each contribution is marked with the number in attached circle with its associated component. However, following is the list of our technical contributions substantiated from this thesis:

1. Stefan Jablonski; Ramzan Talib:
   Agent Assignment for Process Management: Pattern based Agent Performance Evaluation. AAMAS Workshop on Agent and Data Mining Interaction (ADMI, 2009), May 10-15, 2009 Budapest, Hungary. LNCS5680, pp. 155-169, 2009, Springer-Verlag Berlin Heidelberg.
2. Stefan Jablonski; Ramzan Talib:

Agent Assignment for Process Management: Agent Performance Evaluation. An International Conference on Frontier of Information Technology (FIT 2009), ACM digital library (ISBN 978-1-60558-642-7), Abbottabad, Pakistan 2009

3. Ramzan Talib; Bernhard Volz; Stefan Jablonski:
   Agent Assignment for Process Management: Goal Modeling for Continuous Resource Management. 6th. Int'l. Workshop on Business Process Design (BPD 2010) in conjunction with the 8th. Int'l. Conference on Business Process Management (BPM 2010), September 13th, 2010, Hoboken, New Jersey, USA
4. Ramzan Talib; Bernhard Volz; Stefan Jablonski:
   Agent Assignment for Process Management: Agent Performance Evaluation (APE) Framework. ICDM 2010 IEEE International Conference on Data Mining Workshop, Sydney, Australia, December 14-17, 2010. Published by IEEE Computer Society Press. DOI Bookmark: http://doi.ieeecomputersociety.org/10.1109/ICDMW.2010.99 ISBN: 978-0-7695-4257-7.
5. Ramzan Talib; Bernhard Volz; Stefan Jablonski:
   Agent Assignment for Process Management: Competency-driven Dynamic Resource Management (CDRM) Methodology. ICDM 2011 IEEE International Conference on Data Mining Workshop, Vancouver, Canada, December 11-14, 2011. Published by IEEE Computer Society Press.

1.6 Thesis Structure

The rest of thesis is organized in the following chapters:

- Chapter 2 presents the related work where we present the current state of the art about our identified issues. Due to the multifaceted contributions we divide the related approaches into four classes: Business Process Modeling Languages, Performance Evaluation Mechanisms, Business Process Improvement Theories, and Resource Allocation Mechanisms. Beside their comprehensive survey, we analyze our contributions based on our identified issues and demonstrate how they are responding to our derived requirements.
- Chapter 3 presents goal modeling support in business process model (Contribution 1). It aims to define success criteria ultimately required to determine certain level of agents' success of business process performance.
- Chapter 4 presents an agent performance evaluation framework (Contribution 2). This framework performs process centric analytical analysis of employees performance to first determine who is performing certain process who well and under what certain

conditions and then feedback its learning into organizational database and assignment policies.

- Chapter 5 presents workflow lifecycle support for continuous resource improvements (Contribution 3). It basically focus the oddly defined link between resource and process and propose process resource success (PRS) conceptual relationship model that sufficiently validates the credibility of the link between resource and process and guide how to support continuous resource improvement throughout different phases of workflow lifecycle.
- Chapter 6: presents competency driven dynamic resource management methodology (Contribution 4) that enables to allocate resources to their processes on the basis of history of achieved business success.
- Chapter 7 summarizes the research work presented in this thesis. We also suggest motivating directions for the future work in this domain.

CHAPTER 2

RELATED WORK

Chapter 2: Related Work

In the previous chapter we have identified main issues, derived key requirements and outlined main contributions of our thesis. This chapter is dedicated to the literature review of existing approaches that are related to our work. Our contributions are related to business process modeling languages, performance evaluation mechanisms, process improvement theories and resource allocation mechanisms. Due to our multifaceted contributions, we divide this chapter into following four parts:

1. **Business Process Modeling Languages**
   In our first contribution, we incorporate goal construct into process model which defines success criteria ultimately required to determine certain level of agents' success of business process performance (Requirement-1). Thus in the first part (Section 2.1), we evaluate business process modeling languages for the availability of a goal construct or any other construct that can be used for this purpose.
2. **Performance Evaluation Mechanisms**
   In our second contribution, our Agent Performance Evaluation Framework performs a process centric analytical analysis of employees' performance that aims to support continuous resource management within process layer. Therefore in the subsequent section (Section 2.2), we report performance evaluation mechanisms from both domains including process centric performance evaluation frameworks from process management domain as well as employees performance evaluation methods from human resource management (HRM) domain. We aim to assess their support for process centric analytical agent performance evaluation mechanism (Requirement-2).
3. **Process Improvement Theories**
   In our third contribution, we present workflow lifecycle for continuous resource improvement. Instead of static link between resource and process, we link resource to process through goal concept. This link clarifies how to perform continuous resource improvement along different phases of standard workflow lifecycle. Thus in Section 2.3, we report different state of the art process improvement theories and analyze their methodological support for continuous resource improvement (Requirement-3).
4. **Resource Allocation Mechanisms**
   In our fourth contribution, we present our Competency-driven Dynamic Resource Management (CDRM) Methodology that aims to allocate work item to resources on the basis of their history of achieved business success (Requirement-4). Therefore, we evaluate different resource allocation mechanisms currently supported by different

WfMSs (Section 2.4). Basically, in this evaluation we assess their support for offering a work item to resources on the basis of their history of achieved business success.

2.1 Business Process Modeling Languages

In this section we describe the overview of business process modeling languages (BPMLs) and outline their expressiveness (in general) for adequately describing a business process. In particular, we evaluate different state of the art BPMLs for the availability of a goal construct. For this evaluation, we have selected those BPMLs that are either well established and currently being used successfully or have sufficient potential for being successful in future. These BPML include Business Process Modeling Notation (BPMN), Unified Modeling Language (UML) 2.0 Activity Diagram (UAD), Petri Net (PN), Event Driven Process Chain (EDPC), Integrated Definition Method 3 (IDEF3), Extendable Enterprise Modeling Language (EEML), and User Requirement Notation (URN).

For each of the above mentioned BPMLs, our evaluation comprises three parts. We initially present its short background information. Afterward, we describe general overview of most of its available constructs along with their meaning and purpose. In particular at the end, we remark our thorough investigation that verifies the status of observed goal modeling support. Finally, subsequent to the evaluation of these BPMLS we will also present summary of our BPMLs assessment in Section 2.1.8. This summary fosters the better understanding of BPMLs' constructs as well as their support for goal modeling.

2.1.1 Business Process Modeling Notation

The Business Process Modeling Notation (BPMN) [Bmn11] was developed by Business Process Management Initiative (BPMI) but It is currently maintained by Object Management Group (OMG) due to their merging in 2005 [OMG06]. It is a standard for business process modeling and aims to provide easily readable and understandable graphical notations for all types of users to specify their business processes in a process diagram (i.e. process model). Its specification also provides the mapping between the graphical notations of the language to the underlying constructs of execution languages i.e. Business Process Execution Language (BPEL) [BPEL11].

According to BPMN [Bmn11], a process consists of one or more activities. An activity is the main part of the language and is specialized through sub-processes that consist of at least one task. A subset of the BPMN notations is shown in Figure 2.1. Generally, core elements of BPMN are differentiated into four broad categories comprising Flow Objects, Connecting Objects, Swimlanes, and Artifacts. The elements such as Activity, Process, Sub-Process, Task, Events and Gateways are Flow Objects that define the behavior (i.e. when and in which order a process will execute) of a business process. In BPMN, an event is represented by a circle which denotes something that "happens" during the execution of a business process in contrast to

activities that are something that are “done”. The Time Event is used for representing the measure of time whereas Flow Events (e.g. Start, Intermediate and End) affect the flow of activities (i.e. their order) in the model. Gateways (e.g. XOR, OR, AND) are represented with diamond shape and determine divergence and convergence of the path depending upon the condition expressed. Basically, Flow Objects are connected to each other using Connecting Objects that consist of three types i.e. Sequence, Messages, and Associations. Basically, a Sequence Flow shows “in which order” the activities are performed. It is represented with “a solid line and arrow head”. Message Flow describes message that flows across the organizational boundaries i.e. between pools. An Association is represented with “dotted line” that relate artifact/text to flow objects using “an open arrow head” to indicate some direction. Furthermore, Swimlanes are visual mechanisms of organizing or categorizing activities. It comprises two categories i.e. Pool and Lanes. Here, pool represents major participants in a process, typically separating different organizations by identifying set of activities that have characteristics in common. Lanes are used to organize and categorize activities within a pool according to a function or role. It is depicted as a rectangle stretching the width or height of the pool and it contains the Flow Objects, Connecting Objects and Artifacts. Basically, Artifacts are used to increase the readability allowing adding more information into process model. Also, there are three types of predefined artifacts namely Data Objects (i.e. which data is consumed and produced in an activity), Groups (i.e. a set of those activities that do not affect the flow in the diagram) and Annotation (i.e. used to give reader an understandable impression about the model).

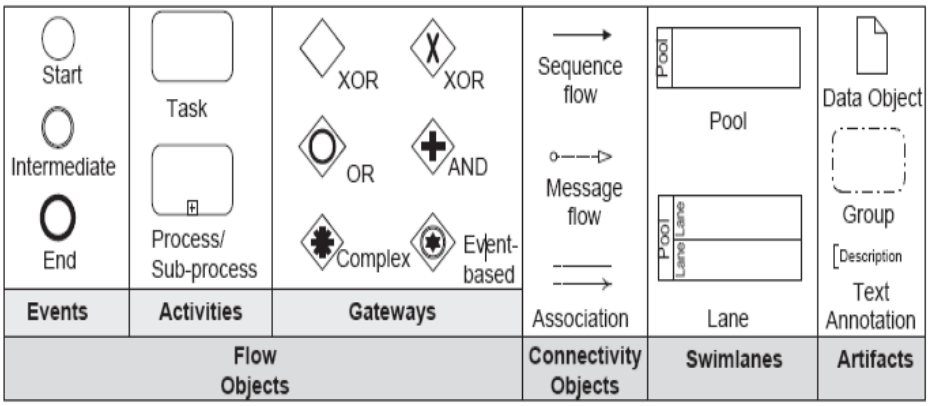

Figure 2.1: Subset of BPMN notations

While analyzing BPMN, we observed that though it is most famous and widely used process modeling language and provides an easy to understand and wide range of modeling notations for all business users but still we observe neither it has supported a goal modeling construct

nor it has offered any other construct that could be used for defining a "success criteria" for the evaluation of agents' success of business process performance.

2.1.2 Unified Modeling Language (UML) 2.0 Activity Diagram (AD)

The Unified Modeling Language (UML) 2.0 [UML11] is a standardized general purpose modeling language in the field of software engineering created and emerged by the Object Management Group (OMG) [OMG05]. To create visual models of software intensive systems, it includes a set of six Structure Diagrams and seven Behavioral Diagrams [OMG05]. UML Activity Diagram is a behavioral diagram that is generally used for modeling business processes. Some of the UML AD notations are shown in Figure 2.2.

According to [UML11], the main elements of an AD are the Activity (rounded rectangle) and its different Activity Nodes. The Action, Object Node, Control Node are specialization of an Activity Node. The Action describes the atomic task whereas the Control Nodes define the behavior of actions defined in the AD using Initial Node, Final Node, Fork Node, Join Node, Decision Node and Merge Node. The Initial Node (filled circle) represents the start of an activity. An activity may also contain many Initial Nodes that indicates the concurrency of actions i.e. different flows execute concurrently. The Final Node is split up into Activity Final Node and Flow Final Node. The Activity Final Node (filled circle with border) terminates all flows within an activity whereas Flow Final Node (circle with x through it) terminates only one flow but the activity is unaffected. A Fork Node (black bar) splits the flow into concurrent paths having one incoming flow and several outgoing flows. A Join Node (black bar) has several incoming flows but only one outgoing flow. The Join Node merges the concurrent paths into one outgoing flow. Also, an optional condition can be placed at the incoming edges of the Join Node. A Decision Node (diamond) has one incoming flow and several alternate outgoing flows, but only one outgoing flow is chosen for processing depending upon the condition described in the diamond. The Merge Node (diamond) merges the outgoing flows of the Decision Node, but it is not used to synchronize the concurrent flows. In an activity, the flow of control from one node to another node is modeled using Control Flow edges and Data Flow edges. The Control Flow models the flow between Actions whereas Data Flow models the flow between Object Node and Action. An Activity Partition is used to group a set of Actions that have something in common.

However, while analyzing UML we observed that though it is another widely used modeling language like BPMN and it has offered wide range of modeling notations but it is not as user friendly as BPMN because it does not explicitly support process modeling. Nevertheless, practitioners who are familiar with UML they use UML AD for this purpose. We also observed

that UML AD has neither supported goal modeling construct nor it has offered any other construct that can be used for defining a "success criteria" for the evaluation of agents' success of business process performance.

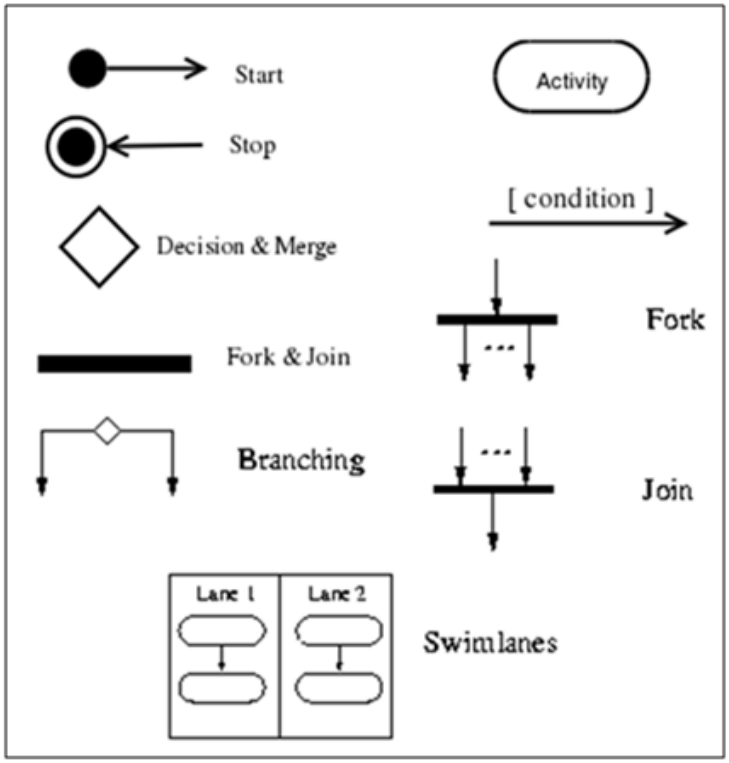

Figure 2.2: Subset of UML AD notations

2.1.3 Petri Nets

Petri Nets (PN) were developed by Carl Adam Petri in his PhD thesis [Pet62]. They are used for describing and studying concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic systems [Jen97]. As a graphical tool, these can be used for visual-communication aid and are similar to flow charts, block diagrams, and networks. In addition, tokens are used in these nets to simulate the dynamic and concurrent activities of systems. Originally the work of Carl Adam Petri did not deal for business process modeling, but nevertheless, today many modeling techniques are based on Petri Nets e.g. UML 2 AD. Till date, basically three different types of Petri Nets are identified i.e. condition/event net, place/transition net and predicate/transition net. Besides, these three Petri Nets, other forms of Petri Nets are also developed e.g. Color Petri Nets and Relation Petri nets.

Essential elements of a Petri Net are shown in Figure 2.3. Basically, a Petri Net is a directed graph that mainly consists of four elements i.e. Transitions, Places, Tokens and

Directed Arcs. Transitions (rectangles) are interpreted as activities, actions or events which cause the change of states. Places (circle) represent possible states of the system. Tokens are placed within the states called marking. The state of a system is recorded through the position of the different tokens in the Petri Net. The Directed Arcs connect a transition with a place, or a place with a transition but not to connect places and transitions among each other. On one side, the places from which an arc runs "to a transition" are called the input places of the transition whereas the places to which arcs run "from a transition" are called the output places of the transition. A transition is enabled to fire, if two conditions are fulfilled. First, every input place must contain at least the value of tokens which are needed for transition. Second, output arcs have to have at least enough capacity to accept all incoming tokens. When a transition fires, it uses the tokens from its input places, and performs processing tasks. Afterwards, it places a specified number of tokens into each of its output places. Furthermore multiple transitions can be enabled at the same time.

However, while analyzing Petri Nets we observed like BPMN (Section 2.1.1) and UML AD (Section 2.1.2), Petri nets offers graphical notations for stepwise processes that include choice, iteration, and concurrent execution. It also has an exact mathematical definition of their execution semantics, with a well-developed mathematical theory for process analysis. We also observed that Petri nets has neither supported goal modeling construct nor it has offered any other construct that can be used for defining a "success criteria" for the evaluation of agents' success of business process performance.

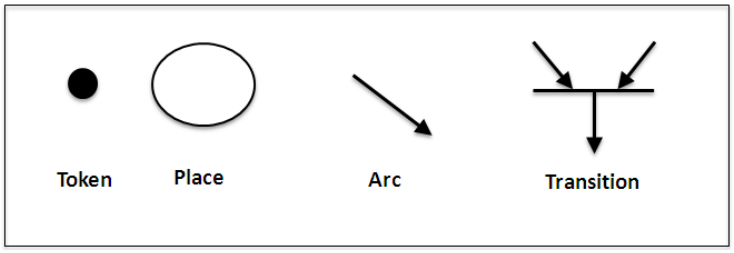

Figure 2.3: Subset of Petri Nets notations

2.1.4 Event Driven Process Chain

Event Driven Process Chain (EPC) [SAP11] is used for analyzing, modeling and redesigning business processes and has been developed within the framework of Architecture of Integrated Information Systems (ARIS). It was developed in 1992 at the Institute for Information Systems of the University of Saarland Germany [Sch99] in collaboration with System Analysis and Program development (SAP) AG [SAP11]. The EPC is based on the stochastic networks and Petri Nets. It is a graphical business process descriptive language that describes processes on the

level of their business logic that is targeted to be easily understood and mostly used by business people. Subset of the EPC notations is shown in Figure 2.4.

According to [SAP11], the EPC consists of elements like Functions, Events, Logical Connectors, Organizational Unit or Role, Information Objects and Flow, Deliverables etc. Functions (rounded rectangles) are active elements that model tasks or activities within the business environment to describe transformation from an initial state to a resulting state. Events (hexagon) are created by processing Functions or by actors outside of the model. An event acts as a precondition of one function, or corresponds to the post-condition of another one. Logical Connectors depict the logical relationships between the elements of control flow i.e. connect Functions and Events. There are three types of logical connector i.e. Branch/Merge, Fork/Join and AND/OR. Branch/Merge corresponds to making decision of "which path" to choose among several control flows. A Branch may have one incoming control flow and two or more outgoing control flows. When the condition is fulfilled, a Branch activates exactly only one of the outgoing control flows and de-activates the others. The counterpart of a Branch is a Merge. A Merge may have two or more incoming flows and one outgoing control flow. A Merge synchronizes an activated and the deactivated alternatives. The control will then be passed to the next element after the Merge. A branch in the EPC is represented by an "opening XOR", whereas a merge is represented as a "closing XOR" connector. Also, Fork/Join corresponds for activating all paths in the control flow concurrently. A Fork may have one incoming control flow and two or more outgoing control flows. When the condition is fulfilled, a Fork activates all of the outgoing control flows in parallel. A Join may have two or more incoming control flows and one outgoing control flow. A Join synchronizes all activated incoming control flows. A Fork in the EPC is represented by an "opening AND", whereas a Join is represented as a "closing AND" connectors. Whereas an OR connector corresponds to activating one or more paths among control flows. An "opening OR" connector may have one incoming control flow and two or more outgoing control flows. When the condition is fulfilled, an "opening OR" connector activates one or more control flows and de-activates the rest of them. The counterpart of this is the "closing OR" connector. When at least one of the incoming control flows is activated, the "closing OR" connector will pass the control to the next element after it. Organizational Unit (ellipse with a vertical line) or Role (rectangle) determines who will execute the Function. Organizational Unit determines a particular organizational element within the structure of the organization (e.g. Apparel Division or Sale Department) whereas Role determines group of people on the basis of similar capabilities towards performing a Function. Information Objects portrays "input data" serving as the basis for a Function, or "output data" being produced by a Function. They correspond to business objects or entities in the real world produced and consumed by Functions. Information Flows show the connection

between Functions and Information Objects upon which Functions read, write or change data to Information Objects. Deliverables represent results in terms of "services or products" that Function produce or require them for execution.

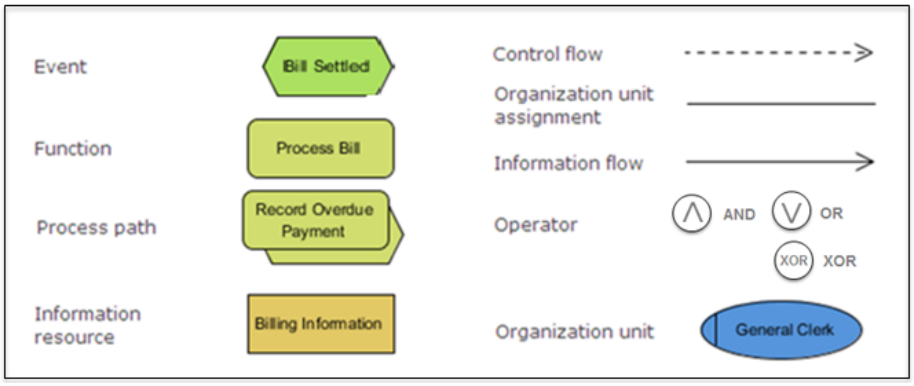

Figure 2.4: Subset of EPC notations

However, while analyzing EPC we observed that EPC has the same objectives as BPMN i.e. to make process modeling simple and easily understandable for business users. We also observed that neither it has supported goal modeling construct nor it has offered any other construct that can be used for defining a "success criteria" for the evaluation of agents' success of business process performance.

2.1.5 Integrated DEFinition Method 3

Integrated DEFinition Method 3 (IDEF 3) [IDEF11] is used for *Simulation Model Design, Business Processes Modeling, Engineering Data Management* and *Function Model Development etc* [Pat89]. For modeling business processes, it basically provides two views namely Process-centered Views (Process Schematics) and Object-centered View (Objects Schematics) [MMP95] as shown in Figure 2.5. The process-centered view models the process sequence with their temporal, casual, and logical relationships whereas object-centered view describes objects and their changing states throughout a particular process.

According to [IDEF11], the building blocks of process schematics mainly consist of Units of Behavior (UOB), Precedence Links, Junctions, and Referents. A UOB describes activities or operations in a business process. If it describes a complex activity then it is possible to decompose it. It is graphically represented as a rectangle with label inside it and placing a current numbering and a reference number in the inside bottom of the rectangle. A Precedence Link represents the relationships between UOBs. UOBs are connected with each other using a Simple Precedence Link (i.e. it expresses temporal precedence), a Constraints Precedence Link (expresses precedence through a constraint) or Relational Link (carry no

predefined semantics). A Junction illustrates logical operators (little rectangle with logical operator inside it) e.g. AND, OR, XOR operator. In IDEF 3, Referents enhance understanding, provide additional meaning, and simplify the construction of both Process Schematics and Object Schematics. Object Schematic consists of Object State, Links, Relations and Junctions. An Object State (or simply Object) is a certain kind of data and is simply represented by a circle and a name inside it. Relationships describe the taxonomic relationships between objects. A Transition describes the change from an Object-A to an Object-B, which are connected through Links (Weak Transition Link or Strong Transition Link).

However, while analyzing IDEF 3, we observed that it also has an aim of being easy to be used like BPMN and UML AD. As a matter of fact, it rather gives more flexibility in process documentations but it does not support event and data flow [May05]. Moreover, we observed that IDEF 3 neither supports goal modeling construct nor it offers any other construct that can synonymously be used for defining a "success criteria" which is ultimately required for the evaluation of agents' success of business process performance.

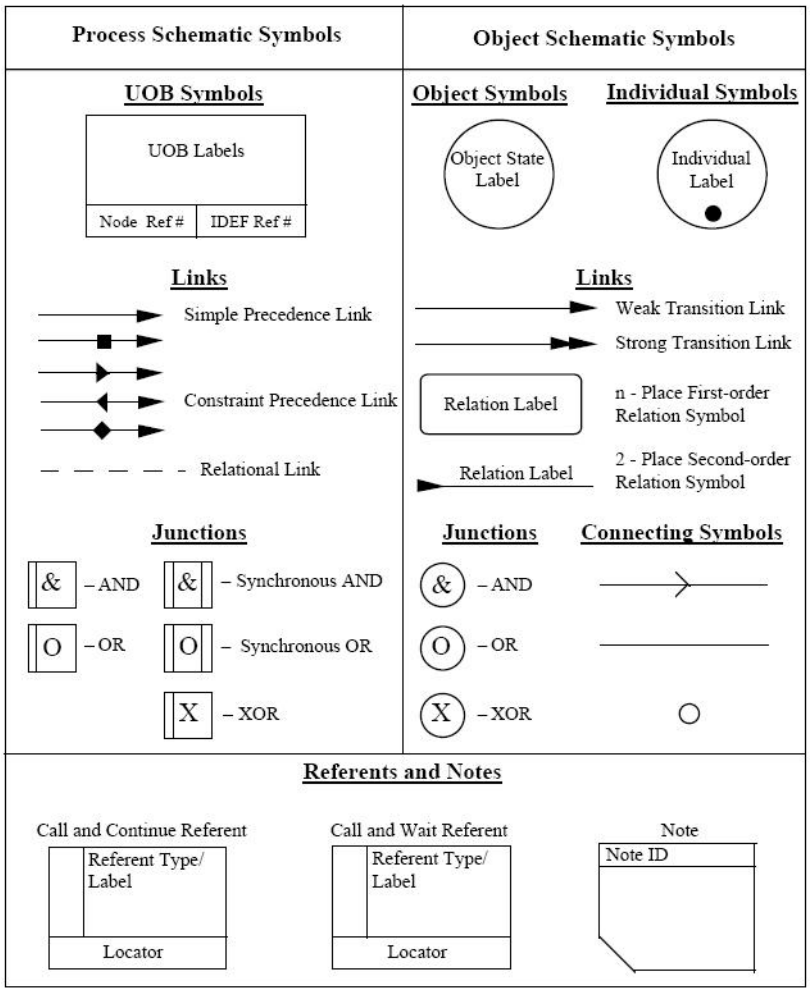

Figure 2.5: Subset of IDEF3 process description schematics

2.1.6 Extendable Enterprise Modeling Language

Extendable Enterprise Modeling Language (EEML) [Hav04] is used for more general enterprise modeling and geared towards generation of process support environments. The main purpose of EEML modeling is to make human-sense of an enterprise and communicate with other people and to gain knowledge about enterprise through simulation or deduction. EEML is divided into four sub-languages namely Process modeling, Data modeling, Resource modeling, Goal modeling [Pau08]. Moreover, it also supports to describe well defined links across these languages as shown in Figure 2.6.

Process modeling supports the modeling of a process logic which is mainly expressed through nested structures of tasks and decision points. The sequencing of the tasks is expressed by the flow relation between decision points. Each task has in minimum an input port and an output port as being decision points for modeling process logic. Resource roles are used to connect resources of various kinds (persons, organizations, information, material objects, software tools and manual tools) to the tasks. In addition, data modeling is supported using UML class diagram. Furthermore, a number of different resource types and constructs related to resources are supported like Person, Organization, Information Object, Material Object, Software Tool, Manual Tool and Physical Location. Goal modeling is one of the four EEML modeling domains. In EEML notations, a goal expresses the desired state of affairs in a certain context. A goal can be related to another goal through simple relationships like AND, OR and XOR. It is also possible to model advance goal relationships using different goal connectors like Necessitate, Obligate, Recommend, Permit, Discourage, Forbid and Contradict. Thus, goals can be related in means and hierarchies in the format. Furthermore, goal model can also be linked with a process model.

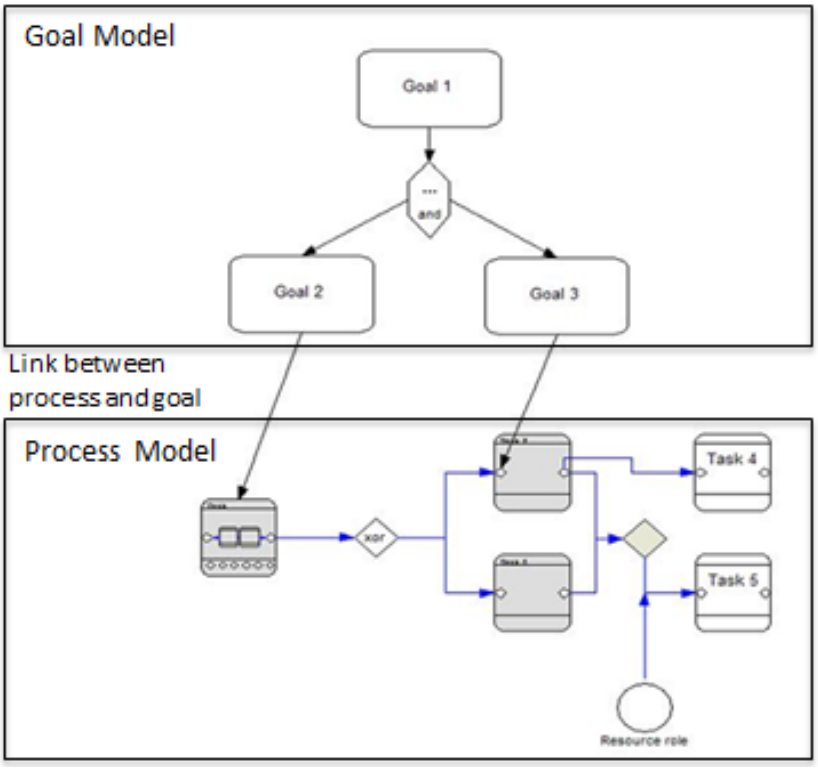

Figure 2.6: EEML goal modeling and process modeling link

In contrast to above languages like BPMN, UML AD, PN, EPC, IDEF3 etc, EEML is such a process modeling language that also supports goal modeling, but it has different semantics for goal construct because it models goal as a "purpose" or an "intension" e.g. to improve cutting faults, which are not measurable. They use goal modeling only for requirement engineering to capture various objectives that the system under consideration should achieve at different levels of abstraction. A goal-oriented requirement is concerned with the use of goal for eliciting, elaborating, structuring, specifying, analyzing, negotiating, documenting and modifying "requirements". Since, these goals are not measurable therefore cannot be utilized for evaluating agents' success of business process performance.

2.1.7 User Requirement Notation

User Requirement Notation (URN) [ITU03] is a standardized effort towards a graphical modeling language that supports both process modeling as well as goal modeling. It was first developed to address the documentation, discovery, completeness, and correctness of functional and nonfunctional requirements for new or evolving reactive and distributed systems. It has also been used for business processes modeling. It combines two

complementary and integrated notations namely Use Case Map (UMC) and Goal-oriented Requirement Language (GRL) [Amy03].

UCM notations are used for modeling operational requirements and high-level design. A subset of UMC notations is shown in Figure 2.7. Basically, UMC is a process modeling language with the ability to depict process, process hierarchies, sequence flows, roles, organizational units etc. A process (or responsibility) is the basic element of UCM models and represent typically a task or a subtask performed by an actor or a system [Pou08]. Processes are connected together using casual paths to form scenarios starting with Start points and ending with End points. A scenario describes a part of the system's behavior. A Use Case Map model usually consists of multiple scenarios to describe possible behaviors in the system. Using forks and joins, one can define alternate or parallel paths in a scenario as well as overlapping and synchronized scenarios. To control scenarios, UCM can be used to define conditions on decisions points (alternate paths). Using stubs (diamond symbols), one can define hierarchical structure in process models. UCM provides two kinds of stubs i.e. static stub and dynamic stub. Static stubs can contain one and only one sub-map while dynamic stubs may contain multiple sub-maps, one of which is selected based on the defined conditions. Sub-maps are also called plug-ins. UCM also supports waiting mechanisms in the form of waiting places and timers.

However, GRL models consist of three main types of symbols namely Intentional Elements (comprising: goal, task, softgoal and resource), Intentional Relationships (comprising: decomposition, contribution, correlation and dependency) and Actors [Pou08]. A subset of GRL notations is shown in Figure 2.8. In GRL, Softgoals are cloud shaped symbols used to represent high-level goals. Softgoals can be connected together using different GRL contribution links (i.e. and/or) with various contribution types (e.g. Break or Make). Softgoals can be decomposed to lower levels of abstractions until they can be illustrated as tangible goals (hard goals) or operational tasks. During this breakdown, decomposition links can be used to specify sub-tasks, and OR decomposition links can be used to demonstrate tasks used for achieving goals. One can also use actor and actor boundaries symbols to specify the actors' actions or a part of the model related to an actor. One can use dependency links to show the dependency of actors on each other for an intentional element.

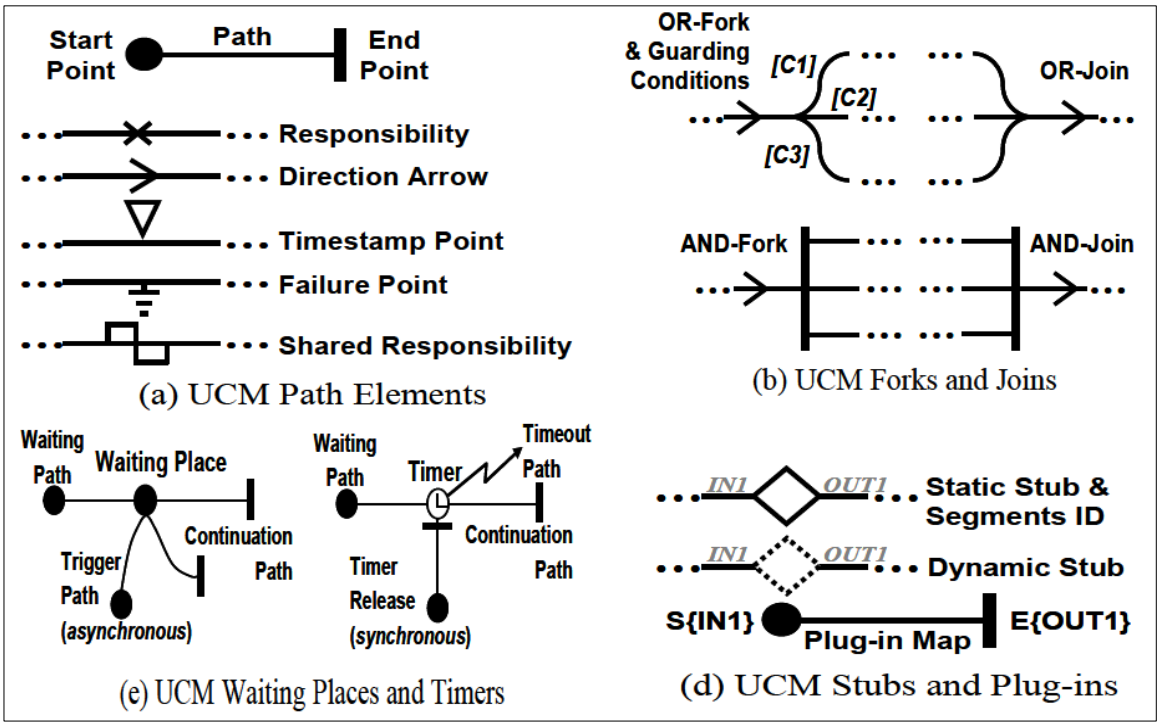

Figure 2.7: Subset of UMC Notations

We have observed, URN is another modeling language similar to EEML that supports goal modeling in addition to process modeling. Similar to EEML, it has different semantics for a goal construct as it models a goal just as a "purpose" or an "intension" e.g. to improve cutting faults, which is not measurable. However, URN is richer than EEML specifically for goal modeling because it offers different types of goal constructs like soft goals and hard goals. URN also offers wide range of relationships among goals like goals' "Dependency" and goals' "Contribution" relationships. Indeed, URN also uses goal modeling for requirement engineering for the same objectives like EEML i.e. to capture various objectives of the system under consideration should achieve at different levels of abstraction for requirement elicitation, elaboration, structuring, specification, analyzing, negotiation, documentation and modification. Real fact is, that goals defined by URN are also not measurable therefore these goals cannot be utilized for evaluating agents' success of business process performance.

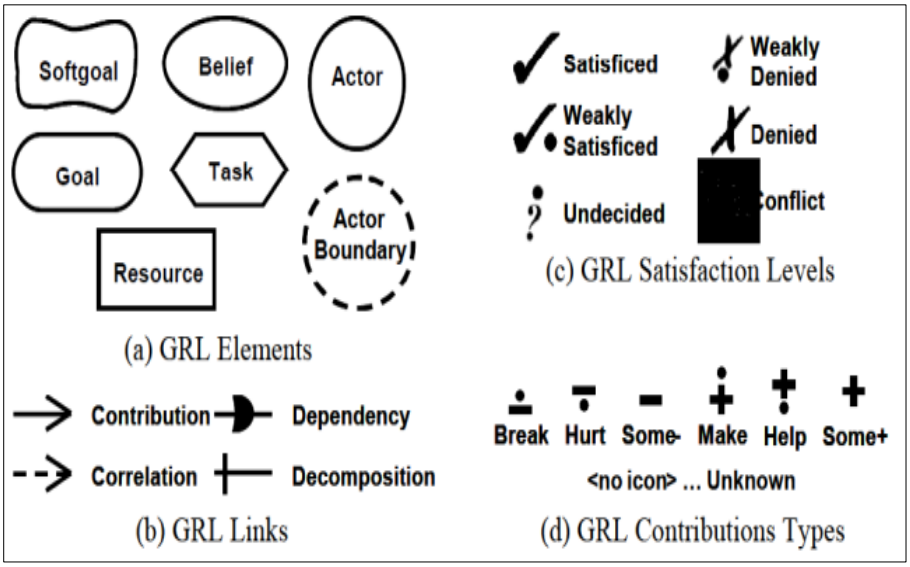

Figure 2.8: Subset of GRL Notations

2.1.8 Summary of Business Process Modeling Languages

In the previous subsections we have evaluated BPMLs for the availability and usability of goal construct in our context of agent performance evaluation criteria. As a matter of fact, it is very difficult to evaluate BPMLs since an accurate description is often missing or sometime elements of a BPML have definition but it is complex, inaccurate, or have even ambiguous meaning. Moreover, sometime usage of a language construct is left up to the interpretation of users. However, we have evaluated BPMLs to the best of our knowledge and have shown a comprehensive summary of our evaluation in Table 2.1.

The result of evaluation in the Table 2.1 indicates that almost all languages have very good support for modeling functional aspect (or perspective). These languages differ by the fact that they either describe the task of a business process with one single element and an activity, or with two explicit elements i.e. a sub-process and an atomic activity. It is obvious that behavioral perspective is also very well supported with different control flow nodes except Petri Nets that do not support OR Split. However, the organizational perspective is partially supported by the BPMLs since Pertri Nets and IDEF 3 do not support any notation for organizational modeling. Except Petri Nets and IDEF 3, all other BPMLs include role element for organizational modeling. Also, the Informational perspective is well defined in BPMN, UML AD and EPC whereas Petri Nets, EEML and URN do not support any notation for this perspective. Besides, the operational perspective is supported by most of the languages except Petri Nets, EPC and IDEF 3. On the other hand, it is mostly mixed with organizational perspective.

The results also conclude that most of these languages like BPMN, UML AD, Petri nets, IDEF 3, EPC do not support goal modeling i.e. measurable or even non-measurable goal. Although, some of the languages are observed that support goal modeling e.g. EEML and URN that support non-measurable goal. Our analysis indicates that they define goal as a purpose or an intension which is not measurable. Such un-measurable goal cannot be used as a success criteria. Therefore, their goal modeling cannot be practiced for measuring the employees' success of business process performance.

To the best of our knowledge, no BPML is available in today's market that defines a measurable goal or any other synonymous construct so that it can add success criteria into process model. Consequently, it cannot be used to determine agents' success of business process performance. However, this does not mean that these BPMLs are not important. On the contrary, every BPML is important in its target context and for its genuinely practical reasons. The real fact is that their vendors have not really stepped up to the challenge of implementing such success criteria in terms of goal construct.

BPMLs Summary Table (Part-A)					
Perspectives	**Elements**	**BPMN**	**UML Activity Diagram**	**Petri Nets**	**EPC**
Functional	Process	Process	Activity	Transmission Hierarchy	Function
	Sub Process	Sub Process	Activity	Transmission Hierarchy	Complex Function
	Atomic Process	Task	Action	Transmission	Elementary Function
Behavioral	Control Flow	Sequence Flow	Control Flow	Sequence	Control Flow
	AND Split	Parallel Forking	Fork Node	Concurrent Execution	AND Split
	AND Join	Parallel Joining	Join Node	Synchronization	AND Join
	XOR Split	Exclusive Decision	Decision Node	Alternative Path	XOR Split
	XOR Join	Exclusive Merge	Merge Node	Depends on previous split	XOR Join
	OR Split	Inclusive Decision	Join Node + Guard	--/--	OR Split
	OR Join	Inclusive Merge	Merge Node	--/--	OR Join
Organizational	Process Participant	Pool	Activity Participant	--/--	--/--
	External	Pool	Activity Participant	--/--	--/--
	Internal	Pool	Activity Participant	--/--	Organizational Unit
	Human	Pool	Activity Participant	--/--	Organizational Unit
	Organizational Unit	Pool	Activity Participant	--/--	Organizational Unit
	Role	Pool	Activity Participant	--/--	Organizational Unit
Operational	Software	Pool	Activity Participant	--/--	--/--
	Service	Pool	Activity Participant	--/--	--/--
Informational	Data Flow	Association	Object Flow	--/--	Data Flow
	(Inform.) Resource	--/--	Object Node	--/--	--/--
	Data Repository	--/--	Data Store Node	--/--	--/--
	Data Object	Data Object	Data Store Node	--/--	--/--
	Database Table	--/--	Data Store Node	--/--	Information Object
Goal	Measurable Goal	--/--	--/--	--/--	--/--
	Non measurable Goal	--/--	--/--	--/--	--/--

BPMLs Summary Table (Part-B)				
Perspectives	**Elements**	**IDEF 3**	***EEML***	***URN***
Functional	Process	Unit of Behavior	Task	Responsibility
	Sub Process	Unit of Behavior	Task	Responsibility
	Atomic Process	Unit of Behavior	Task	Responsibility
Behavioral	Control Flow	Link	Flow	stub
	AND Split	AND Junction	AND Split	AND Split
	AND Join	AND Junction	AND Join	AND Join
	XOR Split	XOR Junction	XOR Split	XOR Split
	XOR Join	XOR Junction	XOR Join	XOR Join
	OR Split	OR Junction	OR Split	OR Split
	OR Join	OR Junction	OR Join	OR Join
Organizational	Process Participant	--/--	Resource	Actor
	External	--/--	Resource	Actor
	Internal	--/--	Resource	Actor
	Human	--/--	Resource	Actor
	Organizational Unit	--/--	Role	Actor
	Role	--/--	Role	Actor
Operational	Software	--/--	Software Tool	System
	Service	--/--	Software Tool	System
Informational	Data Flow	Relationships/ Transition /Link	--/--	--/--
	(Inform.) Resource	Object State	--/--	--/--
	Data Repository	--/--	--/--	--/--
	Data Object	Object State/Object	--/--	--/--
	Database Table	Object State/Object	--/--	--/--
Goal	Measurable Goal	--/--	--/--	--/--
	Non measurable Goal	--/--	Goal	Soft goal, Hard goal

Table 2.1: Results of comprehensive BPMLs evaluation

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2.2 Performance Evaluation Mechanisms

This section aims to present a literature review related to different performance evaluation mechanisms that are closely related to our Agent Performance Evaluation (APE) framework (contribution-2). Since, our APE framework addresses the issues basically stemming from the process domain as well as the HRM domain, therefore, we overview performance evaluation mechanisms from both domains i.e. process centric performance evaluation frameworks from Business Process Management Systems (BPMS) domain as well as employees performance evaluation methods from Human Resource Management (HRM) domain.

For this purpose, we divide this section into three parts. We start with the evaluation of process centric performance evaluation frameworks from BPMS domain in Section 2.2.1. Then, we precede for the overview of employees' performance evaluation methods from HRM domain in Section 2.2.2. Finally in Section 2.2.3, we will present the summary of our evaluation to conclude our thorough investigation stemming from both domains.

However, for the evaluation of process centric performance evaluation mechanisms (Section 2.2.1) we select those BPMS products that have strong position or leading role in the market of performance pure-players BPMS suites. These frameworks include IBM WebSphere, Appians Enterprise BPM Suite, Global360 Enterprise BPM Suite, Tibco iProcess Suite, Pigasysystems SmartBPMS Suite and Savvion BusinessManager. Likewise, to review employees' performance evaluation methods from HRM domain, we select those methods that are currently deployed in most of HRM departments of the today's organizations. These methods include Essay Evaluation, Critical Incident Method, Graph Rating Scale, Multi-person Comparison, Forced Distribution, Management By Objectives (MBO) and Balanced Scorecard (BSC).

In fact, the ultimate aim of our investigation is not to highlight their general demerits rather our intention is to identify and understand their objectives and methodology they adapt for performance evaluation. We aim to leverage our APE framework after customizing their vision and experiences in our own context. We would merely focus to the drawbacks and inadequacies of their methodology we observed while these need to be utilized in our context.

Throughout our evaluation, we initially present a short overview of each BPMS suite or HRM method and then evaluate each of them particularly for their suitability in our context. For this purpose, we have designed a criteria that basically comprises of three questions (Figure 2.9, left column). Based on this criteria, each of the performance evaluation mechanism is assessed to determine its best fit category out of three broad categories of performance evaluation mechanisms shown in Figure 2.9. Eventually, these categories determine the

suitability of a performance evaluation mechanism in our context i.e. category-1 being inappropriate, category-2 being least fit and category-3 being best fit.

It should also be noted that these three criteria questions are chosen only for the evaluation of existing frameworks or methods purely interpreting the objectives of our thesis (Requirement-2). However, it is not a general evaluation of these frameworks or methods. Nevertheless, for general evaluations and broad comparisons of these BPMS frameworks and HRM methods, interested readers are referred to [Sin10][Hill09][Cla07][Moor06][Voll06] and [Sid03][Jer97], respectively.

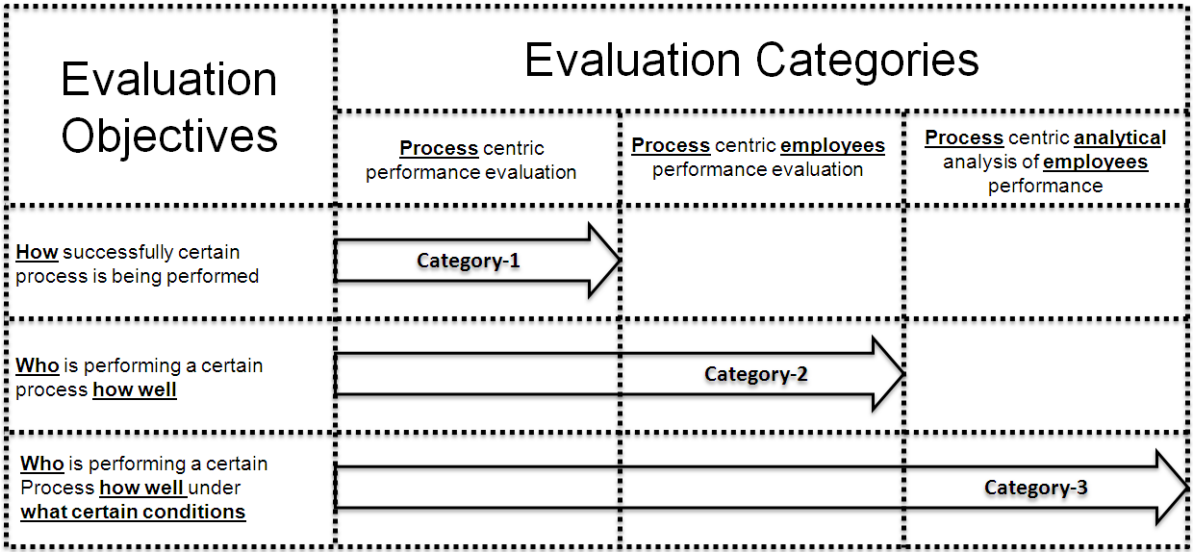


Figure 2.9: Evaluation criteria

2.2.1 Process Centric Performance Evaluation Frameworks

2.2.1.1 IBM WebSphere

IBM WebSphere [Wah07] [Iws11] is one of the leading BPM solution providers in the industry. It offers a wide range of products for modeling, implementation, execution, evaluation and simulation of business processes. For modeling a business process, the IBM solution provides a WebSphere Business Modeler. This WebSphere Business Modeler is a BPEL based process modeling tool used for modeling processes, process flows, business data and data flows, and organizational resources, thus using this tool various process models can be built. Process models created in WebSphere Business Modeler are initially exported to its WebSphere Integration Developer. Then this WebSphere Integration Developer generates Enterprise ARchive (EAR) files that are then deployed on the WebSphere Process Server for execution [Wah07]. Beside its process modeling and execution support, it also offers WebShpere Business

Monitor to generate data schema and script files. These schema and script files are then executed in IBM DB2 to create an OLAP cubes [Chen07].

For performance management, it offers WebSphere Business Modeler for modeling Key Performance Indicators (KPIs). It also offers WebSphere Business Monitor for monitoring of these KPIs. Basically, a KPI measure some aspect of a business process represented by a numeric value e.g. average orders fulfill time for the "Order Processing" process of an enterprise. During process monitoring, this KPI' numeric value shows the status of that specific aspect of a process i.e. current status of "average orders fulfill time". WebSphere Business Modeler also allows users to define multiple KPIs for the processes. However in WebSphere Business Modeler, basically two types of KPIs i.e. in terms of numbers and time duration, can be defined and attached to a process. WebSphere Business Monitor is used to evaluate the process execution data for analyzing KPIs defined on their processes. It displays the current status of process performance specific to a KPI metric i.e. average order fulfill time. Thus, current KPIs values help organization for continuous "process" improvement because if it is observed that average fulfill time is becoming greater than expected time then organization can make subsequent action to overcome the delay problem.

- **Criteria Question 1**: IBM WebSphere Business Modeler organizes KPIs in a process based manner and its Business Monitor shows the status of KPIs' values during evaluation. Thus, it helps to determine "*how successfully certain process is being performed"* therefore it meets our criteria question 1.
- **Criteria Question 2**: IBM WebSphere Business Modeler neither associates a KPI with the resource nor evaluates employees' performance in line with their processes therefore WebSphere' KPIs cannot be used for employees' performance evaluation in determining *who is performing a certain process how well*. Thus it does not fulfill our criteria question 2.
- **Criteria Question 3**: IBM WebSphere neither incorporates process context while modeling KPIs nor it determines certain conditions where employees are performing their task well. Furthermore, it does not associate a KPI with the resource to evaluate employees' performance in line with their processes. Thus, IBM WebSphere Business Modeler does not perform process centric analytical analysis of employees' performance in determining *who is performing certain process how well and under what certain conditions*. Therefore it does not meet our criteria question 3.

2.2.1.2 Appian Enterprise BPM Suites

Appian enterprise BPMS Suites [Lar05] is a comprehensive BPMS suite that offers wide range of products to cover all phases of workflow lifecycle [App11]. It supports process modeling, assembling and integration, execution, evaluation and simulation etc. For modeling a business process, the Appian BPM Suite offers Appian Process Modeler that is a browser based process modeler. It allows users to analyze and built process models conforming to BPMN. Appian' Process Engine in the suite provides process automation capabilities. Also, its Process Simulation tool provides capabilities to identify potential bottlenecks in the process. Additionally, Appian Business Activity Monitor generates event triggers and alerts to control process flows based on rules defined on the processes.

To evaluate performance, it supports the modeling and the evaluation of KPIs. Basically, Appian BPMS suite supports two types of KPIs modeling i.e. Business KPIs and Process KPIs. These KPIs are modeled using its two different and independent components namely Appian Business Analytics and Appian Process Analytics. Appian Business Analytics models KPIs related to business relevant data that is not linked with process whereas its Process Analytics models KPIs that are attached with a process. Moreover, Appian supports Dashboard Reporter that offers monitoring of these KPIs (process KPIs as well as business KPIs) with various charts and graphical views options.

- **Criteria Question 1**: Appian Process Analytics allows modeling KPIs that are attached with a process. These KPIs are monitored using Appian Dashboard Reporter that helps in determining *how successfully certain process is being performed* thus Appian meet our criteria question 1.
- **Criteria Question 2**: Appian Process Analytics neither associate a KPI with the resource nor evaluates employees' performance in-line with their processes. Thus through Appian it is not possible to determine *who is performing a certain process how well* therefore it does not meet our criteria question 2. Although it allows defining KPIs for any business metric using its Business Analytics but these KPIs are also not linked with the resource to fulfill our criteria question 2.
- **Criteria Question 3**: Neither Appian Process Analytics nor Appian Business Analytics incorporate process contextual information while modeling these KPIs therefore it is not possible to determine certain condition where processes are being performed well by whom? These KPIs are also not linked with resources therefore they do not support in determining certain conditions where employees are performing their processes the best. Thus it does not support process centric analytical analysis of employees'

performance in determining *who are performing a certain process how well and under what certain conditions* so it does not meet criteria question 3.

2.2.1.3 GLobal360 BPM Suite

Global360 BPM Suite [Glob11] is a business process management platform that combines process modeling, design, execution, control, and analytics components to manage complete process lifecycle [Cla07]. It includes the G360 Process Designer which is used to define business processes with BPMN and XPDL support. G360 Process Designer can respond to business and transactional events and is also responsible for the execution and overall management of business processes. Global360 BPM Suite offers the G360 Process Simulator that helps in determining how process will behave in various scenarios by testing and driving business processes and its alternate models [Chen07].

G360 Process Designer also has the capability of defining KPIs and Goal thus Global 360 is the only solution that gives the visibility into both processes through KPIs as well as people through business goals. Global360 BPM suite offers Analytical Engine that allows modeling KPIs and attaches them with process like IBM WebSphere and Appians BPM Suite. It is the only solution that allows to define measurable goals and links goal measurement infrastructure with people i.e. resources. Thus Global 360 provides complete visibility about people and processes so as to know the status of all processes, and people with their goals.

- **Criteria Question 1**: Global360 BPM Suite allows modeling KPIs that are attached with a process. These KPIs are monitored using G360 Process Designer that shows current status of process performance. Thus, Global360 BPM Suite helps in determining *how successfully certain process is being performed* therefore it meets our criteria question 1.
- **Criteria Question 2**: Global360 BPM Suite allows modeling and evaluation of measurable goals using G360 Process Designer. These goals are defined and are attached with process. Further, goals evaluated are specific to people who actually execute these processes using G360 Process Designer. Goal modeled and evaluated using G360 Process Designer helps in determining *who is performing a certain process how well* thus it meets our criteria question 2.
- **Criteria Question 3**: While modeling goal using G360 Process Designer, neither process context information is incorporated into a goal definition nor goals are evaluated specific to process context. Goals modeled and evaluated by G360 Process Designer cannot be used in determining certain conditions where employees are performing their processes the best. Thus, it does not support process centric analytical analysis of

employees' performance therefore cannot determine *who is performing a certain process how well and under what certain conditions* so it does not meet our criteria question 3.

2.2.1.4 Tibco iProcess Suite

Tibco is a leading company in the BPM field that enables end users not only to automate their operations but also to continuously improve their efficiency and performance [Tib11]. It provides iProcess Suite [Tib11a] that is a comprehensive business process management solution. iProcess Suite allows users to automate processes involving information from multiple systems, with rules to define the sequence in which the tasks are performed as well as responsibilities, conditions, and other aspects of the process are defined. It not only allows a business process to be executed more efficiently but it also provides the tools to measure performance to identify opportunities for improvement and easily makes changes in processes to act upon those opportunities. iProcess suite includes Business Studio that is an Eclipse based process modeling tool with full support for BPMN and XPDL notations. It also has iProcess Conductor that aims to model goal oriented concepts.

Basically, organizational goals are identified and are modeled in iProcess Conductor that allows to model different organizational goals and their interrelationships. Once goals are identified then based on these goals, processes are identified and defined that are required to achieve these goals. iProcess Conductor coordinates business processes that are executed in the TIBCO iProcess Engine according to a plan that is dynamically modified at run time as business events occur in order to meet organizational goals. It enables business users to define high level business goals and uses loosely coupled pre-defined, interdependent sub processes to accomplish these goals. Business users can select templates for creating the execution plan or can assemble processes on the fly. In fact these goals are not measurable rather they are high level organizational requirements that simply aims to categorize processes against their overall goal. Basic aim is to facilitate end users to specify goals for processes and to categories processes against their overall goals. Therefore, such goals are not utilized for employees' performance evaluation but rather help to categorize their processes that contribute to attain a specific goal.

However, to evaluate performance, it supports the modeling and evaluation of KPIs. For this purpose, it offers iProcess Analytics that enables the establishment of KPIs and their continuous measurement for ongoing processes. These KPIs are defined and attached to process to measure its overall performance.

- **Criteria Question 1**: Tibco iProcess Analytics allows modeling and evaluation of KPIs. Further these KPIs are attached with processes. When KPIs are attached with process and are evaluated using Tibco iProcess Analytics, it shows the current status of process performance. Thus, it helps in determining *how successfully certain process is being performed* so meets our criteria question 1.
- **Criteria Question 2**: Tibco iProcess Analytics PKI does not allow measuring employees' performance because it does not have any link with resources. Since it does not allow in determining *who is performing a certain process how well* thus it does not fulfill our criteria question 2.
- **Criteria Question 3**: In Tibco iProcess Suite, when KPIs are modeled within iProcess Analytics it neither models process context information within these KPIs nor these KPIs are evaluated specific to process context within Tibco Business Studio. Therefore, these KPIs do not have sufficient information about process context to determine *certain conditions where employees are performing the processes well*. Thus, it does not support analytical analysis of employees' performance so it does not meet our criteria question 3.

2.2.1.5 Pega System Smart BPM Suite

Pega System Smart BPM Suite [Peg11] has a leading position in BPMS market with its strength in process and business rules engines [moor06]. The components of the Pega System Smart BPM Suite cover the whole BPMS life cycle including process modeling, implementation, execution, analysis and improvements. In the suites, PegaRULES Process Commander integrates Microsoft Visio through a web browser to build processes with its support for XPDL. In addition to that processes can directly be built in Microsoft Visio. Processes that are built in Microsoft Visio are then imported into the PegaRULES Process Commander that has the ability to create alerts and triggers to automatically respond to events through e-mail, fax or wireless message as a part of workflow [Chen07]. J2EE complaint application servers such as IBM WebSphere, Apache Tomcat and BEA WebLogic can execute these processes. Pega System Smart BPM Suite offers PegaRULE Process Simulator to simulate processes. Through the wizards provided by a PegaRULE Process Simulator, analysts can simulate business processes to quantify and compare service levels, time, errors, and cost reductions [Cla07]. Pega System Smart BPM Suite also offers Process Analyzer that provides online analysis and recommendations for continuous process improvement.

Pega System Smart BPM Suite also supports KPI modeling and evaluation. These KPIS are modeled using PegaRULES Process Commander that attaches KPIs with processes. In

addition to KPIs, it also supports to define metrics which are different from KPIs and are linked with any facet of business data. These KPIs and Metrics are evaluated using PegaRULES Process Analyzer. Thus, through the use of PegaRULES Process Commander as well as PegaRULES Process Analyzer, user can model and monitor KPIs and Metrics via preformatted reports.

- **Criteria Question 1**: PigaRULES Process Commander allows modeling KPIS that are evaluated using PegaRULES Process Analyzer. Moreover, these KPIs are attached with processes and show the current status of process performance in determining *how successfully certain process is being performed* to meet our criteria question 1.
- **Criteria Question 2**: KPIs that are modeled using PigaRULES Process Commander but these KPIs are not linked with resources while performance is being evaluated it does not support measuring employees' performance because they do not have its evaluation link with resources. Therefore, these KPIs do not support in determining *who is performing a certain process how well* thus PigaRULES Process Commander does not fulfill our criteria question 2.
- **Criteria Question 3**: In Pega System Smart BPM Suite, KPIs are modeled using PigaRULES Process Commander. It neither incorporates any information about process context nor does it linksKPIs metric with resource performance. These KPIs do not have sufficient information in their evaluation mechanism for determining *certain conditions where employees are performing the process well.* Since, it does not support analytical analysis of employees' performance so it does not meet our criteria question 3.

2.2.1.6 Savvion BusinessManager Platform

Savvion BusinessManager Platform [Sav11] is one of the leaders in human-centric business process management systems platform [Moor06]. It allows users to design, test, analyze and optimize business processes. In this platform, Savvion Process Modeler provides a user friendly environment for business process modeling. In Savvion Process Modeler, processes are built based on BPMN notations. In addition to process modeling, it allows users to create business rules, events and exceptions within these models. Savvion Process Modeler also includes simulation environment to provide deficiency information about the designed processes and to help process improvements. Savvion BPM server executes processes and enables web-based workflow by assigning and tracking tasks. Savvion Process Modeler also allows users to create rules, events and exceptions in business processes. The Savvion BPM server in the BusinessManager platform contains business rules/events management engine, which can handle procedures, policies, events and exceptions. Savvion BPM Portal can also provide real time alerts which are generated based upon particular process conditions. Furthermore,

process engine is included in the Savvion BPM server to execute processes and enables Web-based work-flow by assigning and tracking tasks.

For performance evaluation, Savvion BusinessManager Platform offers Savvion BPM studio and Savvion BPM Portal. Basically, Savvion BPM studio supports modeling of KPIs and Metrics (different from KPIs). KPIs are linked with processes and Metrics are linked with any facet of business data. However, for the evaluation and monitoring of these KPIs and Metrics, Savvion BusinessManager Platform offers Savvion BPM Portal. Savvion BPM Portal displays current status of KPIs or Metrics values as a dashboard view and report.

- **Criteria Question 1**: KPIs are modeled in Savvion BPM studio and are monitored in Savvion BPM Portal. These KPIs show the current status of process performance thus these KPIs helps in determining *how successfully certain process is being performed*. Thus it fulfills our criteria question 1.
- **Criteria Question 2**: KPIs and Metrics that are modeled using Savvion BPM studio and are monitored using Savvion BPM Portal. But these KPIs are not linked and evaluated for resources performance. Thus, these KPIs do not support measuring employees' performance. Since, it does not allow to determine *who is performing a certain process how well* thus it does not fulfill our criteria question 2.
- **Criteria Question 3**: In Savvion BusinessManager Platform, KPIs and Metrics are modeled using Savvion BPM studio. This Savvion BPM studio neither incorporates any information about process context nor does it link these KPIs/Metrics with resource performance. Therefore, these KPIs/Metrics do not have sufficient information and any incorporated performance evaluation mechanism for determining *who is performing certain process how well and under what certain conditions.* Thus, it does not support process centric analytical analysis of employees' performance so it does not meet our criteria question 3.

2.2.2 Employees Performance Evaluation Methods

Now after a thorough evaluation of process centric performance evaluation frameworks, we now overview HRM based performance evaluation methods and techniques with our aim to investigate how successfully they can be utilized in our context of process centric analytical analysis of employees' performance.

2.2.2.1 Essay Evaluation

Essay Evaluation [Druc54] is one of the simplest and oldest methods of employees' performance evaluation. In this method, performance evaluator begins with the blank piece of

paper and personally involves in writing a narrative description of employees' performance [Esm11]. He describes his observation regarding employees' strength, weaknesses and potentials. Employees' strengths and weaknesses are evaluated based on his observations without having any well-defined criteria for evaluation. He also describes his suggestions how an employee can improve his strengths and overcomes his weaknesses. Indeed, essay evaluation method requires no extensive training from evaluator to complete evaluation. However, main disadvantages of essay evaluation are:

- It is a non-quantitative method of employees' performance evaluation because such narrative descriptions of evaluator' observations are least structured for an automated computation.
- It is a most time consuming technique since a supervisor spends a significant amount of time in documenting his observations regarding employees' performance.
- An evaluator may also write a bias evaluation report thus this method may reveal employees deterioration.
- A busy evaluator may write essay in hurry without properly addressing actually issues concerning employees' performance.
- Some evaluators may be poor in writing essay, others may be superficial in explanation and use flowery language, and thus may not reflect the actual performance of employees.

This technique usually works well for those evaluators who have a high level of confidence in their judgment, and in addition their employees are also tolerant of ambiguity. This method requires additional ability to think and to write clearly and concisely. Therefore, to proceed for an essay evaluation, an evaluator must be acquainted with:

- Job knowledge and potential of the employees.
- Employees' understanding of the company's programs, policies, objectives etc.
- Employees' relations with their co-workers and superiors.
- Employees general planning, organizing and controlling ability.
- The attitude and perception of the employee in general.

Although this method is currently being used in most of the government offices or departments, but we observed this method has poor potential to be utilized in our context.

- **Criteria Question 1**: Since, it is difficult for an automated performance management system to evaluate and then write the narrative description of process performance i.e. *how successfully certain process is being performed* without any criteria of evaluation thus Essay Evaluation does not meet our criteria question 1.

- **Criteria Question 2**: It is also difficult for an automated performance management system to evaluate and then write the narrative description of employees' strengths, weaknesses or potentials. In addition to that, an automated performance management system cannot propose and outline improvement suggestions specific to the employees' weaknesses. Since, strengths or even weaknesses are usually observed differently for different employees therefore it is almost not feasible for an automated performance management system to judge and write the narrative description of suggestions specifically because there are no concrete definitions of employees' strengths and weaknesses. Thus, essay evaluation technique has poor potential to be used for process centric employees' performance evaluation. Since, it cannot determine *who is performing certain task how well* thus it does not support our criteria question 2.
- **Criteria Question 3**: We have realized that without having any concrete criteria for evaluation and without process context information, this method neither supports nor have any potentials to support for determining *who is performing certain process how well and under what certain condition* i.e. process centric analytical analysis of employees' performance thus does not meet our criteria question 3.

2.2.2.2 Critical Incident Method

Critical Incident Method [Flan54] focuses the evaluators' intension on those behavioral aspects of an employee which are very important in making the difference between performing a job effectively or ineffectively [Twel11]. Mostly, an evaluator writes down the anecdotes describing what is effective or ineffective with respect to a specific job or task (i.e. process in our context). Then throughout his evaluation, the evaluator reports what the employee did, and how much it is effective or ineffective in light of these anecdotes. Basically, a supervisor maintains a daily record of what an employee does. Using daily log, a supervisor periodically consolidates critical incidents of each workers behavior anecdotes. The advantage here is only description of specific behavioral aspects instead of vaguely defined personal traits similar to that of Essay Evaluation. As a matter of fact, this technique can only be used effectively as long as employees are confident that evaluator is not prejudicing or prejudging. At the same time, it has following disadvantages:

- While using this method, usually negative incidents are more noticeable than positive incidents.
- Recording of incidents may be chore for the manager concerned who may be too busy or forget to do it.

- Although, it has somehow job objectivity in anecdotes description about specific events but it does not eliminate evaluators' bias or inconsistency.
- This method is also suspicious to charges of favoritism because a proper trail of negative anecdotes can be regarded to justify a decision that the supervisor has already made about an individual.

We observed, this method also has very poor potential to be utilized in our context.

- **Criteria Question 1**: As a matter of fact, in this method anecdotes are defined that are specific to those behavioral aspects of a job or task (i.e. process) that distinguish efficiency and effectiveness, yet it is very hard for an automated performance management system to preprocess managers' daily log against these anecdotes and then describe the result of process performance as a whole i.e. *how successfully certain process is being performed*. Although text preprocessing and mining techniques are available and can be incorporated to process text logs but process centric performance evaluation cannot be performed simply using anecdote and supervisors' daily log without concrete definition of "What is success and how to measure it". Since, it does not support in determining *how successfully certain process is being performed* thus it does not fulfill our criteria question 1.
- **Criteria Question 2**: It is also very hard for an automated performance management system to preprocess managers' daily log against these anecdotes and then describe the result of employees' performance evaluation. Simply using anecdote and supervisors' daily log but without having concrete definition of "what is success and how to measure it", it is almost not possible to determine *who is performing a certain task how well*. Thus, it has very poor support for our criteria question 2.
- **Criteria Question 3**: It is very hard for an automated performance management system to perform process centric analytical analysis of employees' performance by simply preprocessing managers' daily log against already defined anecdotes but without having any process context information, without having any analytical analyzing mechanism, and without having concrete definition of "what is success and how to measure it". Thus, it has very poor support to determine *who is performing certain task how well and under what certain condition* so does not meet our criteria question 3.

2.2.2.3 Graphical Rating Scale

Graphical Rating Scale Method [Bor74] is one of the oldest and most popular methods of employees' performance evaluation [Grs11]. In this method, a set of performance factors related to a particular job such as quantity, quality, speed, depth of knowledge, cooperation,

loyalty, attendance, honesty, initiative etc. are listed first by the performance evaluator, and then for each performance factor, evaluator specifies grades such as Unsatisfactory, Fair, Satisfactory, Good, and Outstanding etc. Finally, evaluator goes through the whole list of these performance factors and then scales each employee against his grades, these rating scales typically specify employee' performance in terms of these grades. In fact, main advantages of the graphical rating scale are:

- Procedure adopted in this method is very simple.
- It is less time consuming to develop criteria and evaluate performance.
- Evaluator can make a precise judgment about employees' performance.
- In addition, it also allows quantitative comparison of employees' performance.

However, main disadvantage of graphical rating method is that different evaluators will use the same graphic scales in slightly different ways. However, one way to get around this ambiguity is to use behavior based scales in which work related behaviors are accessed. More validity can be obtained by comparing workers ratings from single evaluator than comparing two workers who were rated by different supervisors.

In comparison to essay evaluation and critical incident method, graphical rating method has comparatively good potential to be utilized in our context.

- **Criteria Question 1**: Set of performance factors related to a particular job such as quantity, quality, speed, depth of knowledge, cooperation, loyalty, attendance, honesty, initiative etc, are actually the attribution of employees towards their task. As a matter of fact process cannot be evaluated on the basis of such as loyalty, attendance or honesty etc. Therefore, this method does not have any potential to evaluate *how successfully certain process is being performed* thus this method does not support our criteria question 1.
- **Criteria Question 2**: Since this method has a good list of performance aspects (quantity, quality, speed, depth of knowledge, cooperation, loyalty, attendance, honesty, initiative etc) against which employees are evaluated. Moreover, it also defines list of grades against which employees are evaluated to determine the ranking of their success. Thus an automatic performance evaluation mechanism can perform such analysis to determine *who is performing certain task how well* specifically for different performance aspects. But the main issue is where to find the concerned data about performance aspects because usually these aspects are evaluated by the managers manually. Since, this method has an average potential to perform process centric employees' performance evaluation thus meet our criteria question 2.

- **Criteria Question 3**: This method uses the information about different performance aspects that are mostly not available within the process context but are rather observed manually by process supervisors. This method also does not support any mechanism for performing analytical analysis. Thus, it does not has potential to determine *who is performing certain process how well and under what certain conditions* thus it does not support our criteria question 3.

2.2.2.4 Multi-Person Comparison

Multi-person Comparison Method is concerned to evaluate an employee' performance relative to the performance of other employees rather than comparing each one to a standard [Rob96] [Wayn86]. It requires the evaluator to place employees into a particular classification. Basically employees are ranked from best to worst by comparing each employee with the every other employee and rank each as either superior or weaker to others with no ties among employees are allowed. What criteria evaluator adopts, is also not specific rather it depends upon evaluators choice, or an evaluation is simply based on his observations or intensions. The aim is clear ranking of employees, from the highest to the lowest. It is intended to effectively eliminate the possibility of giving the same rating to all employees thus evaluator must choose one high performer from the list of employees or give certain scores to employees at different ranks. However, it suffers following disadvantages:

- In practice, it is very difficult to compare employees possessing various individual traits.
- Result of evaluation speaks only of the position where an employee stands in his group. It does not test anything about how better or how worse an employee is when compared to another employee.
- This method does not eliminate the possibility of snap judgments.
- It causes rating errors because it forces discriminations between employees even if their job performance is quite similar.

Although, this method is currently being used in most of the organizations but in combination of other methods like graphical rating, however we observed, it has poor potential to be utilized in our context.

- **Criteria Question 1:** As a matter of fact, results of evaluation by this method speak only of the personal position where an employee stands but do not have any concern with process performance evaluation. Since, this method does not has any potential to be used in determining *how successfully certain process is being performed* thus it does not fulfill our criteria question 1.

- **Criteria Question 2:** Since, result of evaluation does not test anything concerning to employees' skills or level of their work done, therefore, this method has poor potential to be used in determining *who is performing certain process how well* so poorly supports our criteria question 2.
- **Criteria Question 3:** Though knowing employees' position but without having any information about employees' skill, process context information and analytical analysis mechanism it is not possible to perform analytical analysis of employees' performance. Therefore, this method does not have any potential to support in determining *who is performing a certain task how well and under what certain conditions* thus it does not support our criteria question 3.

2.2.2.5 Forced Distribution

Forced Distribution Method [Forc11] is another method comparing of performance of an employee to one another employees like Multi-person Comparison Method [Wayn86]. As the name "forced distribution" implies, the overall distribution of rating is forced into a normal, or bell shaped, or curve under the assumption that relatively employees are truly outstanding, or relatively a small portion of employees are unsatisfactory, and everybody else falls in between. For example, the distribution requested with 10 percent in the top category, 80 percent in the middle, and remaining 10 percent in the bottom. Advantages of forced distribution are following:

- It forces reluctant evaluator to make difficult decision to identify the most and least talented members of the work group.
- It also creates and sustains high performance culture in which workforce continuously improves.
- It tends to eliminate evaluators' bias

As a matter of fact, forced distribution does eliminate clustering of almost all employees at the top of the distribution (evaluator leniency), or at the bottom of the distribution (evaluator severity), or even in the middle (central tendency). However, it can foster a great deal of employee resentment if an entire group of employees (as a group) is either superior or substandard. It is more useful to evaluate each employee individually by more than one evaluator. Despite all this it has following disadvantages:

- It creates unhealthy cut-throat competitiveness.
- Discourage the collaboration of team work.
- It also harms the employees' moral.

Although, this method is currently being used in most of the organizations but in combination of other methods like graphical rating, we observed, this method itself has poor potential to be utilized in our context.

- **Criteria Question 1:** Since, result of such evaluation only identifies the groups of most talented, average and least talented members in the workgroup but does not have any concern with evaluation of process performance. Therefore, this method cannot determine *how successfully certain process is being performed* thus it does not meet our criteria question 1.
- **Criteria Question 2:** As a matter of fact, the result of such evaluation in terms of groups cannot determine individual performance of employees in determining *who is performing certain process how well* thus it does not support our criteria question 2.
- **Criteria Question 3:** With the availability of information about groups of most talented, average and least talented members in the workgroup it is not possible to perform analytical analysis of employees' performance because it neither provides any information about process context nor this method supports any analytical evaluation mechanism. Therefore, it is not possible to determine *who is performing certain process how well and under what certain conditions*. Thus, it does not support process centric analytical analysis of employees' performance so does not meet our criteria question 3.

2.2.2.6 Management By Objective

Management By Objective (MBO) [Geo65][Mob11] is a systematic and organized approach that allows management to focus on achievable goals and to attain the best possible results from available resources. Using this method, supervisor sets goals for employees working under his supervision. These goals are defined specifically to their tasks. Manager then periodically evaluate the performance and rewards according to the results. MBO focuses attention on goal achievements rather than how it is to be accomplished as it all depends upon employees' capabilities. Fundamentally, the essence of MBO is participative and goal setting, choosing course of actions and decision making. An important part of the MBO is the measurement and comparison of the employees' actual performance with the goals that are ideally set because employees themselves are involved in the goal setting and choosing the course of action to be followed by them therefore they are more likely to fulfill their responsibilities. The basic principle behind MBO is for employees to have a clear understanding of the roles and responsibilities they expect. It also facilitates better communication and coordination between employees and employer. The advantages of MBO are:

- Helps and increases employees' job satisfaction and commitment thus increases employees' motivation.
- It reduces conflicts and ambiguity.
- Leads to good planning.
- Managers are more likely to compete with the others.
- It identifies problems.
- Develop leadership qualities.

Although, MBO is a concept of management that has become very famous over the years and is widely used process for setting an agreeable objective by the mutual understanding between management and employees and then working for its achievement yet it has its own disadvantages:

- Danger of inflexibility.
- Competition may lead to tug of war.

This method is currently being used in most of the organizations and has good potential to be utilized in our context.

- **Criteria Question 1**: This method allows evaluator to define success criteria against which all of the employees are evaluated. Moreover, this method can also be used to define criteria for "process success" and then evaluate process performance based on this criteria. Therefore, this method has potential to be utilized in determining *how successfully certain process is being performed* it has potential to meet our criteria question 1.
- **Criteria Question 2**: Since, this method allows defining success criteria for all employees who are assigned to a specific task against which all its employees are evaluated. Thus this method supports in determining *who is performing certain tasks how well* so it supports our criteria question 2.
- **Criteria Question 3**: However, using this method context information are neither visible nor any mechanism is supported to perform analytical analysis of employees performance. Therefore, it does not help to determine *who is performing certain task how well and under what certain conditions* thus it does not support our criteria question 3.

2.2.2.7 Balanced Scorecard

The balanced scorecard [Kap92] has evolved from its early use as a performance measurement framework to a full strategic planning and management system. It was developed by Robert Kaplan and David Norton in 1990s, which is shown in Figure 2.10. It is currently being used as a

strategic planning and management system to align business activities to the vision and strategy of the organization, involve internal and external communications, and monitor organization performance against strategic goal. It adds strategic non-financial performance to traditional financial metrics to give managers and executives a more balanced view of organizational performance and thus enables executives to truly execute their strategy. Balanced scorecard is not only a measurement system rather it is more a management system that enables organizations to classify their vision and strategy that translate them into actions. Balanced scorecard views organization from following four different perspectives which are then used to develop metrics, collect data and analyze them relative to each perspective accordingly.

- Learning and Growth: To achieve our vision, how will we sustain our ability to change and improve
- Internal Processes: To satisfy our shareholders and customers what business processes must we excel at
- Customer: To achieve our vision how should we appear to our customers
- Financial: To succeed financially how should we appear to our shareholder

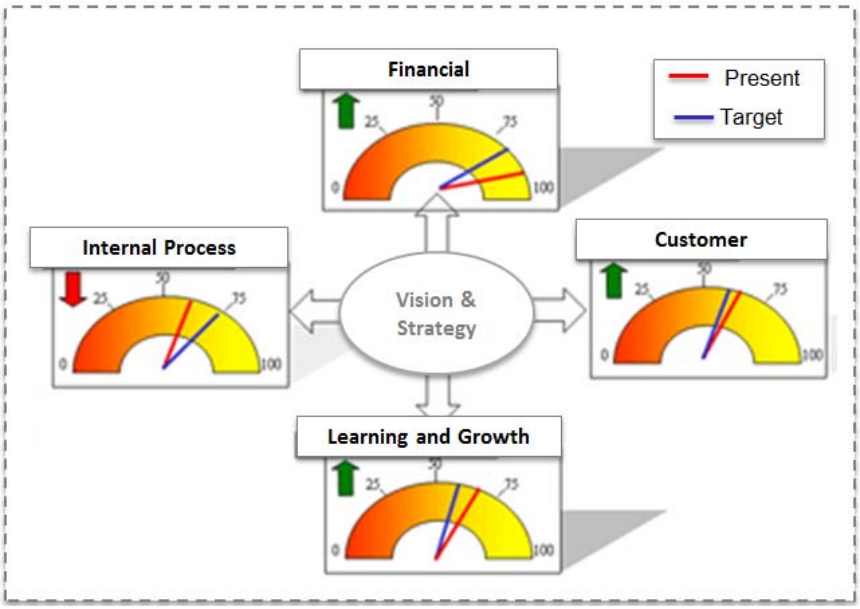


Figure 2.10: Balanced scorecard

Advantages of the balanced scorecard are:

- The balanced scorecard methodology helps leaders move from reactive mode to proactive mode.

- It gives balanced and full view of performance by looking at four aspects i.e. to determine whether organization is meeting its objectives. While it may seem that a company is doing well financially, it may be that customer satisfaction is down, employee training is inadequate, or that the processes are outdated.
- Generally balanced scorecards reflect overall company performance at the highest level. But an advantage of the scorecards is that they are scalable: the same or related metrics can be used at different levels of operations to assess performance.
- It sufficiently supports business growth because it includes assessments of the success of employee development and succession planning efforts, which are necessary for business growth.

While there are many advantages of using balanced scorecards, however there are a few disadvantages as well:

- Balanced scorecard approach is not quick fix rather it takes considerable thought to develop an appropriate scorecard.
- While communication can commence within short time, the complete implementation should be staged.
- When using balanced scorecards, it is vitally important to make the information being tracked applicable to your needs and if an organization is using metrics other than these four metrics of balanced scorecard then these metrics will be meaningless and are not applicable to their situations.
- There is needs for a good deal of work, sufficient funding and higher management eagerness to meet organizational challenges or to handle the risk that plan will not work.

This method is currently being used in most of the organizations as a strategic tool and has good potential to be utilized in our context.

- **Criteria Question 1**: Since, balanced scorecard views organizational performance by following its four different perspectives. It first develops metrics, then collects data against these metrics and finally analyzes these metrics. One of its perspectives (i.e. Internal Process) is to view process performance that basically defines a specific success criteria used in evaluating process performance. Thus, it has good potential in determining *how successfully certain process is being performed* so it meets our criteria question 1.

- **Criteria Question 2**. Similarly out of its four perspectives, one of its perspectives (Learning and Growth) is also concerned with resources. Thus, it allows defining success criteria for resources, develops metrics, collects data and finally analyzes resources' performance. Since, it has good potential in determining *who is performing certain task how well* thus it meets our criteria question 2.
- **Criteria Question 3**: Since balanced scorecard neither incorporates process context information nor incorporates analytical analysis mechanism in determining *who is performing certain task how well and under what certain conditions*. Therefore, it does not have any potential to perform process centric analytical analysis of employees' performance thus it does not meet our criteria question 3.

2.2.3 Summary of Performance Evaluation Mechanisms

Table 2.2 compares the major performance evaluation mechanisms from both domains i.e. WfMSs and HRM. These performance evaluation mechanisms were evaluated based on our three criteria questions. Depending upon their suitable support against these three criteria questions, appropriate evaluation category was determined. We have also ranked their support suitability into five categories: Doesn't Support, Poorly Support, Averagely Support, Good Support and Excellent Support, with their ascending order of appropriateness.

The results of comparison show that almost all BPMS products have "Excellent Support" for process centric performance evaluation because they support evaluating *how successfully certain process is being performed*. However, they lack to provide any mechanism for process centric employees performance evaluation because they do not support any mechanism that can determine *who is performing certain process how well*. Although exception exists in case of Global 360 BPM Suite that supports both criteria questions i.e. how successfully certain process is being performed (criteria question 1) as well as who is performing certain process how well (criteria question 2). But its support for criteria question 2 is on the average as it uses graphical rating method to perform such evaluation instead of MBO approach. Moreover, their support to our criteria question 3 is totally missing because no such framework is observed that support process centric analytical analysis of employees' performance.

On the other part, HRM performance evaluation mechanisms do not support process centric performance evaluation because they cannot determine *how successfully certain process is being performed* (criteria question 1). Although exception exists in case of Balanced Scorecard that supports process centric performance evaluation but its approach is not quick

fix rather it needs considerable thinking and time to develop an appropriate scorecard. We have observed that HRM methods mostly focus evaluating employees' performance i.e. *who is performing certain task how well,* nevertheless, each method uses different technique with different aspects for evaluation. At the same time, all HRM methods are unable to support for analytical analysis of employees' performance because such analysis can neither be performed manually by the performance evaluator nor any automated system has been developed to perform analytical analysis to determine who is performing certain task how well and under what certain conditions (criteria question 3).

Criteria Questions		Evaluation Categories		
		Process centric performance evaluation	Process centric employees performance evaluation	Process centric analytical analysis of employees performance
How successfully certain process is being performed		Category-1		
Who is performing a certain process how well			Category-2	
Who is performing a certain process how well under what certain conditions				Category-3
Process Centric Performance Evaluation Frameworks →	IBM WebSphere	●	⊗	⊗
	Appians Enterprise BPMS Suite	●	⊗	⊗
	Global360 Enterprise BPM Suite	●	◒	⊗
	Tibco iProcess Suite	●	⊗	⊗
	PegaSystems SmartBPMS Suite	●	⊗	⊗
	Savvion Business ProcessManager	●	⊗	⊗
Human Resource Performance Evaluation Methods and Techniques →	Essay Writing	⊗	◔	⊗
	Critical Incident Method	⊗	◔	⊗
	Graphic Rating Scale	⊗	◒	⊗
	Multi-person Comparison	⊗	◔	⊗
	Forced Distribution	⊗	◔	⊗
	Management By Objectives	⊗	●	⊗
	Balanced Scorecard	◒	◕	⊗
LEGEND:	*Doesn't Support* ⊗	*Poorly Support* ◔	*Averagely Support* ◒	*Good Support* ◕ *Excellent Support* ●

Table 2.2: Summary of performance evaluation mechanisms

Indeed, our thorough investigation of performance evaluation mechanisms from both domains indicates that there still does not exist such performance evaluation mechanisms that can perform *process centric analytical analysis of employees' performance*. Such that it has the ability to determine *who is performing a certain process how well and under what certain conditions*. Such deep and critical analysis of employees' performance specific to their task is prerequisite for continuous resource development (Table 1.1).

However, their missing support does not mean that existing BPMS frameworks and HRM methods are not useful. Instead, every framework and HRM method is important in their

target context and for their genuinely practical reasons. But the real fact is that their vendors have not really stridden up to this challenge.

2.3 Process Improvement Theories

In this section we present literature review regarding our contribution 3 that aims to provide "Lifecycle support for continuous resource improvement" as an add-on to standard process improvement lifecycle and will overview the existing literature regarding different process improvement theories. For this purpose, we have selected those process improvement theories that are mostly being used in the recent business process management market. These process improvement theories include Total Quality Management (TQM), Six Sigma, Lean Thinking, and Business Process Reengineering. The ultimate aim of our evaluation is to identify:

- What is the purpose of each process improvement theory?
- What are its common steps?
- What are its critical success factors?

We believe the knowledge gained through this evaluation gives us the better understanding and a suitable mean to develop our own lifecycle support for continuous resource improvement. In addition, we would like to address some of the drawbacks and inadequacies of these theories. Nevertheless, at the end of this section (Section 2.3.5) we will also present the summary of our evaluation that will comprehend these improvement theories.

2.3.1 Total Quality Management

Total Quality Management (TQM) is a structured system that aims at continuous improvements in all organizational processes. It aims for customer satisfaction and requires the contribution of everyone within the organization by focusing all aspects of organizational processes. "Total" means every persons and all processes organization-wide; "Quality" means improving customer satisfaction; and Management means the management system with steps [Vond04]. Hence, TQM focuses on quality and works on the basis that all person and roles involved in an organization's processes should be involved in the quality improvement lifecycle.

Dr. W. Edwards Deming is known to be the pioneer of TQM's philosophy. Using Deming Cycle [Dem86] for continuous improvement efforts, the necessary steps to align an organization with its processes can be structured along four phases namely Plan, Do, Check and Act as shown in Figure 2.11.

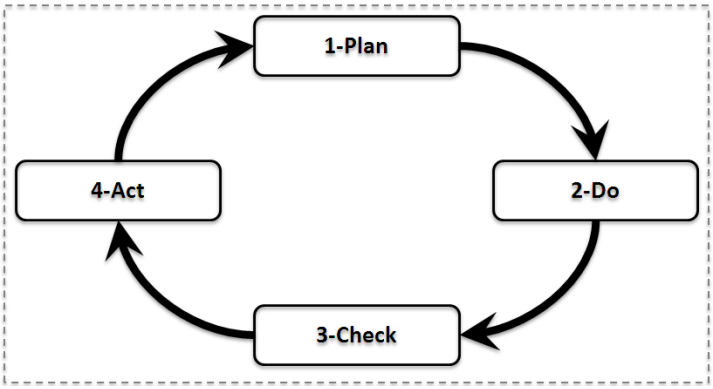


Figure 2.11: Deming cycle

Within the planning phase (Plan), organizational processes are identified and modeled using a process modeling tool/method. Throughout the execution phase (Do), processes are implemented and the organizational structure is realized to fit these processes. Information systems that support single process steps are implemented. During the execution of these processes, metrics of process executions are collected. Based on the data collected during execution phase, the existing processes are analyzed in the evaluation phase (Check). During Reengineering Phase (Act), adjustments to the underlying processes are reengineered observed in the evaluation phase.

One of the main principles of TQM is that most of the mistakes by people are due to problems in system and processes. As a result, most of the mistakes can be prevented by eliminating process defects. Some of the TQM objectives are:

1. Focus on customer satisfaction.
2. Involve all people in the organization.
3. Standardize the process.
4. Identify process goals and conventions for measurement of goal satisfaction.
5. Generate step-by-step action plans to solve the observed problem.

A common factor between all successful TQM practices is using measurement in an ongoing and continuous manner and providing feedback for the next round of improvement [Hab94]. Continuous incremental improvements result in large gains over long term. In addition, participative management motivates employees to gain better understanding of the operation. The best known strategy for implementation of TQM is Goal /QPC but it is very long for today's agile business environment because this approach is highly dependent on long-term management support and the first feedback of the project progress is only observable after two years [Pou08].

2.3.2 Six Sigma

Six Sigma is highly structured and disciplined system originally developed to eliminate defects, wastes, and quality problems. It has been widely adopted for business performance improvement and has become a management trend in many industries. Its implementation methodology identifies the source of defects by means of large amount of data analysis. It thus requires having precise understanding of business requirements in order to identify and eliminate defects in business processes. Thus, resulting improved performance costs less and returns more to the bottom-line [Vond04].

It is based on the principle of TQM and adds more to the quality method and is one of the most highly regarded quality methods of recent years. It is well known due to the following five main factors [Vond04]:

- Structured
- Resource Dedication and Involvement
- Customer Focus
- Error Reduction
- Bottom-Line Enhancement

Six sigma uses DMAIC methodology that consists of five phases namely Define, Measure, Analyze, Improve and Control (Figure 2.12). During the first phase (Define) the scope, benefits, and plan of the project are spelled out. In addition, the target processes are specified and mapped. Then, the current state of the process is studied and measured (second phase). In the analysis phase (third phase), the cause and effect analysis is done to identify the main reasons behind the defects in the processes. Then improvement phase (fourth phase), tries to provide solution to reduce the defects in the processes. Finally, the control phase (fifth phase) tends to keep the achieved results by ongoing measurement and monitoring the trends [Tru07][Pau08].

Some tools known to be useful in the method are: Kano's model, which helps in capturing customer requirements, SIPOC (Suppliers, Inputs, Process, Outputs, Customers), which is a statistical software for identifying the predominant family of variation or inconsistencies [Tru07]. There are several other tools and charts that are used with this method like affinity diagrams, benchmarking, brainstorming, flow charts, GANTT charts, cycle time analysis, scatter diagrams, histograms, and failure modes and effects analysis [Vond04]. In summary, Six Sigma is highly dependent on statistical methods and tools [Pau08].

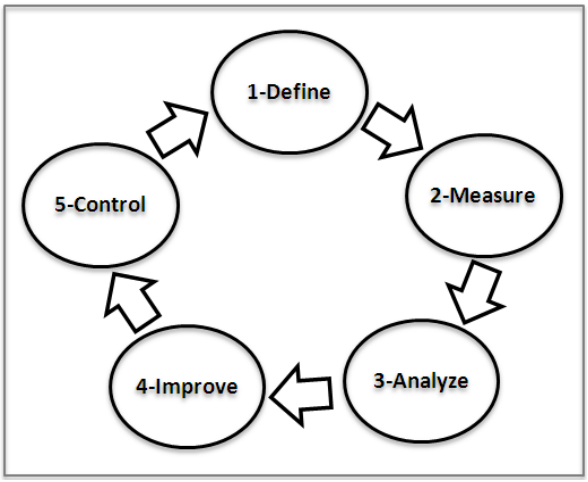


Figure 2.12: Six sigma design and improvement methodology

The indicators usually measured during a Six Sigma process are defect opportunities, defect per unit and defect per million opportunities, which make this process somehow closed and limited to what has been dictated in the methodology and not what the real needs of the organization are [Vond04][Tru07]. However, six sigma is difficult to use for processes that do not contribute to the bottom line or when their sole objective is not serving the customers.

2.3.3 Lean Thinking

Lean Thinking or simply Lean is a quality method introduced by Toyota [Vond04] and delivers "what customers are looking for". It basically aims for shortening the cycle of a process and only doing those activities that provide value for the customers. All other activities are considered waste and should be eliminated from the process cycle. It fundamentally uses continuously repeated five steps processes improvement [Vond04][Bizm11], shown in Figure 2.13.

- Identify Values: The activities providing values are specified.
- Map the Value Stream: The process flow and sequence of activities are illustrated.
- Create Flow: The activities with no value are removed from the cycle.
- Establish Pull: The services for customers are changed to be ready exactly when they want it i.e. let customer pull value from the next upstream activities.
- Seek Perfection: The process is improved or remaining wastes are removed in the next iteration.

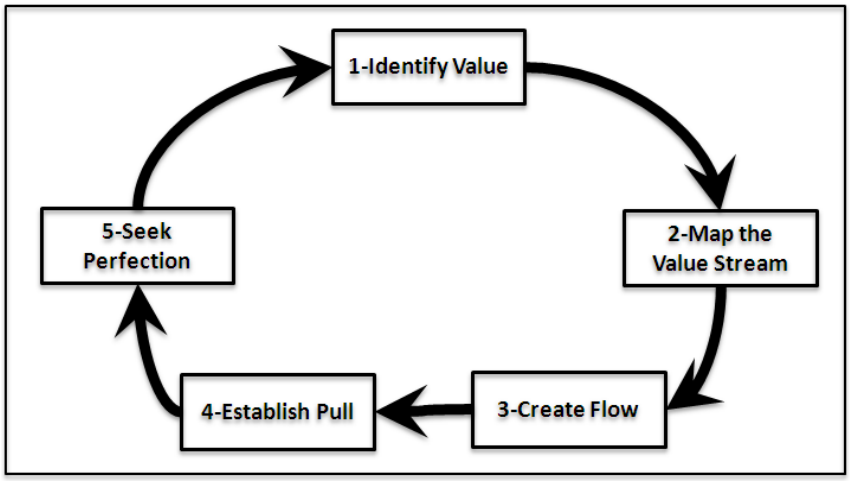


Figure 2.13: Leans thinking principles

The critical success factors of this approach, are the support received from top level management, the authority operational managers have, a detailed implementation plan, teamwork and communication (especially when it comes to cross-functional processes), efficient use of available resources, and finally, continuous improvement determination [Key04].

Like other classical quality methodologies, Lean Thinking is rather a management approach and, consequently, it uses management and statistical tools. Some of the common tools include simple flow charts and process mapping, time-function mapping, relationship mapping, Pareto charts, control charts, cause-and-effect charts, failure modes and effects analysis, and fault tree analysis [Vond04].

2.3.4 Business Process Reengineering

Business Process Reengineering (BPR) is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance such as cost, quality, services and speed. It is well known process improvement method introduced by Micheal Hammer and James Champy in early 1990s [Def03]. BPR is basically the fundamental rethinking and radical re-design made to existing resources of an organization. It is more than just improving business. It is an approach for redesigning the way work is done to better support the organization' mission and reduce costs. Reengineering starts with a high-level assessment of the organization's mission, strategic goals, and customer needs. Basic questions are asked such as:

- Does our mission need to be redefined?
- Are our strategic goals aligned with our mission?
- Who are our customers?"

An organization may find that it is operating on questionable assumptions, particularly in terms of the demands and needs of its customers. Within the basic assessment of mission and goals, reengineering focuses on the organization's business processes—the steps and procedures that govern how resources are used to create products and services that meet the needs of particular customers or markets. As a structured ordering of work steps across time and place, a business process can be decomposed into specific activities that are modeled, measured and improved.

Reengineering recognizes that an organization's business processes are usually fragmented into sub-processes and tasks that are carried out by several specialized functional areas within the organization. Often, no one is responsible for the overall performance of the entire process. Reengineering maintains that optimizing the performance of sub-processes can result in some benefits, but cannot yield dramatic improvements if the process itself is fundamentally inefficient and outmoded. For that reason, reengineering focuses on redesigning the process as a whole in order to achieve the greatest possible benefits to the organization and their customers. This drive for realize for dramatic improvements by fundamentally rethinking how the organization's work should be done distinguishes reengineering from process improvement efforts that focus on functional or incremental improvement.

There are several methodologies for implementing BPR. Although most of them use the same principles introduced by Hammer and Champy, however Muthu reviewed existing methodologies and introduced a comprehensive and coherent BPR methodology shown in Figure 2.14. However, critical success factors that should be considered for BPR application are:

- Clear understanding of reengineering.
- Strong executive leadership and support.
- Appropriate reengineering teams.
- Organizational commitment, ownership and accountability.
- Actionable business case.
- Clear and measurable objectives.
- Continuous measurement of results.

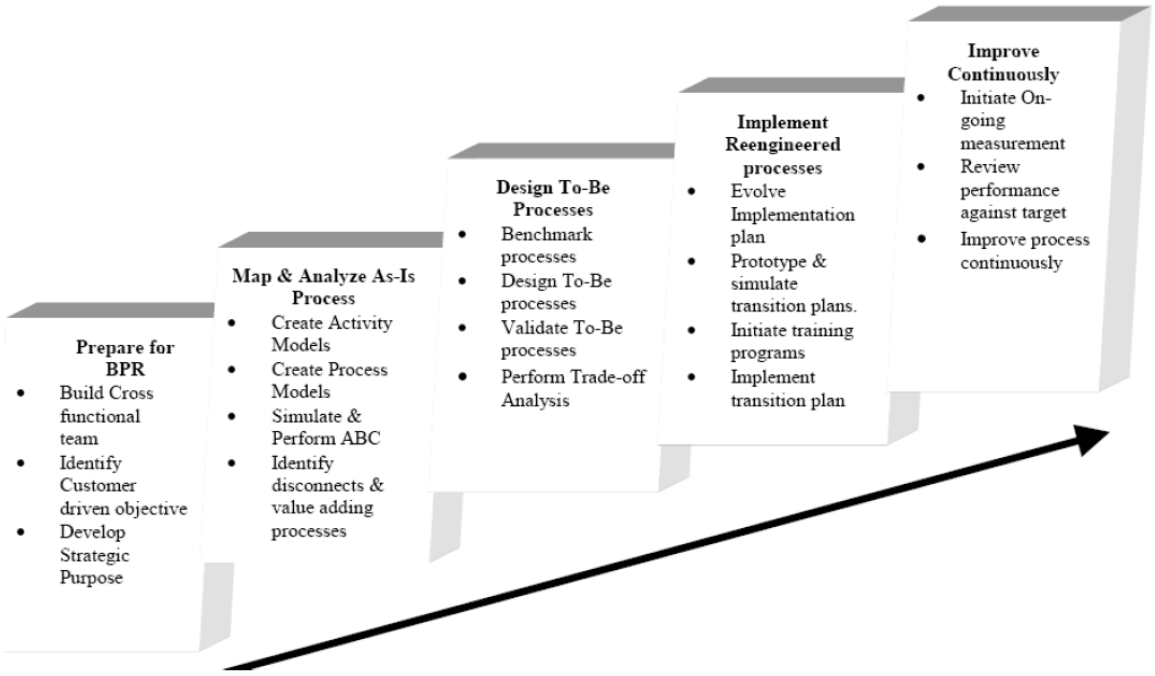


Figure 2.14: BPR Methodology

2.3.5 Summary of Process Improvement Theories

In this section we have reviewed process improvement theories. Table 2.3 provides a summary of these methodologies including their objectives, steps, tools and success factors.

Reviewing literature related to process improvement theories helped us to gain a better understanding of existing methodologies for process improvements along with their common steps used in these methodologies. For instance, TQM methodology guided us that using measurement within process improvement in an ongoing and continuous manner and then providing feedback on the basis of measurement for the next round of improvement [Hab94] results in large gains. Also, we observed that Six Sigma is highly structured method developed to eliminate defects, wastes and quality problems. It also identifies the source of defects by means of "data analysis" thus it guided us to perform deep analysis for resource performance management in our methodology (Chapter 5).

However, the focus of Leans thinking is on shortening the cycle of processes because it considers only those activities that provide values for customer. Furthermore, BPR approach focuses on redesigning the work that supports organizational goal achievements. However, for the basic assessment of goals, reengineering focuses on the organization's business processes—the steps and procedures that govern how resources are used to create products and services that meet their needs. Thus, BPR ultimately aim at the "assessment" of the organization's goals according to their needs.

Our thorough analysis of these theories concludes that measurement is important for improvement. Lack of measurement of resource performance is the major problem for resource management in our context. Further Harrington [Har91] stated “Measurement is the key. If you cannot measure it, you cannot control it. If you cannot control it, you cannot manage it. If you cannot manage it, you cannot improve it”. We used this knowledge as a baseline for the development of our goal oriented methodology for resource improvement within process lifecycle in Chapter 5.

	Process Improvement Theories			
	Total Quality Management	**Six Sigma**	**Lean Thinking**	**Business Process Reengineering**
Objectives	Reduce variation	Eliminate waste	Reduce non-value activities	Reinvention and Radical change of processes
Steps	1-Plan 2-Do 3-Check 4-Act	1-Define 2-Measure 3-Analyze 4-Improve 5-Control	1-Identify Value 2-Map the Value Stream 3-Create Flow 4-Establish Pull 5-Seek Perfection	1-Prepare for BPR 2-Map and Analyze As-Is Process 3-Design To-Be Process 4-Impliment reengineered Process 5-Improve continuously
Tools	1-Statistical management	1-Statistical management	1-Statistical management 2-Modeling & visualization	1-Process Modeling tool 2-BPML Notation
Success Factors	1-Deployment plan 2-Active Participation 3-Project Review 4-Project Tracking	1-Participative management 2-Continuous improvement 3-Teamwork	1-Leadership support 2-Detail Implementation Plan 3-Teamwork & Communication 4-Efficient use of resources 5-Continuous improvement	• Clear understanding • Leadership support • Appropriate Team • Commitment • Clear Objectives • Continuous Evaluation

Table 2.3: Summary of process improvement theories

2.4 Resource Allocation Mechanisms

This section describes the literature review concerning our contribution-4 i.e. CDRM Methodology. It basically aims to allocate work items to resources on the basis of their history of achieved business success (Requirement-4). Therefore, in this section we report different state of the art WfMSs to investigate their resource allocation mechanisms currently being offered. For this purpose, we have selected those well-known industrial as well as open source WfMSs that are well established in the market and are well known specially for their resource management abilities. These WfMSs include Staffware, WebSphere, FLOWer, COSA, iPlanet, jBPM, OpenWFE, Enhydra Shark and Oracle BPEL Process Manager. However, for each of the above mentioned WfMSs, our investigation proceeds as following

- Initially we proceed for a short introduction of a WfMS.

- Then, we overview its different task allocation mechanisms it currently supports.
- Finally, we outline how sufficiently it can be utilized in our context i.e. for the allocation of work items to resources on the basis of history of their achieved business success.

After a general evaluation of each of the above mentioned WfMSs, in conclusion we will present a summary of resource allocation mechanisms currently being offered (Section 2.4.10). This summary will give a better understanding of their general resource allocation mechanisms currently facilitated by them. However, it is not an overall evaluation of resource management abilities of these WfMSs. For a general evaluation of these WfMSs, we refer interested readers to [Rus07][Woh06][Rus06][Rus05][Mueh04a][Mueh04b][Rus04].

2.4.1 Staffware

Staffware Process Suite version 9 [Staf02][Staf02a] is a comprehensive process management software solution from TIBCO [Tib11]. It streamlines internal and external processes involving people and systems across organizations and geographical boundaries. It has relatively simple organizational model that denotes users, groups and roles only. Therefore, it supports relatively fewer numbers of resource allocations mechanisms [Rus07a]. It supports allocation of employees to processes **Directly** (e.g. Amir), or on the basis of **Groups** (e.g. winners) or **Roles** (e.g. cutters) they belong. However, Staffare have most restrictive definition for role because only one resource is identified as a role although it allows specifying multiple roles when assignment strategy is being defined at process design time. Nevertheless, it allows defining a single resource within many groups or roles. It also supports the allocation of a process to an automatically software service (i.e. **Automatic Execution**) without needing allocation to resource (i.e. human agent). Due to its limited support of organizational model (i.e. Agent, Role, Group) for defining organizational relationships therefore it has limited support for the allocation of resources on the basis of **Organizational Relationships** because it cannot define additional organizational relationships, for example, ManagerOf (e.g. ManagerOf(Ali) can *Sign* Ali's leave). It supports **Delegation** (e.g. if a user is not available, process should be allocated to an alternate user to avoid excessive delay) directly through task forwarding. However, it does not support **Binding of Duties** (e.g. customer complaint should be handled by a person who actually sold the product) as well as **Separation of Duties** (e.g. user should not approve his own bill). Moreover, it does not support any mechanism to specify additional **Authorization** that a resource possesses in regard to the execution of a process thus to have the ability to redefine the range of actions that a resource can initiate like RORDER, SUSPEND, SKIP, and DE_ALLOCATE etc. In particular to our context, it does not have the ability to allocate a work item to resources on the basis of their previous history of success of business process

performance. Neither the history of success of business process performance is evaluated nor incorporated into future assignment strategies.

2.4.2 WebSphere MQ

WebSphere MQ version 3.4 [Web03][Web07] is a WfMS by IBM [Ibm11] and it stands today at the forefront of a worldwide industry. It aligns and integrates organizational resources with their business processes for improving workgroup productivity. It provides richer organizational model that allows enterprises to be described in broader organizational contexts (agents, groups, roles, organizational unit, organizational relationships, branch, division etc) [Rus07a]. In contrast to the staffware' vision of role, it supports many to many correspondences between agents and roles because it allows specifying multiple resources for each role and also allows specifying multiple roles for a process when assignment strategy is being defined at process design time. It supports allocation of agents to processes **Directly**, or on the basis of their **Groups** or **Roles** (e.g. cutters) they belong to. It also supports **Separation of Duty** constraint by specifying a link between two tasks at process design time, subsequently, at runtime instances of these two tasks are not allocated to the same resource. WebSphere allows individual work item to be allocated to the same resource who started another work item in the case i.e. **Binding of Duties**. Since, it supports hierarchical organizational model and in addition to direct, role based, group based allocation it also allows to define task assignments on the basis of **Organizational Relationships** i.e. coordinator of a role, member of organizational unit etc. However, it does not supports **Automatic** execution of tasks i.e. allocation of a process to an automatically software service. Additionally, it does not support any mechanism to specify additional privileges (i.e. **Authorization**) like REORDER, SUSPEND, SKIP, DE_ALLOCATE etc that a resource process in regard to the execution of a process. Moreover in our context of competitive business environment, WebSphere does not support any mechanism that can be used in allocating resources to process on the basis of history of their achieved business success.

2.4.3 FLOWer

FLOWer version 3 [Flo04] is a workflow management system by BPM|one Pallas Athena [Bpm11]. It facilitates enterprises for designing, analyzing, managing, controlling, and automating their business processes. It supports an organizational model that is exclusively role-based and is defined in terms of role hierarchy [Rus07a]. Correspondences are established between individual users (or group of users) and roles. It supports multiple users per role and allows a user to play different roles in distinct cases. It supports allocation of employees to

processes **Directly**, or on the basis of **Groups**, or **Roles** they belongs. In addition, it supports to define additional organizational constraints like **Separation of Duties** and **Binding of Duties** except **Delegation**. Also, it supports **Automatic** execution of tasks i.e. allocation of a process to an automatically software service. Furthermore, the unique ability of FLOWer is that it is a **Case Handling** system because it allows to allocate a resource to all process steps of a workflow instance (case) i.e. the ability to allocate all tasks (atomic steps) of a given workflow instance to a single resource. For this purpose, it uses case-queries to determine which cases can be allocated to a specific resource. However, it has a limited support for the allocation of a resource to a process on the basis of **Organizational Relationships** because its organizational model defines organizational relationships only in terms of role-hierarchy without defining other organizational relationships like Supervisor, ManagerOf etc within the organizational model. One of the admiring ability of FLOWer is to specify additional privileges (**Authorization**) like REORDER, SUSPEND, SKIP, DE_ALLOCATE etc, that a resource possess regarding to the execution of a process. Despite, FLOWer having a wide range of resource allocation mechanisms it does not support to allocate resource on the basis of history of achieved business success. It neither evaluates history of success of business process performance nor utilizes it for future assignment strategies thus it cannot be utilized in our context.

2.4.4 COSA

COSA version 4 [Tran03] is one of the pioneers in the sector of intelligent Workflows, business process management systems and document management systems. It provides very rich organizational model that comprises many of the human resource concepts [Rus07a]. Users can be defined and organized into groups and hierarchies of groups can also be established. Additionally, users and groups can be assigned to roles. Also, it supports the identification of group supervisors. Therefore, it supports the allocation of employees to processes **Directly**, or on the basis of **Groups**, or **Roles** they belongs to. In addition, it supports to define additional organizational constraints like **Separation of Duties** as well as **Binding of Duties**. However, it achieves the effect of separation of duties through the use of access right which restrict the resource who undertook the preceding task in the workflow from executing the latter. Also, binding of duties is managed using a customized distribution algorithm for a specific task that requires it to have the same executor as another process in any workflow instance. Similar to FLOWer, admiring feature of COSA is its ability to specify additional privileges (**Authorization**) that a resource possesses regarding to the execution of a process like REORDER, SUSPEND, SKIP, DE_ALLOCATE etc. Also, it supports **Automatic** execution of tasks i.e. allocation of a process to an automatically software service. Unlike to FLOWer, it does not has the ability to

allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. **Case Handling**. COSA is one of the WfMSs that partially supports the history based resource allocation mechanism. It evaluates history just on the basis of "more executions - more experience" and/or "quick execution time" without focusing on success of business process performance. For example, the ***heart bypass task*** should not be assigned to a surgeon who is able to complete this surgery fastest – instead, it should be assigned to a surgeon who will most likely complete the surgery "successfully". Thus it cannot be utilized in our context.

2.4.5 iPlanet

Sun One iPlanet Integration Server 3.1 [Sun03] is a software product designed for enterprises that need to integrate packaged, custom, legacy, and new applications. It has a minimal organizational model that allows defining only users and roles as organizational elements for the identification of users and the assignments of roles to users [Rus07a]. However, it does not support to define groups of users having different capabilities or authorities in the organizational model. It supports the allocation of employees to processes directly, or on the basis of roles they belong to but does not support group based allocation. It supports separation of duties constraints. Basically IPlanet utilizes the concept of linked activities which allow the data elements of two distinct tasks to be shared. Then evaluation methods within the system define how the work items for a given task will be allocated to the various resources. Also, it supports binding of duties using the linked user concept which requires two work items to be executed by the same resource. However, unlike to FLOWer, it does not has the ability to allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. case handling. Moreover, it does not support to allocate resources on the basis of organizational relationships because its organizational model does not support to define organizational relationships. Rather, it provides facilities for defining tasks which can run automatically within the context of workflow without allocating it to a resource (i.e. human agent). In fact, similar to COSA its also supports history based resource allocation mechanism. Since, it evaluates history just on the basis of "more executions - more experience" and/or "quick execution time" without focusing on success of business process performance, it cannot be used in our context because neither the history of "success of business process performance" is evaluated nor incorporated into future assignments.

2.4.6 jBPM

jBPM [Cumb07][Jbpm11] is an open source business process management suite that makes the bridge between business analysts and developers. It is based on a generic process engine,

which is a foundation to support multiple process languages natively. It focuses on BPMN 2.0 as a language for expressing business processes. It supports the allocation of employees to processes **directly**, or on the basis of **groups** they belong to but do not support **role** based allocation. Also, it does not support additional constraints like **separation of duties**, **binding of duties**. Furthermore, it does not offer any mechanism to allocate employees to business process on the basis of **organizational relationships**. Moreover, it does not has the ability to allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. **case handling**. However, it facilitates defining tasks which can run automatically within the context of workflow without allocating it to a resource (i.e. human agent). Automatic execution of a task is supported through the notion of Nodes, where any customized behavior can be defined. But, it does not have any task allocation mechanism that can be used to allocate employees to their business process on the basis of their history of achieved business success thus it cannot be utilized in our context.

2.4.7 OpenWFE

OpenWFE [Ope11] is an Open source WorkFlow Environment / Engine. It is written in Java and it is not just limited to that language rather connectors are available to use OpenWFE from Python, Perl, C# (.NET), PHP and Ruby. It does not support a mechanism to allocate a resource to a business process **directly**. It allows to define only **roles** and a work item, whenever is created, and is directly assigned to employees via role concepts. Groups are neither defined by OpenWFE nor does it support any mechanism to allocate resources to a group. Further, similar to jBPM, OpenWFE also does not support to define additional constraints like **separation of duties, binding of duties**. Moreover, it does not offer any mechanism to allocate employees to business process on the basis of **organizational relationships**. It does not has the ability to allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. **case** handling. Nevertheless, it facilitates in defining tasks which can **automatically** be executed within the context of workflow without allocating them to a resource (i.e. human agent). However, automatic execution of a task is supported through the notion of nodes, where any customized behavior can be defined. In particular, it does not has any task allocation mechanism that can be used to allocate employees to their business process on the basis of their history of achieved business success so it cannot be utilized in our context.

2.4.8 Enhydra Shark

Enhydra Shark [Enh11] is an open source Java native WfMC and OMG compliant XPDL and BPMN Workflow. It supports allocation of a resource to a process directly, or on the basis of

groups, or the basis of roles. Similar to jBPM and OpenWFE, it also does not support to define additional constraints like **separation of duties, binding of duties**, and it does not offer any mechanism to allocate employees to business process on the basis of **organizational relationships**. It also does not has the ability to allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. **case** handling. Nevertheless, it facilitates for defining tasks which can **automatically** be executed within the context of workflow without allocating them to a resource (i.e. human agent). However, automatic execution of a task is supported through the notion of nodes, where any customized behavior can be defined. In particular, it does not has any task allocation mechanism that can be used to allocate employees to their business process on the basis of their history of achieved business success thus it cannot be utilized in our context.

2.4.9 Oracle BPEL Process Manager

Oracle BPEL Process Manager Version 10.1.2 [Ora05][Ora11] provides a framework for designing, deploying, monitoring, and administrating processes based on BPEL standards [Mul05]. It supports allocation of a resource to a process **directly**, or the basis of **groups**, or on the basis of **roles** they belong to. But, it does not support the organizational constraint namely **separation of duties**. However, it supports **binding of duties** through its built in function i.e. getPreviousTaskApprover(), which gets a specific resource who has executed the previous process. It also has the ability to allocate all tasks (atomic steps) of a workflow instance to a single resource i.e. **case handling** through its built in functions. However, it indirectly supports allocation of resources on the basis of **organizational relationships** because organizational structure is stored in the xml format and it can be extended or modified through a role based hierarchy. It allows specifying tasks involving the user as well as the tasks which need to be performed automatically. In particular, it does not has any task allocation mechanism that can be used to allocate employees to their business process on the basis of their history of achieved business success thus it cannot be utilized in our context

2.4.10 Summary of Resource Allocation Mechanisms

In Section 2.4, we have addressed the issue of insufficiency of resource allocation mechanism (issue-4) and reviewed different WfMSs for resource management support. Table 2.4 gives a comprehensive summary of the major leading WfMSs in the industry along with their support for resource allocation mechanisms. Reviewing the literature related to workflow resource allocation mechanisms, it helped us in gaining a better understanding about our identified

Requirement-4 i.e. a WfMS needs for a mechanism to allocate work item to resources on the basis of their history of achieved business success.

Through our analysis we observed that some of the WfMSs (e.g. COSA, iPlanet and ORACLE BPEL PM) partially support history based resource allocation. They evaluate history just on the basis of "more executions - more experience" and/or "quick execution time" without focusing on success of business process performance. Therefore, they cannot sufficiently be utilized to meet the requirement of competitive business environments. For example, the cutting process should not be assigned to a cutter who is able to complete this cutting quickly – instead, it should be assigned to a cutter who will most likely complete the cutting successfully i.e. with minimal cutting faults.

We use this knowledge as a base for the development of our Competency-driven Dynamic Resource Management (CDRM) Methodology introduced in Chapter 6. Our CDRM Methodology enables a WfMS to allocate resources on the basis of history of achieved business success.

Allocation Mechanisms	Workflow Management Systems								
	Staffware	WebSphere	FLOWer	COSA	iPlanet	jBPM	OpenWFE	Enhydra Shark	OracleBPEL PM
Direct	+	+	+	+	+	+	--	+	+
Role Based	+	+	+	+	+	--	+	+	+
Group Based	--	+	--	+	--	--	--	--	--
Authorization	--	--	+	+	--	--	--	--	--
Separation of Duties	--	+	+	+/--	+	--	--	--	--
Binding of Duties	--	+	+	+	+	+	--	--	+
Case Handling	--	--	+	--	--	--	--	--	+
Organizational Relationships	+/--	+	+/--	+	--	--	--	--	+/--
Automatic Execution	+	--	+	+	+	+	+	+	+
History Based Allocation	--	--	--	+/--	+/--	--	--	--	+/--
Legend:	Supported: +				Not Supported: --			Partially Supported: +/--	

Table 2.4: Summary of WfMSs' supported resource allocation mechanisms

CHAPTER 3

GOAL MODELING

Chapter 3: Goal Modeling

In this chapter we present our contribution-1 i.e. goal modeling support in business process model. Its aim is to define "success criteria" for a process within the process model against which all of its authorized agents are evaluated to determine their success of business process performance in today's competitive business environments.

It is basically structured into following five sections. Initially in Section 3.1, we will give a general overview about a goal concept and explain how goals are generally perceived in competitive business environments. Then in Section 3.2, we will present the conceptual foundation of our process modeling methodology namely, Perspective Oriented Process Modeling (POPM) methodology. We will explain what is POPM and why POPM methodology is an ideal candidate for goal modeling construct. Subsequently, in Section 3.3, we will explain support for goal modeling in our process modeling environment namely i>PM. Basically, i>PM is a generic process modeling tool that is built on POPM notion and supports goal modeling. In Section 3.4, we present the POPM Meta Model. Here, we will initially explain our POPM Meta Model Architecture and then subsequently, explain the customization of our goal construct in POPM Meta Model Architecture.

3.1 Goal Overview

A goal is a measurable target that an organization sets up to be achieved by their employees who are responsible to perform a certain task [Loc81][Sha07]. Goals are defined as mutually understood and agreed-upon targets between employers (process controllers) and employees (process participants). Goal definition itself contains "success criteria" that helps in determining certain level of agents' achieved success of business process performance. Because, it is defined in such a way that it assists performance evaluation mechanism in determining "what is success" and "how to measure it" – thus, it serves as a yardstick to access employees' success of business process performance.

Goal setting is an effective approach commonly adopted in competitive business environments because it ensures that participants of a process having a common goal are clearly aware of what is expected from them. It also provides sense of direction and purpose. It also capitalizes on the human brains' amazing powers since human brains are problem-solving and goal-achieving machines [Gold94]. In contrast to goal setting, apparently and expectably some managers may believe it is sufficient to urge employees to "do their best". But the real fact is that people who are told to "do their best" will not do so because "doing your best" has no external referent which implies that it is useless in eliciting specific behavior. To elicit some specific form of required behavior, it is important that employees have a clear view of what is expected from them. A goal is thereby of vital importance because it facilitates individuals in focusing their efforts in a specified direction as demanded from them [Loc81].

Mostly, goals are defined by the task supervisor (i.e. process manager) and are assigned to employees initially during task assignment. For example, in the textile industry a production manager defines goals for the Production Process and also for all of its sub-processes (process steps) that are involved in the production of different apparels. This production process consists of process steps such as Marker Making, Cutting, Sewing, Washing, Buttons and Rivets Attachment, Trimming, Pressing. In fact, employees are assigned to processes specific to their capabilities e.g. cutters are assigned to cutting process and sewers are assigned to sewing process etc. Likewise, goals are defined specific to their processes and are assigned to all the employees synonymously who are responsible to perform them accordingly. For example, ***cutters*** (i.e. employees responsible for **Cutting Process**) are assigned the goal that is specific to the cutting process e.g. ***cutters goal***: "cutting faults should be less than 2%".

Indeed, there are some specific guidelines that need to be carefully followed in defining goal perfectly. Most prominent and generally suggested guidelines are wisely described by the SMART acronym [Dor81]. This **SMART** acronym stands for **S**pecific, **M**easurable, **A**chievable,

Relevant, and **T**imeliness. Elements of this SMART acronym are basically used in describing the essential elements of a perfect goal as following:

- ***Specific***: Goal should be defined straightforward and as specific as possible. It should clearly describe about "what we want to achieve". For example for the **Cutting Process,** goal like "reduce cutting fault" is not specific rather it is broad, general, intangible and abstract statement. In contrast, goal like "cutting fault should be less than 2%" is more precise, narrow, tangible and concrete. Thus, for defining perfect goal, goal definition must be specific.
- ***Measurable***: How it can be identified that a goal has successfully been met or not? In order to clearly determine, if a goal has been achieved or not, it should be measurable. Measurement is important because if you do not measure results, you cannot tell success from failure, and if cannot recognize success, you cannot learn from it [Har91]. Therefore, goal definition must clearly specify its measurement infrastructure so that a performance measurement system can determine:
    - What different success levels are?
    - How each success level can be identified?
    - What certain success level is highly desirable?
    - Up to what certain level the goal has been achieved?

  For example, for the **Cutting Process**, goal achievement levels are: **Good**, when cutting fault are less than 2% (priority = 100); **Average**, when cutting faults are between 2 and 5 % (priority = 0); **Poor**, when cutting faults are greater than 5% (priority = -100). Furthermore, priorities assigned to each level determine its ranking relevant to different success levels.
- ***Achievable***: Goal should be realistic and attainable. It should not be out of reach of the employees – rather it should be achievable, practicable and also retainable by all employees to whom goals are assigned. Therefore, a goal definition should be correlated with employees' expectations and potentials. Because, if employees are satisfied and motivated for its achievement then there exists positive relationship that helps in developing employees' capabilities towards achieving success of business process performance.
- ***Relevant***: Goal assigned to employees should be relevant to their assigned task and their capabilities. For example, ***cutters*** should be evaluated only for the faults relevant to the **Cutting Process** – instead of evaluating them against e.g. poor quality of fabric, improper material used or machine malfunctioning etc.
- ***Timeliness***: Goal should be evaluated for a defined time span. This time span should be clearly communicated between employer and employees.

Employees' performance improvement through goals requires goal evaluation through a performance evaluation mechanism and also feedback in terms of employees' competencies. Although, evaluation of a goal is a continuous process where the follow up can be given even after each and every activity is being performed and measured [Dona06]. However, achievement of a goal determines one's level of success that guides organization in decision making whether he/she should continue with his/her forthcoming processes or should be suggested for training to improve his/her capabilities. Thus goal setting, goal evaluation and feedback go hand in hand. Without evaluation and feedback, goal setting is not likely to be effective because goal evaluation and provision of feedback helps to sustain motivation and commitment to achieve a goal [Ski05].

3.2 Conceptual Foundation

We employ an innovative process centric method for modeling business processes and workflows called Perspective Oriented Process Modeling (POPM) [Jabl96]. The advantage of the POPM notion is that it is generic enough to simultaneously handle the modeling of business processes and workflows. Therefore, for modeling goal we exploit POPM notion since we found POPM an ideal candidate for expressing the business process in a more generic way because it covers all facets of workflow based application and handles each concern in a well structured and modularized manner. POPM is a generic approach that allows us to incorporate goal model in process models by introducing a new perspective.

The main idea behind POPM is that a modeling construct consists of several building blocks, which we call perspectives, as shown in Figure 3.1. A modeling construct is then defined through the composition of these building blocks. An example of such a modeling construct is a "work step" which is the most prominent ingredient in the recipe for building a workflow. We identify five main perspectives for a basic workflow modeling language. These perspectives are generally independent of a specific application domain and can commonly be used.

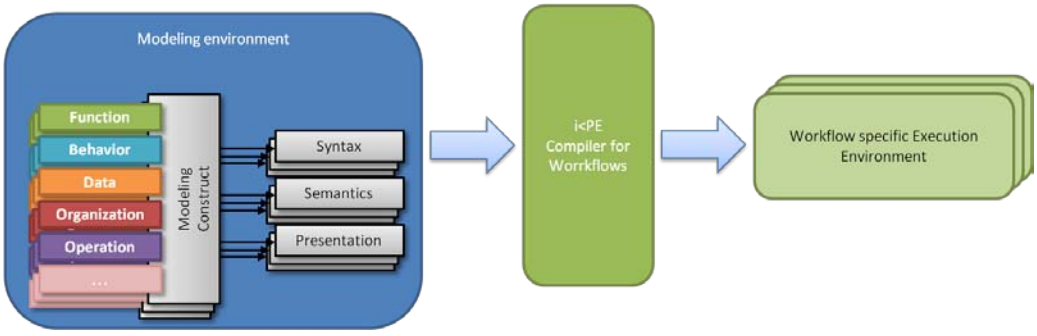


Figure 3.1: POPM Building blocks for process modeling constructs

- The ***Functional perspective*** determines the existence of a work step and defines its purpose. Work steps can either be atomic (e.g. Cutting Process) i.e. they are defined through their existence only or they can be composite (e.g. Production Process) i.e. they are defined through the existence of other steps which are properly connected (workflow hierarchy). By work steps, we do not mean an application or tool rather steps emphasize the functionality of a step. An application or tool can be associated to any work step through the definition of separate perspective.
- The ***Data (flow) perspective*** defines data products used in a workflow. It thus identifies the existence of data items in a workflow. Additionally, it defines the flow of data between the steps of a workflow i.e. where a certain data item is produced and where it is consumed. Optionally, it relates the data of the workflow to external data models that can be used to define their structure.
- The ***Operational perspective*** specifies how a task is done by using a particular tool, service, application or system. For a process step, it describes required application or program that is invoked in order to execute a work step thus it relates workflow process step to a specific tool, application, program or service ultimately required for its successful execution.
- The ***Organizational perspective*** provides a mean for the modeling of manual tasks through the involvement of human agents. It identifies who (employees) will execute the process step. Basically, for a process step it defines agents who are eligible to perform a work step. Also to reduce the possible numbers of task assignments, it allows defining different task assignment mechanisms using real world human abstractions i.e. agents, roles, groups etc. It also relates agents to organizational models through assignment policy that defines these eligible agents in terms of agent selection criteria.
- The ***Control flow or Behavioral perspective*** is used to define causal dependencies among the process steps and determines their order of execution. It uses constructs like sequence, conditional branching, parallel branching, XOR etc, to define their specific order in which the single step of a process is being scheduled for execution.

It is crucial that this list (of perspectives) is neither complete nor fixed, further perspectives can be added easily due to the availability of flexible meta model [Jabl08b] (Section 3.4). Indeed, this extensibility is especially important since some application domains require specific functionalities which are not provided a prior [Jab09a][Jab09b]. For example, to define success criteria for their employees' performance evaluation, competitive business environments require the specification of goals within the process model [Tal10]. Since, the POPM methodology is generic enough to allow us to incorporate goal model in process models by introducing a new perspective therefore POPM can be extended with goal perspective to support goal modeling within POPM based process model.

The introduction of perspectives encounters that we foster the integration of modeling constructs – better: perspectives of modeling constructs – into the existing information infrastructure by relating these perspectives to external resources. Through this integration, process descriptions become much more consistent. For example, incorporation of a goal within the process model enables organization to not only define success criteria for a process against which all of its eligible agents are evaluated but it also allows to specify only successful agents instead of merely eligible agents – not only during runtime but also during design phase of a process, when goals are specified.

3.3 Goal Modeling in Process Modeling Environment

Our proposed solution of modeling goals within a process model is implemented in the Integrated Process Manager (i>PM). It is a graphical process modeling tool that supports Perspective Oriented Process Modeling (POPM) notion [Jabl08b]. Figure 3.2 shows this i>PM process modeling environment while modeling the garment **Production Process** from a textile industry. This production process is a complex process and consists of sub-processes called *Marker Making, Cutting, Sewing, Washing, Buttons and Rivets Attachment, Trimming, and Pressing*.

Figure 3.2 is focusing one of the garment production processes called **Cutting Process**. Within the i>PM modeling environment where each process step is depicted as a rectangle; the **Functional** perspective is represented within that rectangle in a text box. **Data and Data Flow** are described by small boxes (data) that are placed on the black arrows (data flow) which connect two steps of a process; a data flow arrow always starts at the producer side of a data item and ends at the consumer side. The execution order of a process is (when this is not specified by data dependencies) defined with the help of the **Behavioral** perspective represented by grey arrows. A text just above the upper left corner of a process step denotes information about the **Operational** perspective. Small text at the lower left corner of the process step represents the **Organizational** perspective; here an assignment policy or simply the role “Cutter” is assigned to the step that describes agent selection criteria used for selecting the cutters (i.e. employees to perform cutting process). The **Goal** perspective is described by the small text at the lower right corner (“Cutter Goal”).

Basically, modeling goals in process modeling environment we concern for the description of goals in a systematic way that defines “what success is” and “how to measure it”. When we aligned a goal with the process we define a “success criteria” for their authorized agents against which we evaluate them (Chapter 4). In i>PM modeling environment, a goal can simply be aligned either with the elementary process or a complex process. When a goal is

aligned with an elementary process it establishes the 'success criteria' (which is a measure for the efficiency of a process) for all the employees who are responsible for executing the process. However, if a goal is aligned with a complex process it establishes the "success criteria" for the collaborative work of all the employees, part of a department, team or group involved in the complex process [Tal10]. It also helps to evaluate how successfully department heads, teams or groups in-charge are managing their subordinates. In our i>PM modeling environment, however goals definition consists of two parts:

1. *Measurement Definition*
2. *Context Definition*

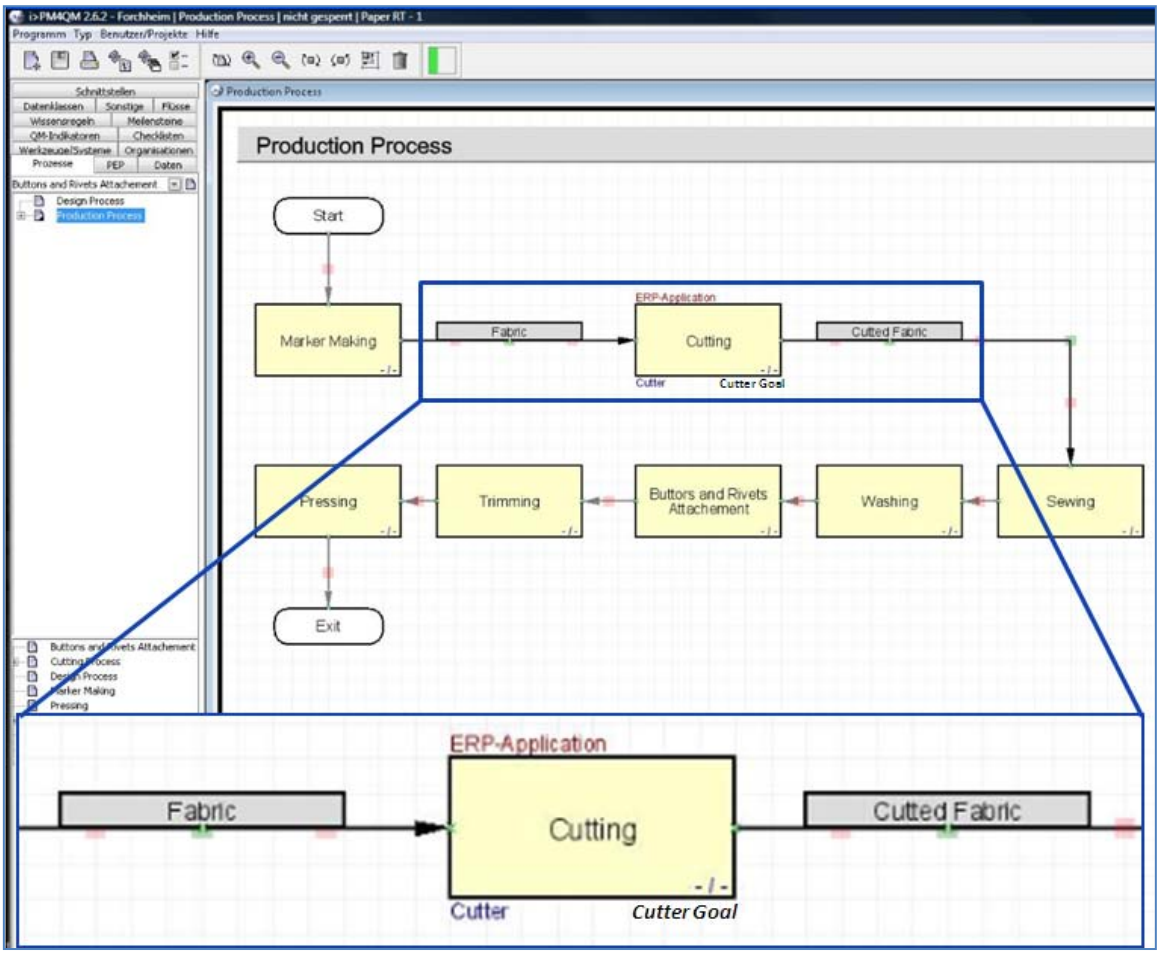


Figure 3.2: I>PM process modeling environment

The *Measurement Definition* basically adds a formula after which a measure for the defined goal is computed. As shown in Figure 3.3, this description includes *goal name*, *goal description*, *goal metric* (data used to measure the goal), *data source* (e.g. FaultTable), *data type*, and a *goal query* (which is needed for retrieving required data). It also includes the specification of

different groups. Additionally, each group is specified in terms of *group name*, *start value*, *end value*, and *priority* (Figure 3.3, lower part). These groups are used to describe:

- What are different success levels?
- How to identify a certain success level using goal metric values?
- How to rank the supremacy of different success levels i.e. which group is better than others?

Based on the current goal metric value, a performance evaluation mechanism determines a particular group. For example, when the goal metric value (FabricFaultPercentage) is less than 2 (%) this corresponds with the group "Good". Next, for this identified group (i.e. "Good"), a performance evaluation mechanism determines its "priority" utilizing its concerned group specification. The priority of that particular group determines the rank of its 'success' among different success levels – the higher the value of the group priority, the better the level of its business success [Tal10].

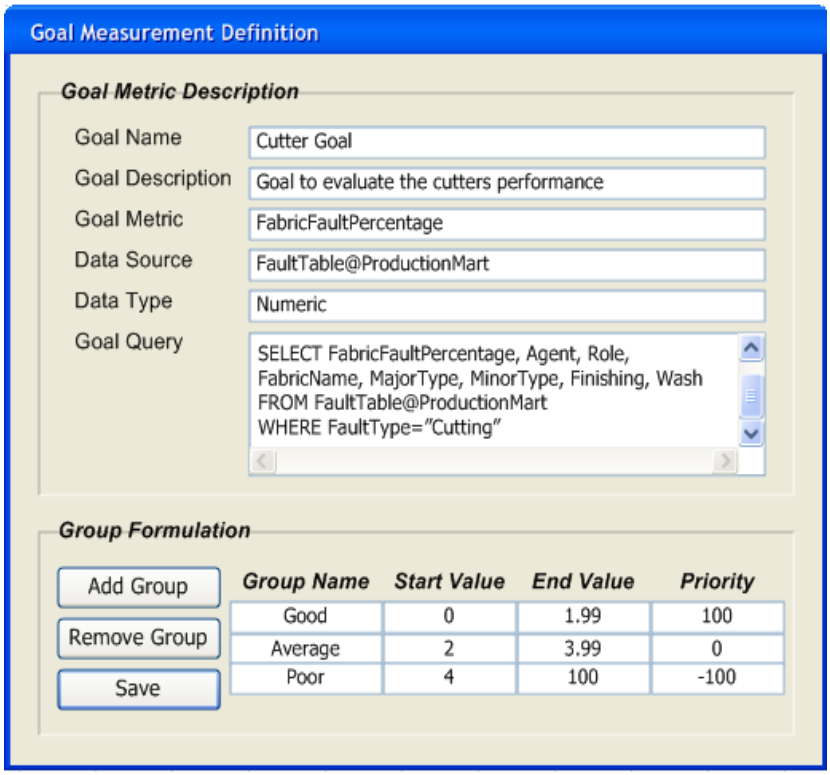


Figure 3.3: Goal measurement definition

These priorities are essential because performance evaluation mechanism cannot rank different levels of goal achievement simply from interpreting the captions like "Good", "Average" or "Poor". Also, these priorities guide performance evaluation mechanisms to perform certain actions that are required for continuous resource management. For example, it

could revoke the authorization of a person who achieved a goal having lowest priority (e.g. -100 for 'Poor' group). On the whole these priorities are used by a performance evaluation mechanism to determine the superiority of certain 'success level' so that it can perform appropriate action that is ultimately required for continuous resource management.

In contrast to the measurement definition, the *Context Definition* describes the information about different perspectives of a process that influence the achievement of a specific goal e.g. application data used during process execution and also the agents who execute the process. In fact, it is the Context Definition that establishes a basis for the application of data mining algorithms in order to evaluate the performance analytically. Therefore due to the context definition, performance evaluation mechanism (Chapter 4) can analyze with data mining techniques that "who" is performing "how well" and under "what certain conditions" goals are being achieved by "whom" and up to "what certain success level". Such analysis is feasible and results are promising if a process context is provided and only then performance evaluation can support actions for continuous resource development [Tal10].

Indeed, process context plays an important role for any application to first perform analytical analysis and then to support implicit decisions within the application. This initiative of incorporating the context definition within the goal model is basically motivated by the fact that any information taken out of process context lessens its value i.e. when information is taken out of context, the results are, at best, limited, if not downright misleading. Therefore, goal modeling on the process layer along with its context as well as its measurement definition enables a WfMS to act on processes for resource management — instead of having an adjunct performance evaluation mechanisms (like BI tools) that do not support actions within the process layer [Tal10].

Actually, *Context Definition* describes those perspectives of a process that may influence the achievements of a goal. As an example, partial view of Context Definition for a cutters' goal is shown in Figure 3.4. It comprises OrganizationalDefinition and DataDefinition. In fact within OrganizationalDefinition, OrganizationElement specifies a particular table of the organizational database where agent competency profiles are defined. For example, OrganizationElement "Play" defined in the context definition helps to identify the particular table of the organizational database. Similarly, Organizational Attribute(s) defined within OrganizationalDefinition basically define(s) key of the "Play" table. Thus, these attributes help to determine particular instances in the table, that are ultimately required in locating and updating particular agents' competency profiles.

Likewise, DataDefinition is concerned for the definition of those data elements that may influence the achievement of specific goal. Such data elements include FabricName, MajorType, MinorType, Fining, and Wash. These data elements also need to be carefully

included in the "goal query select clause" of goal measurement definition (Figure 3.3) and be carefully included accordingly in the context definition. Inclusion of these data elements in measurement definition helps performance evaluation mechanism to retrieve required data source for performance analysis whereas their inclusion within context definition helps data mining techniques to perform some preprocessing tasks (e.g. Discretization or Removal) to proceed for analysis [Tal10].

```
ContextDefinition
    OrganizationalDefinition
        OrganizationalElement       Play;
        OrganizationalAttribute     Agent;
        OrganizationalAttribute     Role;
    EndOrganizationalDefinition
    DataDefinition
        FabricName                  String;
        MajorType                   Nominal;
        MinorType                   Nominal;
        Finishing                   Nominal;
        Wash                        Nominal;
    EndDataDefinition
EndContextDefinition
```

Figure 3.4: Goal context definition

We propose that context definition has to include not just these two perspectives (Organizational and Data) but – in an optimal case – all perspectives of a process model that influences the achievement of specific goal. For example, in case if operational or behavioral perspective influences employees' performance towards achieving their goal then concerning features of the operational perspective need to be identified first and then can be included in the Context Definition, appropriately. In lieu of that inclusion, performance evaluation mechanism must also be tailored, accordingly. However, in our analysis of the textile processes we realized only these two perspectives that were crucial and were influencing employees' performance therefore we have incorporated them in the context definition.

Eventually, such a precise description of goal' *Measurement Definition* along with its *Context Definition* enables performance evaluation mechanism to first analyze how successfully a certain process is being performed by their authorized agents and under what particular conditions and then feed the result of analysis back for forthcoming instances of a process allocations which then supports for continuous resource development.

In this section we explained method for modeling goal within our process modeling environment where process engineer can easily model goal but only if he knows all detail about a goal (e.g. cutters' goal), goal metric (e.g. FabricFaultPercentage), goal groups (e.g. Good, Average, Poor), groups ranges (e.g. Good = 0—1.99) part of measurement definition as well as definition of influencing factors (e.g. DataDefinition and OrganizationDefinition) part of context

definition. As a matter of fact, these information are domain specific and process engineer does know them in advance therefore these information need to be analyzed before modeling start. How process engineers analyze them? We describe this methodology in Chapter 5. However, in the next section we will explain how a goal construct is customized within our process meta model.

3.4 Goal Customization in the POPM Meta Model

Here, we will first overview what our meta modeling technique is and how we customize our goal construct in our POPM Meta Model Architecture.

To define a language, there is also a need for another language to write the definition in. Similarly, within the modeling domain the language of a model is often called a Meta Model, hence the language used for defining a modeling language itself is called a Meta Meta Model. Likewise, Process Meta Model defines the Process Modeling Language, whereas the language that is used to define the process modeling language itself is called Process Meta Meta Model [OMG01] [Mof11].

Initially, in the following subsection (Section 3.4.1), we will briefly overview the POPM Meta Model Architecture that will highlight what different levels of this architecture are and what each level aims for. Then to formally define goal concept, we will describe goal schema in Section 3.4.2 whereas its syntax is presented in appendix. Finally in Section 3.4.2, we give details about the structural composition and framework of each level within our POPM meta model hierarchy. We will also clarify how each level achieves its overall aim and how the result of each level is actually being recorded within different models in our POPM Meta Model Architecture. More specifically we will highlight how the flexibility of our POPM meta model architecture enable us to customize our newly introduced goal construct at each level of POPM meta model architecture.

3.4.1 POPM Meta Model Architecture

For defining the structure of our process modeling language in i>PM, we use POPM Meta Model Architecture [Jab08b][Jab09a][Volz10]. It is four levels architecture and its meta model stack is shown in Figure 3.5. Within this architecture, each successive level is labeled from M3 to M0 and are named as POPM Process Meta Meta Model (POPM—PM^2M at level M3), POPM Process Meta Model (POPM—PMM at level M2), POPM Process Model (POPM—PM at level M1), POPM Process Instances (POPM—PI at level M0) [Jab09b] [Vol10a][Volz10b]. Since focus is on the modeling, therefore the result of each level (from M3 to M0) is also recorded in the

model. Moreover, a model at the M_i level is an instance of a model at the M_{i+1} level. Thus, through our POPM meta model architecture, meta modeling becomes a structured and systematic procedure for the definition of process modeling languages as well as process models.

Figure 3.5 gives the short description of these different models on each layer in our POPM meta model stack. Now, we will give a short introduction of the meta model hierarchy. However, in order to understand the approach easily we do not explain it chronologically instead we start on M1 with the definition of process models.

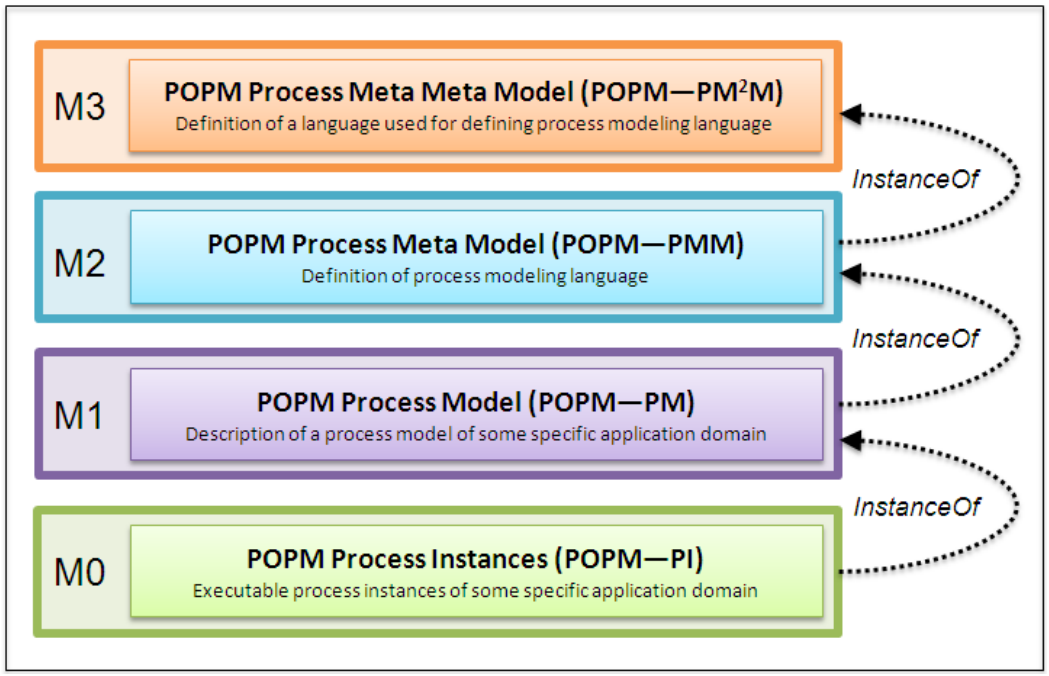


Figure 3.5: The POPM meta model stack

M1—POPM Process Model (POPM—PM): On level M1, the generation of our process models takes place. As an example, the process model for "Production Process" (textile process in Figure 3.2) is defined at level M1 using i>PM modeling tool (Section 3.3). The perspectives (i.e. characteristics and features) of a process model are actually defined here at level M1. Different process steps e.g. Marker Making, Cutting, Sewing, Washing etc (Functional Perspective) as well as their execution order (Behavioral Perspective), data consumed and produced by these process steps (Informational Perspective), assignment policies for these process steps (Organizational Perspective), applications used for the execution of these processes are mentioned (Operational Perspective) are defined at this level.

M2—POPM Process Meta Model (POPM—PMM): To define a process model at level M1, a process modeling language must be defined. This process modeling language is defined

on M2 and is called process meta model. it contains the definition of process modeling "constructs" such as process steps, control flows or data flows, assignment policies or simple roles etc. Thus, constructs of a process modeling language are defined here at level M2 and are made available into a process modeling environment so that process modeler can use (pick and drop) these constructs in designing process model at level M1. Our i>PM modeling tool supports wide range of process modeling constructs following the POPM notion (Figure 3.5, top right corner).

M3—POPM Process Mete Meta Model (POPM—PM^{2}M): Similarly, to define a process modeling language (i.e. POPM—PMM) on M2, a basic language definition is also required. This basic language used in defining process modeling language (i.e. POPM—PMM) is called POPM Meta Meta Model (POPM—PM^{2}M). Basically, POPM Meta Meta Model at M3 level defines modeling principles for our POPM framework. Fundamental structure or structural template for a language is defined at this level. This language (POPM—PM^{2}M) is defined in terms of directed graphs i.e. nodes and edges. Thus, a language used for defining process modeling language at level M2 is defined here at this level using directed graphs through nodes and graphs.

M0—Process Instances: Indeed, the level M0 is not the part of modeling environment instead it concerns with the execution environment. It contains the instances of a process model that is defined at level M1. These process instances are executed in a process execution environment. For example, the process model "Production Process" that was defined at level M1 is instantiated here at level M0 when there is need to start the production of a specific garment e.g. dress shirt, of an apparel division within textile industry.

3.4.2 Goal Schema

We define goal as a perspective within our POPM meta modeling methodology. Goal perspective is basically defined through a "Goal" concept (defined as an abstract level) and its schema is shown in the Figure 3.7. As shown, a goal concept has a name (which should be unique such that it can be used as an identifier), Description (which describe the general detail about a goal) and also comprises two sub-concepts i.e. MeasurementDefinition (Multiplicity: exactly one) and ContextDefinition (Pultiplicity: zero to one).

MeasurementDefinition concept is further defined in terms of two more sub concepts: MetricDescription (mutiplicity: exactly one) and GroupDefinition (multiplicity: two or more). Concept MetricDescription is defined in terms of attributes i.e. Metric (data used to measure goal), DataSource (source wherefrom data is extracted), DataType (data type of metric data) and Query (SQL query to retrive goal relevant data) as all string type. Similarly, the concept

GroupDefinition is defined in terms of atteibutes i.e. Name (unique group name as string value), StartValue (group value start from), StartValue (group value ending point) and Priority (ranking of this specific group relevant to other groups as an integer).

While, ContextDefinition concept is defined in terms of four sub concepts namely DataDefinition (multiplicity: zero or one), OperationalDefinition (multiplicity: zero or one), BevavioralDefinition (multiplicity: zero or one) and OrganizationalDefinition (multiplicity: zero or one). DataDefinition concept describes influencing factors from application data to describe those data elements that help in performing analytical analysis and in finding different scenarios that may influence agents' performance. It describes the name and data type of these data elements (multiplicity one to many). OperationalDefinition concept describes influencing factor from operational perspective. It describes the names of applications used in performing task (multiplicity one to many). BehavioralDefinition concept describes influencing factor from behavioral perspective in case it affects the performance of an employee. It describes the behavioral element that was followed in reaching this task that may influence employees' performance (multiplicity one to many).

The OrganizationalDefinition concept describes OrganizationalElement (multiplicity: exactly one) and OrganizationalAttribute (multiplicity: one to many). OrganizationalElement references to a particular organizational element or relationship where competencies profiles are updated and OrganizationalAttribute describes the name(s) of primary key attribute(s) of the organizational element or relationship. For the complete syntax of our goal concept please see Appendix.

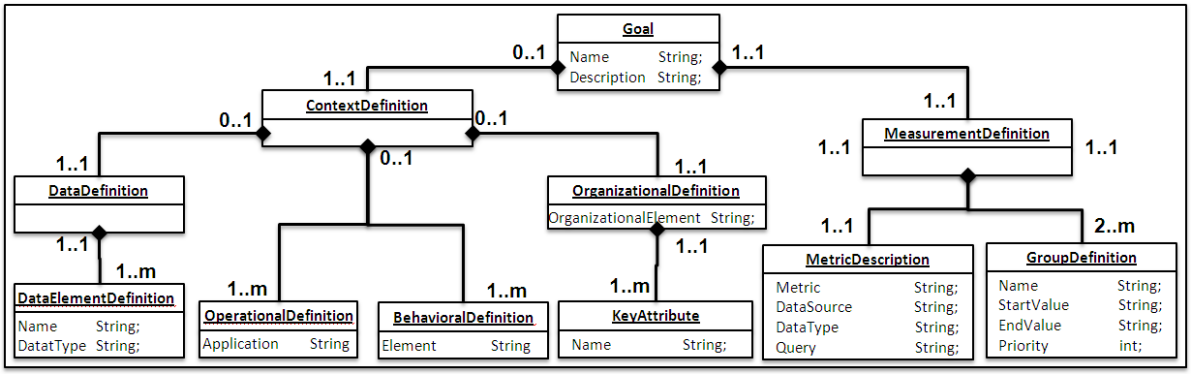


Figure 3.6: Goal concept definition

3.4.3 Goal Customization in POPM Meta Model Architecture

Structural details of different levels within the POPM Meta Model Architecture are shown in Figure 3.6. As shown, our POPM—PM^{2}M is located at M3 level and provides the basic framework structure that is used for defining our process modelling language.

Since, "Perspective" is the foundation of our POPM methodology, therefore in POPM—PM^{2}M, perspective is defined as an abstract concept (at level M3). Further, this abstract concept ("Perspective") is extended with other concepts (i.e. perspectives) such as Functional, Behavioral, Informational, Operational and Organizational perspectives. Essentially, we differentiate these five major perspectives. Flexibility of POPM—PM^{2}M allows to define more perspectives here at this level such as the Goal Perspective is defined here at level M3 that extends the abstract concept "Perspective".

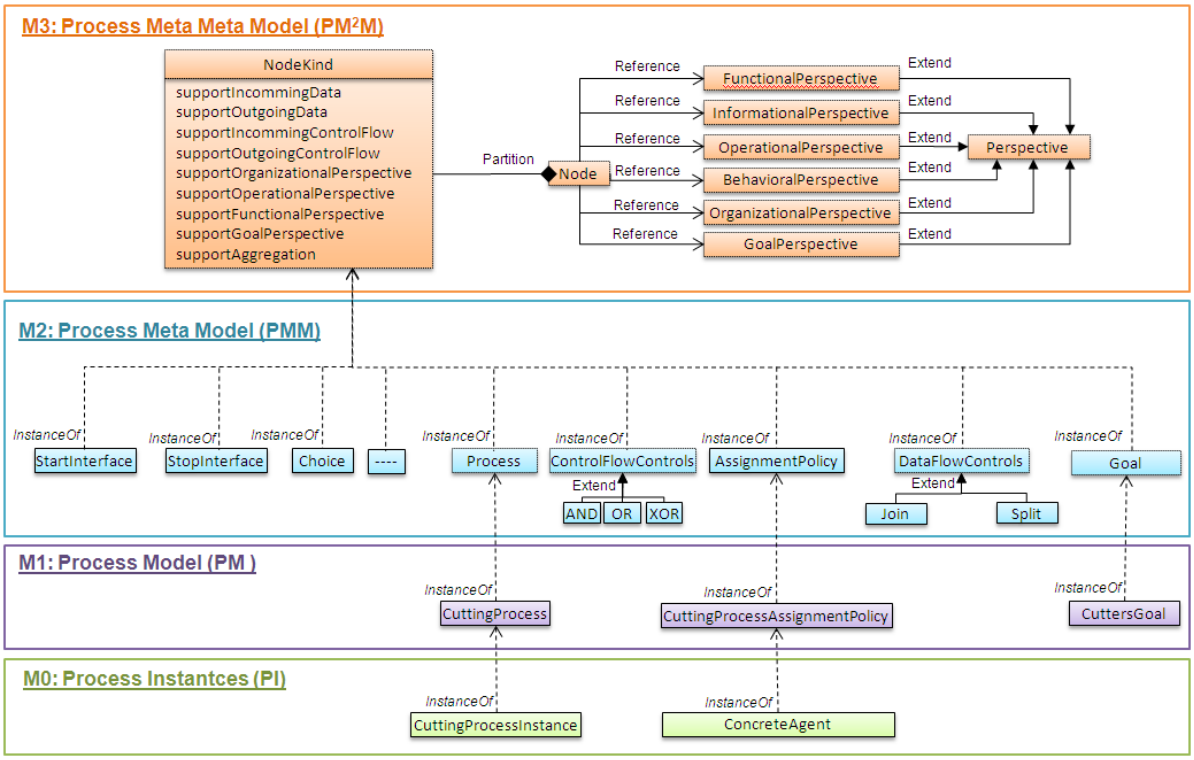


Figure 3.7: POPM meta model hierarchy

Since, in POPM we regard a process model as a graph whereby processes are the nodes of a graph, therefore, we represent these nodes by the **Node** concept in the POPM—PM^{2}M at level M3. The concept **NodeKind** then describes the characteristics (features) of nodes in the graph where each feature corresponds to an attribute of NodeKind (Figure 3.6). The Powertype pattern between Node and NodeKind is established through the "partition" relationship. Node represents the partitioned type and NodeKind is the powertype of the Powertype pattern.

Processes are just one type of nodes in such a graph; other types of nodes are e.g. StartInterface, StopInterface, Choice etc. The different capabilities of these nodes types are determined by the attributes within NodeKind. Features defined and implemented by the partitioned type Node are:

- supportIncommingData
- supportOutgoingData
- supportIncommingControlFlow
- supportOutgoingControlFlow
- supportOrganizationalPerspective
- supportOperationalPerspective
- supportFunctionalPerspective
- supportGoalPerspective
- supportAggregation

Meaning and purpose of each feature can easily be derived from their names or can be found in [Volz11]. In summary, features presented above determine whether elements of Node can establish the relationships of a certain kind to other types of the POPM—PM2M.

Within our POPM meta model hierarchy, level M2 shows the Process Meta Model of POPM that defines the fundamental components (constructs) of a POPM-related process model i.e. Process, ControlFlowControls, DataFlowControls, StartInterface, AssignmentPolicy. In the POPM process meta model, a process is an element in a graph that can be interconnected with other nodes (supportIncommingControlFlow = true, supportOutgoingControlFlow = true), can receive and produce data (supportIncommingData = true, supportOutgoingData = true) and can be used as a container for other elements (supportsAggregation = true). A process – and in general every element on layer M2 – is an instance of a corresponding type (sometimes a powertype) on M3. For instance, process is an instance of the powertype NodeKind and inherits all activated features from the partitioned type Node. The type StartInterface is also an instance of the powertype NodeKind but does neither support the creation of hierarchies (supportAggregation = false) nor incoming connections (supportIncommingControlFlow = false) etc.

Similarly, a goal construct is defined as “Goal” at level M2 by instantiating the powertype NodeKind and activate features from the partitioned type Node (Figure 3.6, level M2, rightmost element). The different capabilities of “Goal” construct are determined by the attributes within NodeKind. We define Goal as an element in a graph that cannot be interconnected with other nodes (supportIncommingControlFlow = false, supportOutgoingControlFlow = false), cannot receive and produce data

(supportIncommingData = false, supportOutgoingData = false) and cannot be used as a container for other elements (supportsAggregation = false) etc. Thus for Goal Construct, features defined and implemented by the partitioned type Node are:

- supportIncommingData = False
- supportOutgoingData = False
- supportIncommingControlFlow = False
- supportOutgoingControlFlow = False
- supportOrganizationalPerspective = False
- supportOperationalPerspective = False
- supportFunctionalPerspective = True
- supportAggregation = False
- supportGoalPerspective = True

Similarly, features of different constructs such as StartInterface, StopInterface, Choice, ControlFlowControls, AssignmentPolicy and DataFlowControles are defined and implemented by the partitioned type Node. Also, the list of constructs mentioned above and even that are shown in Figure 3.6 (at level M2) is not complete as compared to that are defined within our i>PM modelling environment. For complete list of constructs along with their specification of features that are defined and implemented by the partitioned type Node we refer to [Vol11].

However, at level M1 of POPM Meta Model Architecture, constructs that are defined at level M2 are made available for designing the process model of an application domain. While designing the process model of an application domain, characteristics and properties of different constructs that are utilized within process model are actually defined at this level. For example, names of process steps, process execution order while using different control flows, data consumed and produced by these process steps, and assignment policies for these process steps, applications used for the execution of these processes are mentioned. Now goals such as the cutters' goal can also be defined and attached with processes at level M1. How characteristics and features of a goal are defined? We have already explained in Section 3.3 (Goal Modeling in Process Modeling Environment).

Although, the constructs that are defined at level M2 can be utilized by the process designers while modeling processes at level M1, in Figure 3.6 we have not shown them just for clarity rather we have shown only few of them that are important in our context.

However, level M0 is not usually concerned with the process modeling rather it emphasizes the process execution because process instances are just instantiated within process execution environments using a process model as a template (defined at level M1). At

this level (M0) the main task of a WfMS is to coordinate all aspects of a process. A WfMS has to take care that all process steps are executed in the right order, consuming and producing the right data, applying the right applications, and the most important it selects the qualified agents. When process instances are executed by a WfMS, it also creates workflow execution history that can be efficiently used for process controlling.

It is worth to mention that a goal that is defined at level M1, is in fact not instantiated at level M0 by the WfMS because it is defined just as a template (abstract concept) that serves as a formula or criteria for measuring agents' success of business process performance. Thus, neither a WfMS instantiates goal at level M0 nor it evaluates goal itself during process execution, rather it creates workflow execution history while executing these business processes. How to evaluate performance, how workflow execution history is used as a data source and how goal definition is used as a success criteria by our Agent Performance Evaluation Framework, will be explain in Chapter 4.

CHAPTER 4

AGENT PERFORMANCE

EVALUATION FRAMEWORK

Chapter 4: Agent Performance Evaluation Framework

In the previous chapter (Chapter 3) we integrated a goal construct into process models that defines a success criteria used to evaluate agents' success of business process performance. In this chapter, we will describe an Agent Performance Evaluation (APE) Framework that basically uses the goal definition as a "success criteria" to measure agents' competency profiles first and then feeds them back into an organizational database so that a WfMS can use them for successful agent selection for its forthcoming process allocation. In addition to simple evaluation of employees' performance, an APE framework preferably supports analytical analysis of agents' competency profiles with its ultimate aim of supporting continuous resource development.

This chapter is organized into five sections. Initially in Section 4.1, we present the motivation for performing analytical analysis of employees' performance. Here, we explain why simple evaluation is insufficient and how analytical analysis is crucial for continuous resource development. In Section 4.2, we explain what domain knowledge is and how crucial it is for advising data mining techniques for performing an implicit analysis of employees' performance as a substitute of personal involvement of data miners. Subsequently in Section 4.3, we will explain the architecture of our APE Framework. Here we will overview different architectural component of our APE Framework and will justify their functionality towards achieving its overall objective and finally how the feedback is provided to a WfMS. At the end, our experiments and experiences are presented that we gain while analyzing the three production units of a text textile industry.

4.1 Motivation

We essentially differentiate between simple evaluation and analytical analysis of employees' performance. Simple evaluation of employees' performance is based on Management By Objective (MBO) technique that simply determines who is performing a certain process how well. On the other hand, analytical evaluation of employees' performance is more specific and precise that is carried out through the utilization of data mining techniques. It concerns to identify who is performing a certain process how well and under what certain conditions.

Principally, the APE framework supports both types of employees' performance evaluations i.e. simple evaluation as well as analytical evaluation. However, for learning agent competency profiles the APE framework preferably proceeds for analytical analysis of employees' performance. Nevertheless, in case when no predominant employees' expertise are observed through analytical analysis, the framework proceeds for simple evaluation of employees' performance. The philosophy to proceed preferably for analytical analysis of employees' performance is basically motivated due to the following two main advantages:

1. On one side, when it is observed that certain employees are performing a process well under certain conditions, a WfMS can utilize their expertise more proficiently. Because, a WfMS can make better decision in assigning them preferably for those process instances that are pertaining to specific situations where their expertise were observed outstanding.
2. On other side, when it is observed that certain employees are not performing a process well under certain conditions then this knowledge can also be utilized to suggest them for more specific and appropriate training that is precise and accurate to the particular situation rather than suggesting them a general training.

For a motivation scenario, we consider an example from a **Production Process** of an apparel division of a textile industry that typically involves in the production of different range of garments e.g. menswear, young men's, ladies wear and works wears. A **Cutting Process** is one of the sub-processes of the production process where **cutters** are responsible to cut the fabric for different types of garments being produced. For a cutting process, cutters' success of business process performance is determined on the basis of goal assigned to cutters (***cutters goal*** i.e. Good, cutting faults less than 2 (%); Average, cutting faults are between 2 and 3.99 (%); and Poor, cutting faults are greater than 3.99 (%)).

Employees	Good	Average	Poor	Total
Amir	48	32	4	84
Rehman	51	36	5	92
---	---	---	---	---
Saqib	67	45	18	130

Table 4.1: Simple evaluation of cutters' performance

As an example, Table 4.1 shows the statistics of employees' performance evaluation by means of a simple evaluation. From Table 4.1, it can easily be seen that the employee called "Amir" has performed 48 times **Good** out of 84 instances of cutting process (i.e. 57% Good). Similarly employee "Rehman" has performed 51 times **Good** out of 92 (i.e. 55% Good). Almost similar results hold for goal group **Average** i.e. Amir has resulted 32 times average out of 84 (i.e. 38% Average) and Rehman has resulted 36 times average out of 92 enactments of cutting process (i.e. 39% Average). Therefore, examining the statistics of Table 4.1, it becomes obvious that competencies of Amir (i.e. 57% Good and 38% Average) and Rehman (55% Good and 39% Average) are almost equally well.

However, using the same data rather more fascinating results are observed by the production manager when he analytically evaluates employees' performance, especially, when he incorporates the garment production data (usually described by the attributes e.g. MajorType, MinorType, Finishing, Stuff, Wash etc) of the garment being produced. As an example, Table 4.2 shows the brief view of such evaluation just focusing "MajorType" of different garments being produced.

Employees	MajorType						Total
	Pants			Shirts			
	Good	Average	Poor	Good	Average	Poor	
Amir	28	1	0	20	31	4	84
Rehman	19	35	4	32	1	1	92
---	---	---	---	---	---	---	---
Saqib	64	43	0	3	2	18	130

Table 4.2: Analytical analysis of cutters' performance

Statistics of the Table 4.2 show that Amir has performed 28 times **Good** out of 29 instances of cutting process when fabric is being cut for the production of Pants (i.e. 97 % Good) whereas Amir has performed 20 times **Good** out of 54 enactments of cutting process when Shirts are being produced (i.e. 37 % Good). It becomes obvious that cutting expertise of Amir are outstanding for Pants but are not as good as in case of Shirts; almost same holds true for Rehman, however, his expertise are outstanding for Shirts but rather average in case of Pants. Besides, Saqib' expertise are rather poor in case of Shirts and are preferable for Pants.

Now, correlating the results of simple evaluation (Table 4.1) with the results of analytical analysis of employees' performance (Table 4.2) disparity of stances are observed. Since, through simple evaluation (Table 4.1) it was observed that employees are performing almost equally well, however, through analytical analysis "predominant" employees' expertise are observed. Analytical analysis provides better stance for efficient resource management because the knowledge gain through analytical analysis can preferably be utilized for two main advantages:

- Utilization of employees' talent to the best use: It means employees who are performing best for specific types of garments can be assigned to those process instances. For example, it is obvious from above statistics that Amir can preferably be assigned to cutting process in case of Pants and Rehman can be assigned when Shirts are being produced. However, Rehman should preferably not be assigned for Pants whereas Amir should preferably not be assigned for Shirts.
- Sufficient support for continuous resource development: It means employees who are not performing well for specific type of garments they can preferably be suggested for more specific training needs rather than just a general training. For example, Saqib can preferably be suggested for training concerning to Shirts as opposed to general training.

Production managers astounded with the diversity of the observations gained through analytical analysis in contrast to simple evaluation.

Moreover in real world competitive business environments, analytically foreseeing employees' performance is neither fixed nor limited to only one predetermined attribute of the application data (e.g. MajorType). Rather, more practicable and interesting results are possible when multiple attributes of application data are considered and analysis is performed "heuristically". However, we have observed that it becomes difficult for production manager to foresee the most interesting and fascinating result of employees' performance by trying all plausible attribute combinations that describe the production data. Thus feasibility for the incorporation of data mining techniques within devised framework becomes obvious and essential.

Therefore, by correlating the result of analytical evaluation (Table 4.2) in contrast to simple evaluation (Table 4.1), along with our interactive discussions with production managers and their observation concerning the complexity of performing analytical analysis of employees performance “manually” have motivated us to incorporate data mining techniques and then to preferably automate such analysis within our APE framework.

Yet at the same time we have noticed, incorporation of data mining techniques within automated systems is also not an easy task. Usually, data mining is a complex task where data miners are “personally involved” to extract required data stemming from various application domains, preprocess them, choose mining algorithm appropriate for available dataset, provide rules and models, and present them to decision makers so that they can finally get benefit out of it.

Of course, to overcome the manual involvement of data miners and to incorporate data mining techniques within our framework some additional knowledge is required usually called domain knowledge. In the next section, we explain what domain knowledge is all about and how we incorporate it in our APE Framework for performing analytical analysis.

4.2 Domain Knowledge Incorporation

Knowledge required for advising the process of a real world data preparation and analysis, the selection of features, the fine tuning of mining algorithms and the evaluation, and the refinement of mining results is generally called domain knowledge [Yen07]. Usually, data miners determine this knowledge through personal interactions with domain experts of a specific application domain. Domain knowledge is very important because it assists not only in filtering subtle concerns but also in capturing incisive issues towards practical design for generating actions that are valuable not only for decision makers but can also be utilized within an automated system of complex domains [Cha05].

Indeed, after a thorough analysis of business process management technology we observed that process models are suitable source for domain knowledge especially when business intelligence is required within the application of a workflow. We realized that even though both technologies (process management and data mining) seem dissimilar, but still both support directly related promises:

- Data mining technology delivers knowledge that leads to “actions” that are incorporated and utilized within business environments for example by means of processes either manually by decision makers or automatically through an application.
- Process management technology defines the “context awareness” of business processes within the process models. Since, it precisely defines syntax and semantics

for different perspectives of processes like data being utilized, eligible agents who execute them, when and in which order processes are executed, and applications required to execute them etc. Therefore, this context awareness explicitly defined for each process can be utilized to support domain knowledge in data mining methods for delivering promising knowledge or actions again which are useful for process.

- Thus process management technology delivers context awareness that supports domain knowledge for data mining techniques. Also, data mining delivers actions that are again useful and proactively deployed in processes.

Convergence of data mining and process management technology is ideal – but still limited. By integrating data mining techniques inside business process management technology organizations, one can leverage from domain (knowledge) relevant information in mining methods for producing more concise knowledge useful for processes. Obviously, the APE framework is an example of such a convergence that addresses the problem of static assignment strategies of workflow technology. It uses the "goal definition" from process models not only as a success criteria but also as a source of domain knowledge, and then integrates data mining methods for performing process centric analytical analysis of employees' performance thus enabling a WfMS to support proper resource management [Tal10a].

As a matter of fact, a goal construct supports domain knowledge because it is not only a simple "success criteria", but rather a precisely and neatly defined performance measurement infrastructure that provides consistent support for domain knowledge in different phases of knowledge discovery. Furthermore, a goal construct is defined with the collaborative efforts of process designer, domain expert, data expert and most importantly agents (employees who execute the process) through different phases of workflow lifecycle (workflow analysis, design, implementation, execution, and evaluation). Therefore, human intelligence, business success factors and expectations etc, are eventually incorporated into this mutually-agreed-upon performance measurement infrastructure by these participants [Tal10a]. How do these technical participants collaborate in each phase of a workflow lifecycle? We will give details in Chapter 5. However, in the following we will give details specifically how goal model incorporates domain knowledge in the APE framework.

As specified in Chapter 3, a goal definition consists of two parts: measurement definition and context definition. How measurement definition supports domain knowledge in mining methods, is shown in Figure 4.1. A measurement definition describes many data items that help in performing the following preprocessing and post-processing tasks normally used within the knowledge discovery phases:

- Data Extraction: Measurement definition describes data items namely “Data Source” and “Goal Query” that in fact help for data extraction because this SQL statement is used to extract the required dataset.
- Feature Selection: The “Goal Metric” defined in the measurement definition helps to identify data element used for goal computation. Data elements that are specified in the SELECT Clause of a goal query actually helps in retrieving only those data elements which are very important for goal computation rather than selecting all data of a process even some of the data elements are not useful for goal computation.
- Data Discretization: Each instance of a workflow execution history extracted using the goal query has numeric value for the data element “Goal Metric” (e.g. FabricFaltPercentage). Before applying data mining algorithm for analysis, it needs to be discretized into nominal values of different success levels (i.e. Good, Average and Poor). Group formulation within the Measurement Definition helps to discretize “Goal Metric” values into nominal groups belonging to different success levels. Depending upon the goal metric value, a specific success level is selected which lies within the boundaries of Start Value and End Value of a particular group definition. For example, when the goal metric value (e.g. FabricFaultPercentage) is less than 2 (%) this corresponds with the cutters’ goal group “Good”.
- Ranking: Data element “Priority” defined within the Group Formulation part of goal measurement definition basically helps in determining the superiority of a specific success level among different success levels. It is hard to decide which success level is superior to another: neither on the basis of their nominal values nor on the smaller/greater value of a Goal Metric. Thus, the higher the value of the success level priority, the better the level of its superiority within the application domain.
- Grouping: On the basis of a specific value of a goal metric, Group Formulation criteria defined within goal definition helps to identify names of different success levels.
- Refinement/Tuning of Mining Algorithm: On the basis of a number of instances extracted through the Goal Query along with the statistics of individual data elements of a goal query help for further refinement and adjustment of the parameters (i.e. setting the support and confidence values) of mining algorithms.

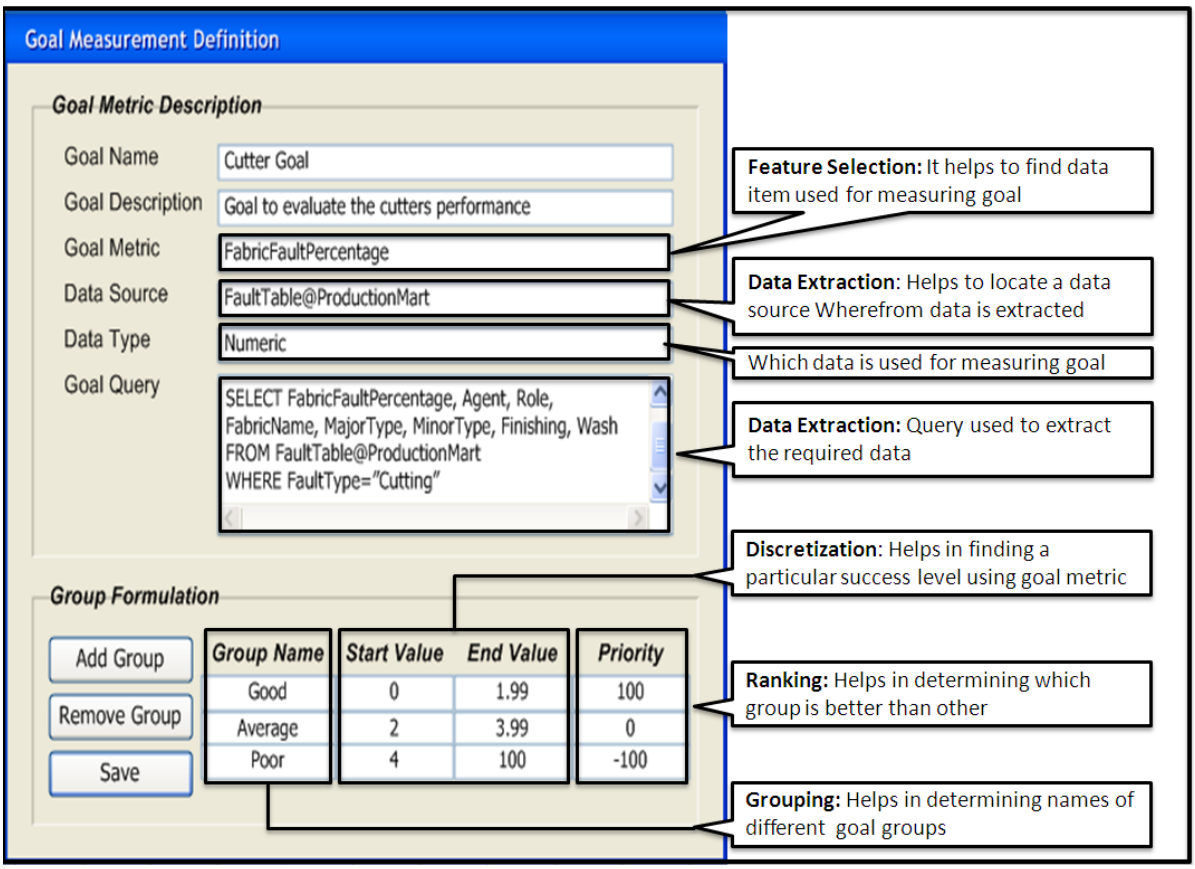


Figure 4.1: Goal measurement definition incorporates domain knowledge

Similarly, how context definition supports domain knowledge its rationale is also shown in Figure 4.2 while using the context definition of cutting process as an example. A context definition describes the influencing factors of a process in terms of OrganizationalDefinition and DataDefinition. Within this scenario, context definition supports domain knowledge for two purposes: feedback and attribute removal.

OrganizationalElement within the OrganizationalDefinition specifies a particular table of the organizational database where agent competency profiles are defined. For example, OrganizationalElement **Play**, defined in the context definition, helps to identify the particular table of the organizational database. Also, OrganizationalAttribute defines the list of those attributes that comprises the primary key of the OrganizationalElement (i.e. **Play**). These attributes help in uniquely determining particular instances in the table and are ultimately required in locating and updating agent competency profiles.

Similarly, DataDefinition is concerned with specifying those data elements that may influence the achievement of a specific goal and are included in the select clause of a goal query e.g. FabricName, MajorType, MinorType, Fining, Wash. This definition helps data mining techniques to perform some preprocessing for the removal of ineffective attributes. Thus, it

helps in removing those attributes that are even selected within a goal query but actually are not relevant for the mining algorithm e.g. FabricName is an attribute that has high cardinality and therefore can be removed within the preprocessing stage.

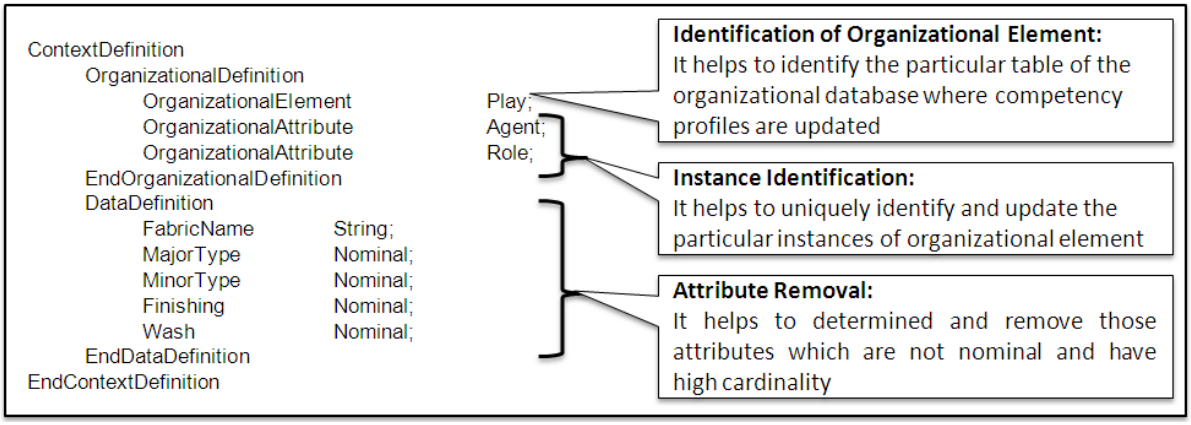


Figure 4.2: Goal context definition incorporates domain knowledge

Therefore, such a precise definition of a goal construct within the process model supports domain knowledge for data mining techniques. In the next section, we present the architecture of our framework that uses a goal definition not only as a success criteria but also as a source of domain knowledge.

4.3 Framework Architecture

An Agent Performance Evaluation (APE) Framework is a software system that aims for evaluating employees' performance specific to their processes within an application of workflow technology. As a matter of fact, it is neither an alternate system for general HRM performance appraisal nor it evaluates employees regarding their personality, cooperation, dependability, initiative, knowledge etc. Instead, it exclusively focuses on evaluating the credibility of "the link between an employee and a process". Therefore, it evaluates how successfully certain processes are actually being performed by their authorized agents and then provides feedback enabling a WfMS to support proper resource management.

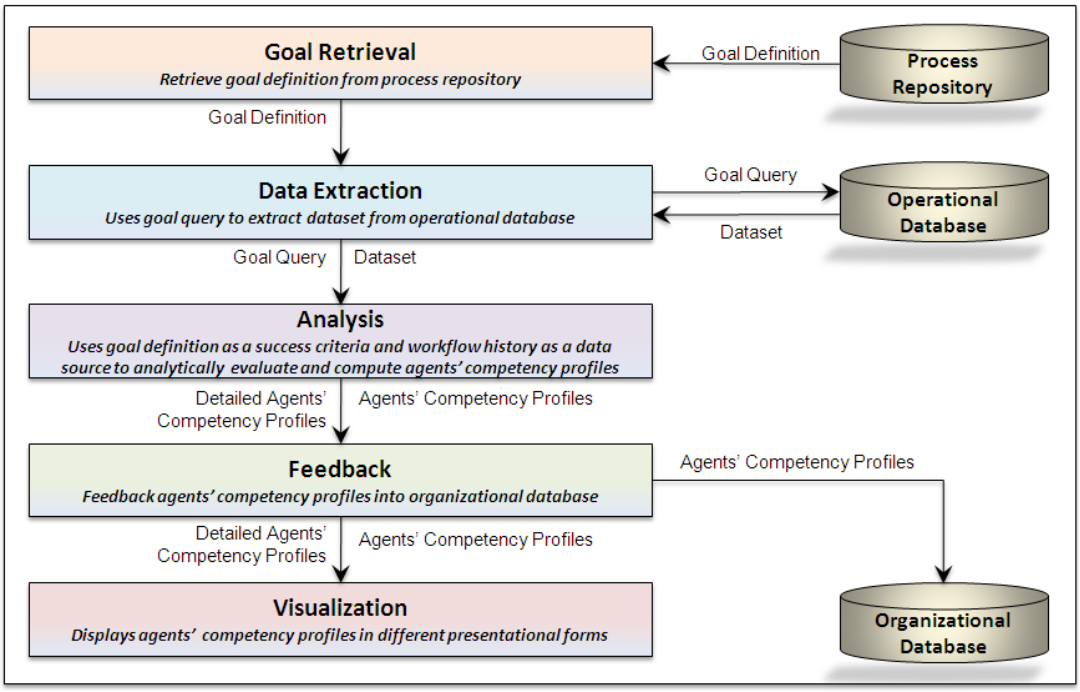


Figure 4.3: APE framework architecture

The architecture of APE framework is shown in Figure 4.3. It has five major conceptual architectural abstractions to achieve its overall objectives. These abstractions include Goal Retrieval, Data Extraction, Analysis, Feedback and Visualization. Details for each abstraction are in the following subsections. The APE framework retrieves a goal definition from process repository and uses it not only as a success criteria but also as a source of domain knowledge. It also extracts workflow execution history as a data source from operational database to perform process centric analytical analysis of employees performance. To perform analytical analysis of employees' performance, it proceeds as following:

- First, it determines whether all employees are performing a certain process almost equally well?
- If it is observed that a certain process is being performed differently by different employees, then it also determines whether certain employees are performing the process differently under certain different conditions?
- If it is observed that certain employees are performing a certain process differently under certain different conditions then it determines:
    - Firstly, what are those conditions where their expertise are outstanding?
    - Secondly, who are performing a certain process how well and what certain conditions where certain employees are performing the process well.

During the analysis, it computes agents' competency profiles which are updated into the organizational database. It also computes detailed agent competency profiles (different from agent competency profiles) to provide feedback to employees/employer through graphical display. Details of each abstraction are presented in the following subsections.

4.3.1 Goal Retrieval

During the design phase goals are set for employees and are attached to processes. These processes are defined inside the processes models that are stored within the process repository. Before proceeding for the evaluation of employees' performance, the APE framework needs to retrieve the goal definition. Within the Goal Retrieval phase, the complete definition of a goal is loaded from the concerned process model. In this phase, goal definition is simply extracted from process repository and is forwarded to the Data Extraction phase without performing any further operation on the goal definition itself. Rather, goal definition is further processed and utilized by the following abstractions of the framework.

4.3.2 Data Extraction

Within the Data Extraction phase, instances of the data that are used for goal computation as well as those data elements that may influence the achievement of a goal are extracted from the operational database. In this abstraction, goal definition extracted in the previous phase supports domain knowledge because:

- the Goal Metric defined in goal measurement definition helps to find data item used for measuring goal.
- the Data Source defined in goal measurement definition helps to locate a data source where from data is extracted.
- the Goal Query defined in the goal measurement definition is used to extract the required data.

This abstraction separates the SQL Query from goal definition and then it connects to the operational database to retrieve the required data i.e. "Dataset" (Figure 4.3). This dataset is then used throughout the analysis phase.

4.3.3 Analysis

This is the main phase of the APE framework that primarily concerns for performing analytical analysis of employees' performance. Within this phase manual involvement of data miner is eliminated through the availability of domain knowledge, in terms of goal definition. Also, instances of the dataset extracted in the previous phase (Data Extraction) are utilized as a data

source. A Functional view of the whole analysis phase is shown in Figure 4.4. It initially uses some pre-processing tasks i.e. Feature Selection, Discretization and Context Classification. How these pre-processing tasks are performed using goal definition as domain knowledge we refer to Section 4.2.

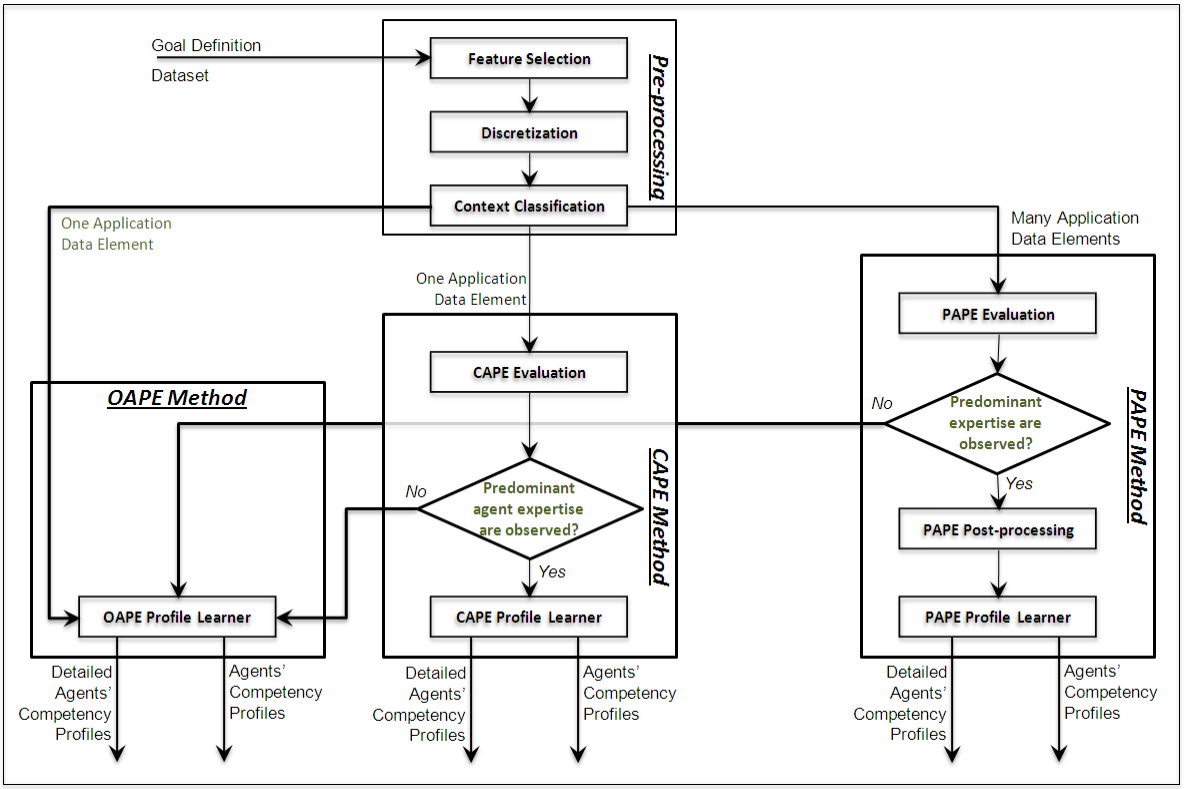


Figure 4.4: Functional view of analysis phase

In order to compute agents' competency profiles, the analysis phase makes use of pre-tuned mining methods. These methods include Pattern based Agent Performance Evaluation (PAPE) method [Jabl09], Context based Agent Performance Evaluation (CAPE) method [Jabl09c] and Occurrence based Agent Performance Evaluation (OAPE) method.

Tuning of general mining algorithms is necessary to utilize them for specific purpose because generally mining methods do not meet the requirements of a specific domain. Also, this list of performance evaluation methods is not fixed. Rather, flexibility of our framework allows the addition of more methods, depending upon the diversity of dataset and/or schema of the operational database deployed for managing workflow history. However, to sufficiently meet our requirements of resource management in a textile industry we have developed these three methods in our current scenario.

When to choose which method, again depends upon the interpretation of the goal definition. As shown in Figure 4.5, dataset extracted through the goal query comprises the Goal Metric, the Organizational Data and the Application Data. It is important to categorize the goal query dataset into the Goal Metric (i.e. FabricFaultPercentage), the Organizational Data (i.e. Agent, Role) and the Application Data (i.e. FabricName, MajorType, MinorType, Finishing and Wash) because different combinations of these data are utilized by these methods.

Again, the goal measurement definition and the goal context definition help to identify and categorize this goal query dataset into above mentioned categories of data. For example, within the goal context definition, the OrganizationalDefinition helps to identify the "Organization Data" and the DataDefinition helps to identify the Application Data from the dataset extracted through the goal query (Figure 4.5).

Number of data elements within the application data helps to choose a particular method. Basically, we classify the context of a process (i.e. Context Classification) on the basis of the number of extracted application data elements into three categories (see Figure 4.4): If a process involves many application data elements, the PAPE method is used. If a process involves one application data element only, the CAPE is applied and thus if a process does not use any (input) data or there is no application data element extracted through goal query, the OAPE is our method of choice. Nevertheless, during analytical analysis of employees' performance when no predominant agent expertise are observed either by the PAPE or the CAPE method then framework uses the OAPE method to compute competency profiles (see Figure 4.4).

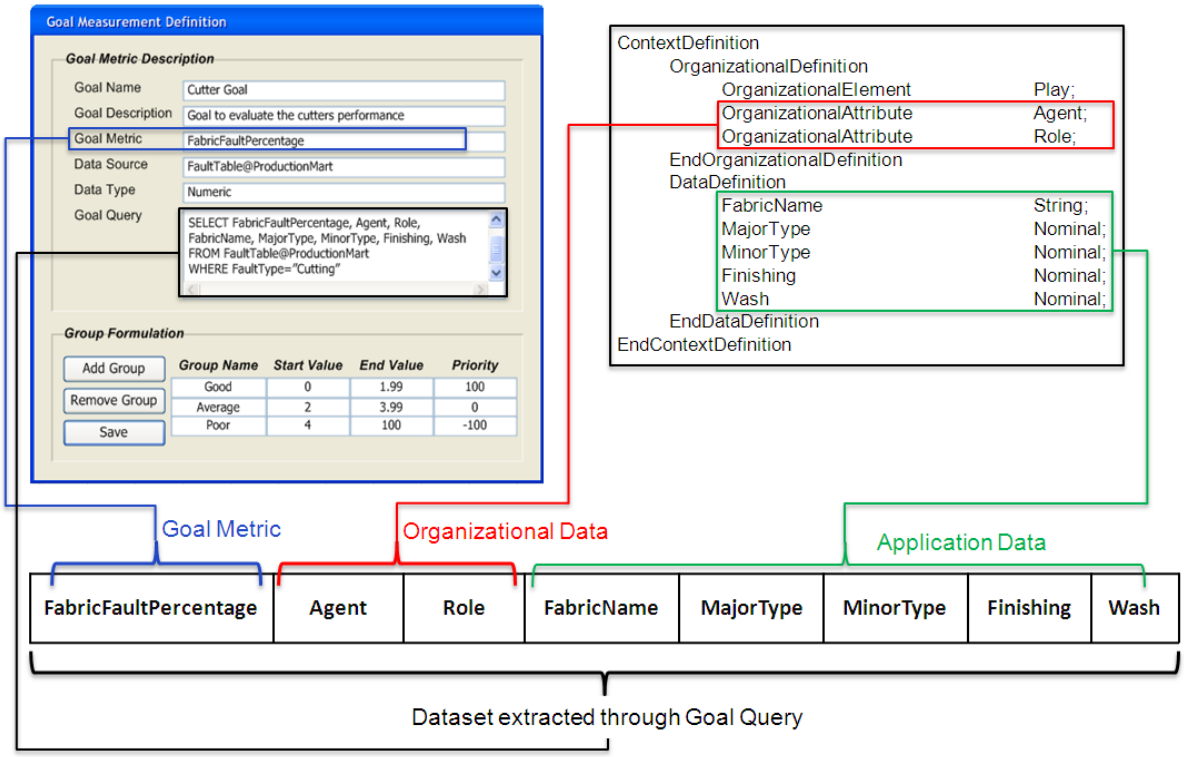


Figure 4.5: Categorization of data extracted through goal query

As stated above, the **PAPE method** is selected in case a process consumes many application data elements (e.g. Cutting Process). This method basically performs the analytical analysis of employees' performance. The PAPE method consists of three steps, namely PAPE Evaluation, PAPE Post-Processing and PAPE Profile Learner. During the first step (PAPE Evaluation), the objective is to determine whether process is being performed differently by different employees under certain conditions.

The PAPE Evaluation uses data mining technique called classification to perform this task. It uses j48 decision tree from the Weka Library [Ian05], which is a slight modification of the C4.5 decision tree [Qui93]. It considers all the possible tests "heuristically" that can split the application dataset and selects a discriminating feature that gives the best information gain. J48 classification algorithm is applied by selecting process application data elements as non-classifying attributes. Also, Goal Metric (i.e. FabricFaultPercentage) data is first transformed into Success Groups using Goal Formulation within goal measurement definition and is used as a classifying attribute.

Thus using Application Data elements and Success Groups (Figure 4.6 upper part), J48 classification algorithm generates a decision tree (Figure 4.6 lower part) for the given dataset by performing recursive partitioning. As shown in Figure 4.6, it classifies application data according to the groups (i.e. success groups) defined within the goal definition. Based on the

information gain value of the data elements (from application data) it heuristically selects some elements that have high information gain value (e.g. MajorType and MinorType) to generate decision tree.

From this tree different patterns can be learned by simply traversing the tree from top to leaves (called branches of the tree). As an example, from the rightmost branch of the tree patterns learned is "MajorType = Shirt and MinorType = Blouse". This pattern can predict under what certain conditions process is being performed how well. For example, it indicates that out of 62 instances 50 are Good and 12 are not Good when. But still it cannot identify who (i.e. performer) that still requires second step (Post-processing) of the PAPE method.

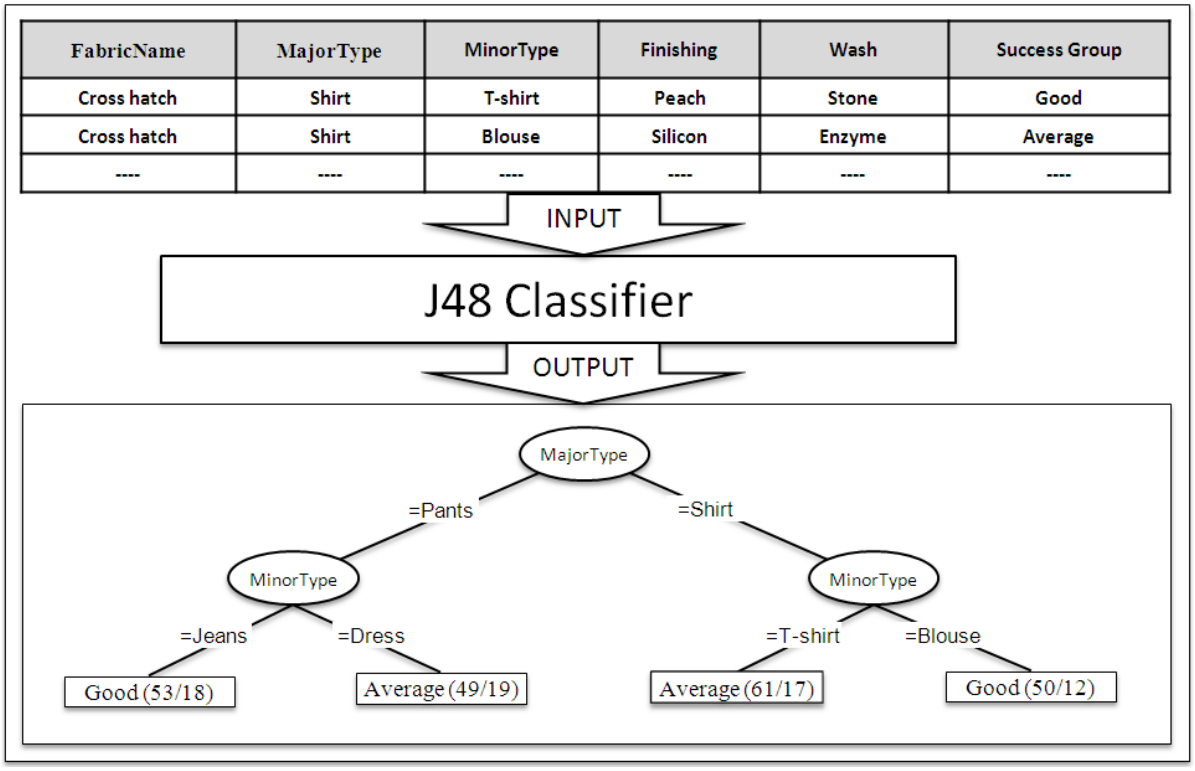


Figure 4.6: Decision tree

Now before to describe the second step it is important to outline what are the possible outcomes of the decision tree and what we drive from them. As a matter of fact, output decision tree can be either empty (no tree is generated) or it contains multiple branches (e.g. shown in Figure 4.6, lower part).

Within PAPE Evaluation, the APE framework recognizes the output of the classifier into two categories:

- An empty decision tree: No discriminating attribute is determined within the data to classify the success levels i.e. no certain conditions are observed where process is being

performed differently by different employees. In this situation, the framework proceeds for simple evaluation using the OAPE method (see Figure 4.5).

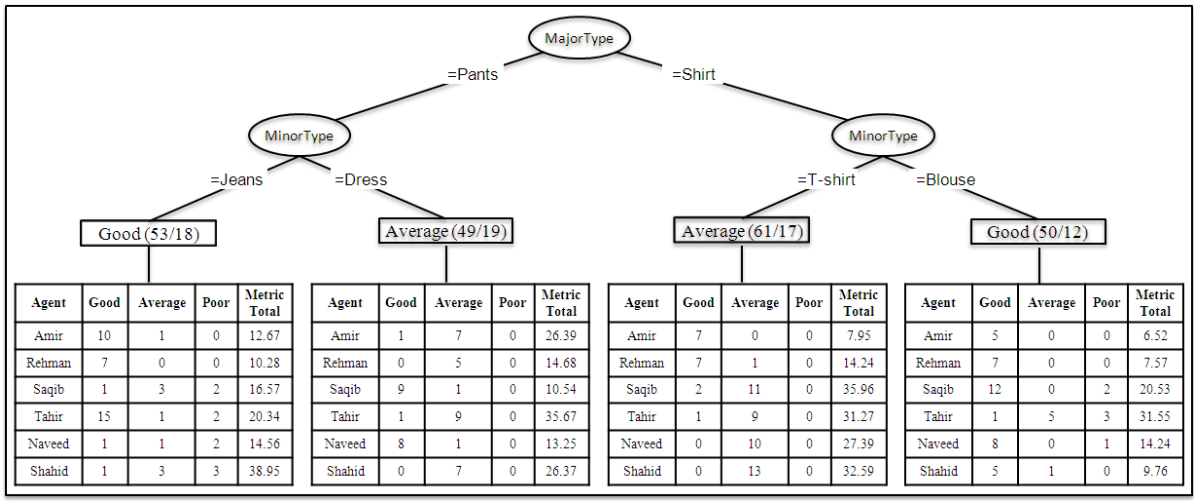
- Multiple branches decision tree: It means process is being performed differently by different employees. It also means that the process is being performed differently by different employees under different conditions. Although, from the tree it can be easily determined that under what certain condition process is being performed how well (which success group/level) because branches of the tree represent these conditions whereas leaves represent success groups. However, performers' information is not available within the tree. It is incorporated through the post-processing step of our PAPE Method.

During the second step (PAPE Post-processing), decision tree is post-processed to incorporate agent data. Basically application data, success group, goal metric and agent data (part of organizational data) are used to perform this post-processing. In this post-processing, the application data elements are the dominant information in traversing the decision tree from the root down to its leaves whereas agent data, success group, goal metric are used in maintaining Agent Intelligence Matrix.

An agent intelligence matrix is a two dimension array whose rows represent agents' data and columns represent success groups (Figure 4.7 lover part). An additional column "MetricTotal" is also added with the agent intelligence matrix that is used to accumulate goal metric values for each agent separately. Before to proceeds for actual post-processing, an agent intelligence matrix is created and is attached to each leaf of the tree. Then, the PAPE post-processing is proceeded to update these agent intelligence matrices.

For each instance of application data, the tree is traversed and whenever a leaf is reached, the agent intelligence matrix is being updated – the number of times each success group has been reached is incremented and also the value of MetricTotal is being updated for the particular agent involved in the execution (Figure 4.7).

The agent intelligence matrix is then used to answer the aforementioned basic question "who is performing how well and under what conditions". This information is summed up in the agent competency profile that first contains information about the "conditions" and second performance information for each agent ever involved in a process running under these conditions. Please note that learned "condition" is referred as "pattern" in data mining terminology.



Agent	Good	Average	Poor	Metric Total
Amir	10	1	0	12.67
Rehman	7	0	0	10.28
Saqib	1	3	2	16.57
Tahir	15	1	2	20.34
Naveed	1	1	2	14.56
Shahid	1	3	3	38.95

Agent	Good	Average	Poor	Metric Total
Amir	1	7	0	26.39
Rehman	0	5	0	14.68
Saqib	9	1	0	10.54
Tahir	1	9	0	35.67
Naveed	8	1	0	13.25
Shahid	0	7	0	26.37

Agent	Good	Average	Poor	Metric Total
Amir	7	0	0	7.95
Rehman	7	1	0	14.24
Saqib	2	11	0	35.96
Tahir	1	9	0	31.27
Naveed	0	10	0	27.39
Shahid	0	13	0	32.59

Agent	Good	Average	Poor	Metric Total
Amir	5	0	0	6.52
Rehman	7	0	0	7.57
Saqib	12	0	2	20.53
Tahir	1	5	3	31.55
Naveed	8	0	1	14.24
Shahid	5	1	0	9.76

Figure 4.7: Integrated data structure

In the third step (PAPE Profiles Learner), Agent Competency Profiles are learned for each pattern observed in the decision tree. These are described in terms of Agent data, Goal Metric and relative success achievement levels among different success groups to precisely describe agents' success of business process performance. In the profile, value of Goal Metric indicates accumulative agents' success of business process performance and is computed from MetricTotal divided by the numbers of process instances executed by the particular agent. For example for the rightmost branch of the tree, Amir' accumulative success of business process performance is 6.52/5 = 1.30 (Goal Metric) and that is used in updating the organizational database. Similarly, his relative success achievement levels among different success groups are also defined in terms of <Good, 5><Average, 0><Poor, 0> that is mostly used for visualization and award distribution e.g. if an employee achieve all Goods. An example of such competency profiles for the rightmost branch of the tree is given below:

Pattern: (MajorType=Shirt AND MinorType=Blouse)

Agent Competency Profiles:

<Agent, Amir><Goal Metric, 1.30><Good, 5><Average, 0><Poor, 0>

<Agent, Rehman><Goal Metric, 1.08>< Good, 7><Average, 0><Poor, 0>

<Agent, Saqib><Goal Metric, 1.47><Good, 12><Average, 0><Poor, 2>

<Agent, Tahir><Goal Metric, 3.51><Good, 1><Average, 5><Poor, 3>

<Agent, Naveed><Goal Metric, 1.58><Good, 8><Average, 0><Poor, 1>

<Agent, Shahid><Goal Metric, 1.63><Good, 5><Average, 1><Poor, 0>

Now these profiles help to answer our question who (Agent, Amir) is performing how well (Goal Metric, 1.30) and under what certain conditions (MajorType=Shirt AND MinorType=Blouse). Similarly, It can be easily seen from the above profile that the agents

called Amir, Rehman, Saqib, and Naveed are performing well while Tahir's performance is only on average if a blouse is being produced (for pattern: MajorType=Shirt AND MinorType=Blouse) whereas the performance of Tahir is on Average because Goal Metric = 3.51.

Similarly, for each observed pattern in the tree different observed patterns along with their associated agent competency profiles are learned by the PAPE Profile Learner. Thus, for each pattern occurring in the decision tree such a profile is computed and is useful not only to identify who performs how well under what certain conditions but also for optimal assignments.

On the other hand as shown in Figure 4.4, in case if a decision tree is empty (i.e. single node) then the **OAPE method** is used because j48 could not observe certain conditions where process is being performed differently by different employees. On the other hand (Figure 4.4), in case there are no application data elements defined in the DataDefinition (Figure 4.5) then the OAPE method is of choice since there is no application data available for computing different scenarios (patterns) of agent performance. Therefore, the OAPE method is used directly for all those processes that do not have any application data elements mentioned in their context definition (Figure 4.4, left path).

The OAPE method uses only the Agent data, Success Groups and Goal Metric to learn the agent competency profiles. It simply computes goal metric and then determine the result by looking up in which success group the value of the goal metric resides. Again, the competency profiles are computed in a similar style as done by the PAPE method – but without any patterns. The following example depicts competency profiles learned by the OAPE method:

<Agent, Amir><Goal Metric, 1.73><Good, 23><Average, 8><Poor, 0>
<Agent, Rehman><Goal Metric, 1.69>< Good, 21><Average, 6><Poor, 0>
<Agent, Saqib><Goal Metric, 1.94><Good, 24><Average, 15><Poor, 4>
<Agent, Tahir><Goal Metric, 2.93><Good, 18><Average, 24><Poor, 5>

Above profiles simply determine who performs how well. As it can be seen that Amir' performance is Good (Goal Metric = 1.73) whereas Tahir performance is on the Average (Goal Metric = 2.93).

The **CAPE method** is used for computing agent competency profiles in case there is only one application data element defined in DataDefinition within goal context definition (see Figure 4.5). An example of such a process is the weaving process that has context values e.g. Naylon, Dainer, and Romex etc. Here, different values of an application data element constitute different contexts depending upon their values.

The objective is to determine whether agents are performing differently for each context value. Within the CAPE method, this task is performed by its component named CAPE

Evaluation. It is necessary to determine whether agents are performing differently for each context value because each different value of application data element forms different process contexts and as a result agents may also have dissimilar competencies specific to that value.

To perform such evaluation, the CAPE method learns agent competency profiles following two different notions: first, profiles in-general likewise the OAPE method; second, context-specific profiles and agent competency profiles are learned separately that are specific to each context value. One may also note that here the context value specifies a simple condition defined in terms of single data elements and its specific context value e.g. FiberType = Tencel. An example of such agents' competency profiles leaned through the CAPE method is defined as following:

In-General Profiles:

<Agent, Amir><Goal Metric, 1.88><Good, 37><Average, 15><Poor, 5>
<Agent, Rehman><Goal Metric, 0.69>< Good, 24><Average, 3><Poor, 0>
<Agent, Saqib><Goal Metric, 3.4><Good, 12><Average, 41><Poor, 3>
<Agent, Tahir><Goal Metric, 2.35><Good, 11><Average, 28><Poor, 5>

Context-Specific Profile: for Context (FiberType = Tencel)

<Agent, Amir><Goal Metric, 1.39><Good, 12><Average, 10><Poor, 2>
<Agent, Rehman><Goal Metric, 1.83>< Good, 7><Average, 1><Poor, 0>
<Agent, Saqib><Goal Metric, 2.94><Good, 3><Average, 19><Poor, 1>
<Agent, Tahir><Goal Metric, 1.54><Good, 7><Average, 2><Poor, 1>

From the above profiles it can be easily seen for FiberType = Tencel, Rehman performance is Good (i.e. Goal Metric = 0.69) whereas Saqib performance is on the Average (Goal Metric, 3.4). These profiles help in determining who is performing a certain process how well under what certain condition.

Please note that similar context specific profiles are learned for each context value like Naylon, Dainer, and Romex etc., for example for the weaving process. The CAPE Evaluation determines "what are the contexts" where agents are performing dissimilarly i.e. having predominant agent competency profiles. For this purpose, it uses the Euclidean Distance [Elen09] function to compute intra-agents-competency distance. This intra-agents-competency distance is computed firstly, using agents' in-general profiles; and secondly, using agents' context-specific profiles (separately for each context e.g. specific to Tencel, Naylon, Dainer and Romex etc.).

Predominant agents' expertise are observed for those contexts whose intra-agents-competencies distance is greater than generic intra-agent-competencies distance. Such contexts are determined. These are the contexts where agents have predominant expertise. These contexts demand for the adoption of such context specific competency profiles therefore, the CAPE Profiles Learner computes agents' competency profiles as well as detailed agents' competency profiles specific to them.

4.3.4 Feedback

During the feedback phase, the agent competency profiles contained in the organizational database are updated. Thus, a WfMS can take decisions basing on the "current" competency of each agent and not on that one which was set up "once", maybe a long time ago. Of course, assignment policies and organizational database structures need to be adapted in order to be able to apply our methodology. However, we do not consider this as a major obstacle.

One may notice that changes to the organizational database (i.e. changes to competency profiles) do not overwrite any data within the database. Thus, it allows for retrieving a history from the organizational database which can be leveraged in evaluating the success of certain training methods and courses (e.g. did the performance increase after an agent visited a special training or not). However, a WfMS uses usually the latest version of a competency profile only.

The organizational database, besides the normal organizational structure, needs to include information about the competency of each agent for certain scenarios. For instance, in case there are many factors that influence the performance of a certain agent, these factors need to be shown in the database. In our example, the organizational database contains a table with agents and a table with roles. An additional link table named "Play" identifies, which agent plays which role. In addition to this quite usual structure for an organizational database, our example relation "Play" was extended to include competency values for each agent, depending on the role he or she plays (Figure 4.8).

Play

Agent	Role	--	Competency
Amir	Cutters	--	1.30
Rehman	Cutters	--	2.08
Saqib	Cutters	--	1.47
Tahir	Cutters	--	3.51
Naila	Attacher	--	1.57
Arif	Trimmers	--	3.91
--	--	--	--

Figure 4.8: Competency driven organizational relation Play

Assignment policies need to be changed such that they also include the newly created attributes of the database, this is shown in Figure 4.9. The assignment policy depicted in the figure selects only those cutters that have competency higher than 2.0. If this policy is used during the assignment of agents within a WfMS, only those agents are selected to be candidates for executing a process which were most successful in the past (under the same conditions).

```
ASSIGNMENT_POLICY
    WORKFLOW                ProductionProcess.Cutting
    OPERATION               Execute()
    AGENT_SELECTION         Agents Play Cutters
                        AND Competency < 2.0
    RUNTIME_CONSTRAINTS     WithinDays(2)
    SYNCHRONIZATION         1
    NOTIFICATION            Worklist
END_ASSIGNMENT_POLICY
```

Figure 4.9: Competency driven assignment policy

The update of the organizational database and the assignment policies for each process can be performed either automatically or semi-automatically.

- Automatic updates are possible if the competency profiles are simple; such simple profiles are constructed by the OAPE method. Since there are no data items that influence the competency analysis, only the competency values need to be updated. The assignment policy refers to a specific competency value only and does not need to

reflect various factors. An update of the organizational database can then be performed by executing a single SQL statement.

- Semi-automatic updates should be performed in case PAPE or CAPE was applied as performance evaluation mechanism. One reason is that updating the assignment policy is not so easy for a system (it might lead to long and hard to comprehend assignment policies). Besides that, also the number of influencing factors is crucial for the size of the resulting database. For instance, if there are many different factors and if a competency value is to be stored for each factor, the number of columns within the exemplary "Play" table explodes. Therefore, it is more feasible to use the computed competency values for splitting up the "Cutter" role depending on the factors e.g. into "BlouseCutters", "DressPantsCutters", "T-shirtCutters" and "JeansPantsCutters" (i.e. role specialization). Then, agents which are "Cutters" but are not good for cutting fabric for blouses, are not selected for such jobs, since, they are not playing this specific role. Since introducing new hierarchies for existing roles need major updates which most likely will also have side-effects (e.g. the process models could be updated as well). This kind of change should not be performed automatically – at least not without any supervision. Figure 4.10 shows an example of an assignment policy which was updated in order to reflect the new hierarchy in the "Cutter" role.

```
ASSIGNMENT_POLICY
        WORKFLOW                ProductionProcess.Cutting
        OPERATION               Execute()
        AGENT_SELECTION
                IF (MajorType='Shirt' AND MinorType='Blouse')
                        THEN {Agent Play BlouseCutters AND Competency Value < 2.0}
                IF (MajorType='Shirt' AND MinorType='T-shirt')
                        THEN {Agent Play T-shirtCutters AND Competency Value < 2.0}
                IF (MajorType='Pants' AND Stuf='Dress')
                        THEN {Agent Play DressPantsCutters AND Competency Value < 2.0}
                IF (MajorType='Pants' AND MinorType='Jeans')
                        THEN Agent Play JeansPantsCutters AND Competency Value < 2.0}
                ELSE {Agent Play Cutters AND Competency Value < 2.0}
        RUNTIME_CONSTRAINTS     WithinDays(2)
        SYNCHRONIZATION         1
        NOTIFICATION            Worklist
  END_ASSIGNMENT_POLICY
```

Figure 4.10: Assignment Policy learned through PAPE method

4.3.5 Visualization

Within the Visualization phase, agent competency profiles are presented in different representations such as pie graphs, tables and 3D scattered graphs. Figure 4.11 shows the overall performance of the cutting process (upper part) and detailed agent competency profiles (lower part) learned using the OAPE for the Kohinoor Apparel Unit. This pi chart shows the detailed agent competency profiles in terms of success groups e.g. Good, Average and Poor groups are marked through different quadrant e.g. Green Blue and Red respectively.

Upper part of the graphs shows collective employees' performance that is useful for higher management and it is computed by simply accumulating employees' performance. However, lower part of the graphs shows profiles that are specific to each employee individually.

Similarly multiple graphs along with their pattern or context conditions are displayed for competency profiles that are learned by the PAPE or the CAPE method.

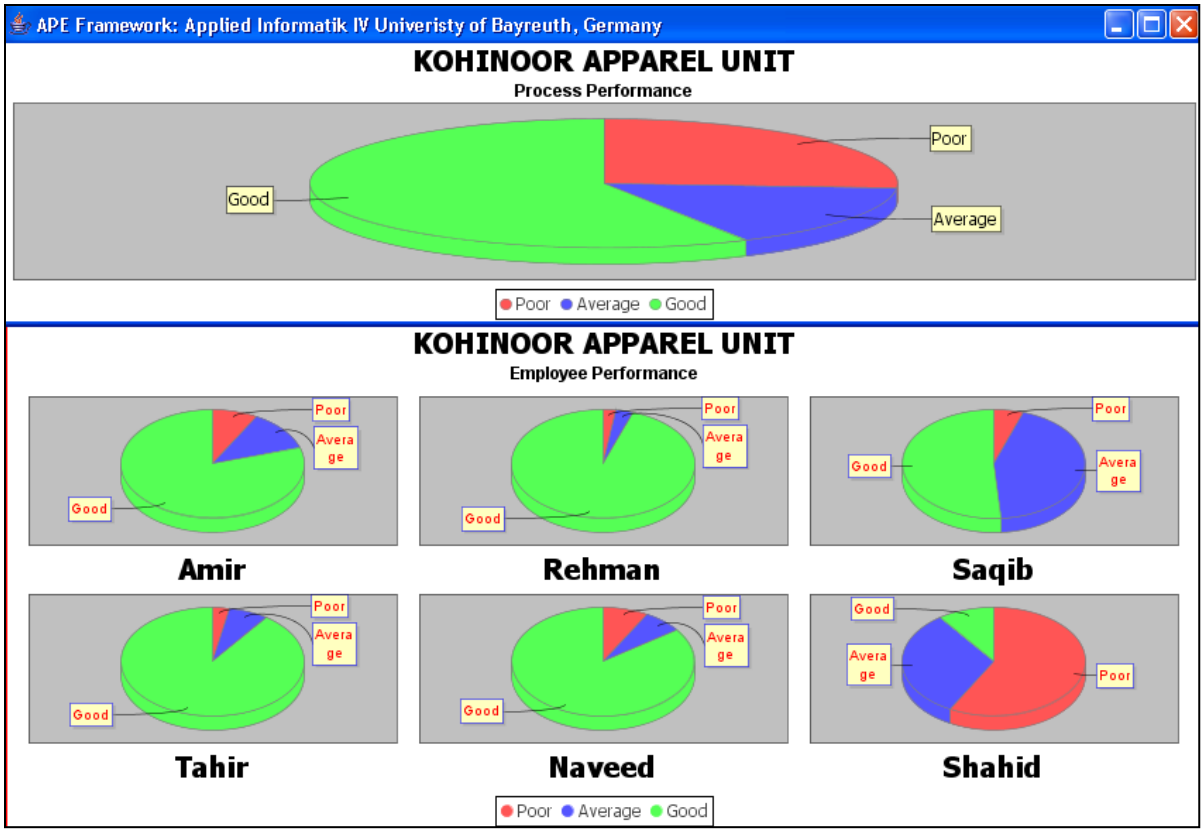


Figure 4.11: Performance graph

4.4 Experiments and Experiences

We exemplified the textile industry for its process improvement effort particularly for improving agent assignment strategies i.e. to allocate successful agents instead of merely eligible agents. We analyzed its three main production units, namely Apparel, Dyeing and Weaving. Each production unit has a list of processes that are performed to complete its production (Table 4.3).

Within a period of probably 25 months (from March 2008 to March 2010) we analyzed their 21 processes. Processes within these production units were performed by more than 730 employees with the total of 29052 process instances completed, averaging 91 completed activities per day. As the statistic in Table 4.3 indicates, quick and correct decision "who should execute a certain process" is crucial for the global process and therefore especially important for companies to compete in a highly dynamic and global market with others. Also, it became obvious that a manual assignment of agents, is not feasible since, (1) it is very time-consuming to determine successful agents more or less "manually" and (2) the quality of such a manual assignment heavily depends on the experience and analytical skills of the person who performs

it since a supervisor usually cannot perform a deep analysis of data as opposed to mining algorithms.

Division Name	Process Name	Employees Involved	Process Instances	Time Period	
				From	To
Apparel Unit	Marker Making	20-28	1584	Mar 2008	Mar 2010
	Cutting	20-29	1386	June 2008	Mar 2010
	Sewing	82-97	1386	June 2008	Mar 2010
	Washing	25-35	792	Dec 2008	Dec 2009
	Attachment	25-40	792	Dec 2008	Dec 2009
	Pressing	40-50	792	Dec 2008	Dec 2009
Dyeing Unit	Washing	10-16	930	Sep 2008	Mar 2010
	Singing	10-16	930	Sep 2008	Mar 2010
	Rotation	10-16	930	Sep 2008	Mar 2010
	Desizing	10-16	930	Sep 2008	Mar 2010
	Beaching	10-16	930	Sep 2008	Mar 2010
	Mercerizing	10-16	930	Sep 2008	Mar 2010
	Peaching	10-16	930	Sep 2008	Mar 2010
	Dyeing	10-16	930	Sep 2008	Mar 2010
	Thermosol	10-16	930	Sep 2008	Mar 2010
	Washing	10-16	930	Sep 2008	Mar 2010
	Stantoring	10-16	930	Sep 2008	Mar 2010
	Sanforizing	10-16	930	Sep 2008	Mar 2010
Weaving Unit	Warping	80-120	3168	Dec 2008	Mar 2010
	Sizing	80-120	3168	Dec 2008	Mar 2010
	Weaving	80-120	3168	Dec 2008	Mar 2010

Table 4.3: Experimental statistics of production units

Figure 4.12 shows the simulation of our expected performance improvement results for the **Cutting** process. Our expectations are based on the current "training and motivation impact factor" of the apparel training center towards performance improvement i.e. 42% on average from 2008 to 2010. We believe that a gradual improvement can be reached due to two reasons: first, only those agents get assigned to new process instances who have a high expectation to be successful and, second, less qualified agents have been sent to training in order to increase their success rate and are therefore expected to produce better results in the future. This causes the overall number of agents with good performance to increase gradually.

Each division has its own in-house training facility with specific tailored courses. The strategy of the company therefore aims at motivating and keeping their highly professional staff. We believe that the provision of training and motivation of employees has an impact on the development of the performance. One can see that the APE framework along with its measurement infrastructure allows for supporting the management not only in making

decisions about future assignments, but also to evaluate which training is needed and what effects it can reveal.

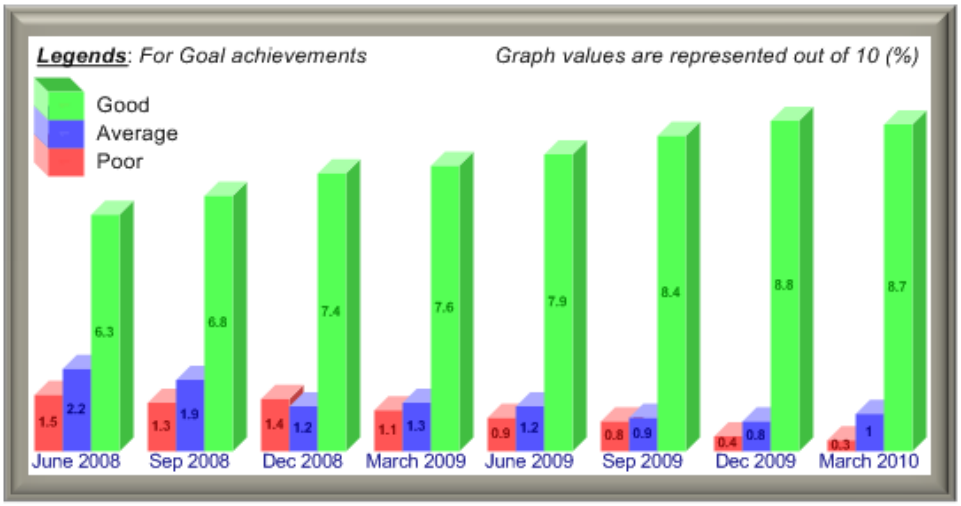


Figure 4.12: Performance evaluation results for cutting process

Consequently, the APE Framework is of utmost importance for both sides – employer and the employees. For employer it is the outcome of more and more process instances that reaches a higher level of quality and for the employees to improve the quality of their work by visiting well-directed training courses and thus are expected to be not only more motivated but also to be more satisfied with the work they are doing and with the employer they are working for.

Our experience shows that introducing the performance evaluation mechanism into assignment strategies, it facilitates the companies to evaluate the operational performance of their business processes inline-with-people (who execute them) in a timely and accurate fashion opposed to traditional organizational performance evaluation e.g. Management By Objective and Balance Score Card (BSC), that are not process centric. Moreover, process centric performance evaluation is not an alternate for organizational performance evaluation, since e.g. BSC focuses more on qualitative aspects of the organization instead of quantitative, analytical, timely and accurate process centric aspects.

We do not claim that performance improvement is directly substantiated by APE Framework; we rather believe that it enables performance improvement based on the outcomes collaborated by training and motivation ventures. We are also planning to implement the framework in other skill intensive environments and to investigate its mutual usefulness with more empirical data in a real industrial setting.

CHAPTER 5

WORKFLOW LIFECYCLE SUPPORT FOR CONTINUOUS RESOURCE IMPROVEMENT

Chapter 5: Workflow Lifecycle Support for Continuous Resource Improvement

In this chapter we present our contribution-3 i.e. workflow lifecycle support for continuous resource improvement. It basically addresses the issue of insufficient guidance for continuous resource improvement within standard process improvement lifecycle since the standard lifecycle explains only the utilization of resource along its different phases without giving any guidance on how to improve these resources. Thus, in this chapter we elaborate a set of basic tasks that needs to be performed along the different phases of a standard workflow lifecycle and justify how these tasks provide sufficient guidance for performing continuous resource improvement.

This chapter is organized into the following five sections. Initially in Section 5.1, we will give a general overview about business process management (BPM) approach to highlight how it promises for continuous process improvement. Then, in Section 5.2 we will present a standard workflow lifecycle that explains how this lifecycle provides methodological skeleton for achieving the promises of BPM approach in realizing continuous process improvement. Subsequently, in Section 5.3, we will explain how the link between resource and process is oddly defined and what its consequences are. Here, we will also propose our process resource success (PRS) conceptual relationship model that enables to sufficiently validate the credibility of the link between resource and process. It also guides what is missing in this link that will ultimately be required for supporting continuous resource improvement. In Section 5.4, we will present our workflow lifecycle that defines a set of different tasks that is needed to be performed in addition to the normal functionalities of a workflow lifecycle within each phase.

5.1 BPM Overview

Business Process Management (BPM) technology is a framework of applications that effectively tracks and orchestrates business processes. It delivers a sophisticated process management approach that focuses on aligning all aspects of an organization according to its needs for bringing their processes, business rules, data, people, and integrated technologies, altogether. Through BPM technology, organizations are enabled to automate their processes that involve information from multiple systems, define business rules that describe sequences or conditions in which these processes are performed, describe the assignment policies to define the responsibilities of people who actually execute or supervise these processes, and also specify data flow between processes as well as the structure of data that is being used within these processes [Broc10].

Advantages of a BPM approach are that it not only promotes business efficiency and effectiveness but it also upholds agility and strives for innovation. It even goes one step further to ensure the viability in times of stress and change through the integration of new technologies. Thus, a BPM approach enables organizations to be more efficient, more effective, more agile, and capable of change through the integration of a new technology than a functionally focused traditional hierarchical management approach [Koh09].

Particularly, a BPM approach supports continuous business process improvement. As a matter of fact, processes tend to evolve over time as the business reacts to market conditions. Consequently, a BPM solution should be easily adaptable to the new conditions and requirements and continue to be a perfect fit for the enterprise. Therefore, to support continuous process improvement BPM technology offers wide range of software tools and components. Generally, these software tools and components comprise process modeling tool, process execution environment, and process monitoring and evaluation components. These software tools and components not only help to build an end-to-end business process of a complex domain but also enable organizations to realize continuous improvement within their processes [Ryan09].

Another important aspect of a BPM approach is its ability to provide a complete lifecycle support for the continuous improvement of business processes. Since, the aim is not simply a one-time improvement for process efficiency rather it is an ongoing improvement in the efficiency of business processes. Such improvement can only be accomplished through a closed-loop continuous process that starts from analyzing business requirements, designing the process models according to requirements, deploying the process models within IT-enabled infrastructure, real time execution of these processes in business environments, and tracking business processes for performance optimization [Card09].

To support continuous improvement of business processes, a BPM approach also enables *close collaboration* between groups of people or communities working around different stages of the lifecycle phases [Card09]. Different groups of people or communities actively participate in performing different tasks within this closed-loop continuous process. Generally, these groups of people or communities include Process Engineers, Process Participants, Application Developers and Data Experts etc. They use different software tools, components and applications to actively participate in performing their associated tasks within this closed-loop continuous process to realize continuous improvement within their business processes. BPM not only pave the way for all participating communities to work in an organized and controlled way but it also supports effective communication between these groups of communities through models which support in implementing and continuously improving efficient, flexible and dynamic processes [Flor08].

A BPM approach also supports a *complete visibility* of what different stages of process improvement lifecycle are, what different process management tools are utilized throughout different stages of process improvement lifecycle, what different groups of people or communities are involved in different stages of process improvement lifecycle, and how different groups of people or communities collaborate to achieve their overall objectives. This complete visibility is described through a standard workflow lifecycle in the following section.

5.2 Standard Workflow Lifecycle

In fact, bringing a new business process to life, modifying or optimizing an existing business process, or continually improving a business process all involve similar set of activities. These activities initially start from the analysis of an existing situation for identification of required improvement, following the designing of different process models based on identified requirements, forwarding towards the implementation of these processes within IT-enabled solutions, delivering the solution for real time execution of these processes in actual business environments, and finally supporting the evaluation of these processes to support continuous improvement. When these activities are performed in a proper order and in an organized way i.e. in a well defined cyclic form, this is called Business Process Management or Workflow Management Lifecycle [Mueh04b]. Generally, BPM lifecycle activities are grouped into five categories usually called phases of a BPM lifecycle. These phases include Analysis, Design, Implementation, Execution, and Evaluation (Figure 5.1).

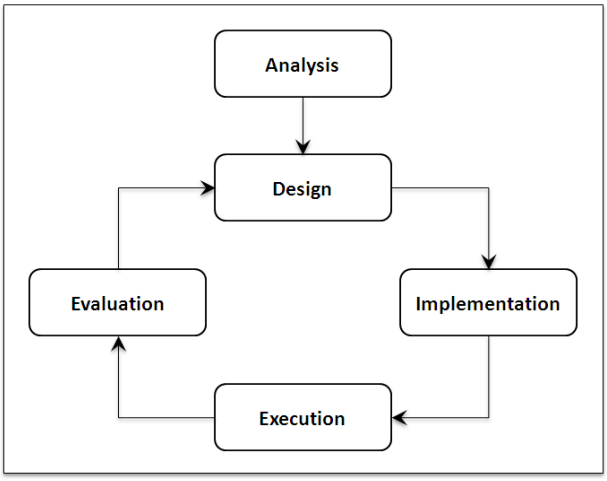


Figure 5.1: Standard workflow lifecycle

5.2.1 Analysis Phase

This phase emphasizes the analysis of the current environment of an organization, identification of their needs and specification of their requirements. Before an organization starts the modeling of its business processes, there is a need to first understand what its business processes are.

A Process Engineer who is responsible for overall process orchestration proceeds for the analysis and interacts with problem domain. Basically, he concerns with the identification of their existing (i.e. as-is) processes as well to-be processes. Initially, a process engineer focuses on a focal process and aims to identify all of its sub-processes. For this purpose, he interacts with process stakeholders including process controller (department head or process supervisor who is responsible for the overall management of process performance) as well as process participants (employees or agents who actually perform the task). These stakeholders guide a process engineer in identifying all of its sub-processes, their order of execution while specifying conditions for their execution.

As a result of this interaction, he develops a process structure that describes all of its sub-processes, their order of execution as well as certain conditions (i.e. business rule) for their executions. However, this process structure is still informal and not yet complete. Some additional information are still required, for example, what application programs or services are used, what data is produced and consumed within these processes, and who is responsible to perform these tasks etc. To acquire these information, process engineer further interacts with stakeholders. Now his focus is more on each sub-process instead of focusing the focal process. For each identified process (i.e. sub-process) within the focal process, data, application

as well as resource (i.e. participants) requirements are identified and yet informally described within the analysis phase.

Within the analysis phase, an important consideration for process engineer is to precede analysis horizontally – instead of vertical analysis. Horizontal analysis initially focuses on a focal process and then determines all of its sub-processes that may span over multiple departments whereas vertical analysis of an organization focuses on each department first, and then identifies all sub-processes running within these departments. Analyzing and designing processes vertically results processes in isolation that also causes tasks duplication, increased cost, delay, and loss of quality [Hari10]. Therefore, BPM recommends for horizontal analysis focusing on focal process and then look processes beyond departmental boundaries i.e. processes lie on the top of these departments – therefore horizontal analysis results optimal process design.

5.2.2 Design Phase

In the previous phase, process engineer has collected Information about organizational processes, their execution order, their need for specific data, required applications or services, and responsibilities for each process participant etc, but all these information are still informal and need to be formalized. This second phase emphasizes the transformation of former informal requirements to a formal specification called process model.

Within this phase, a process engineer uses a process modeling tool and is responsible to develop the required process model. Basically, process modeling tool supports a user friendly environment with pick-and-drop capabilities for designing process models. To describe all process relevant information into a process model, a modeling tool offers a wide range of process modeling notations e.g. flow objects (activity, process, sub-process, task, events and gateways), connecting objects (sequence, messages, and associations), artifacts (data objects, groups, and annotation) and swimlanes (pool and lanes) etc. A process engineer uses language notations to adequately describe the functional, behavioral, informational, operational and organizational aspects of each (sub-)process for developing a comprehensive process model. However, to adequately describe a comprehensive process model, selection of a particular process modeling tool is also very important because for some specific situation a required construct may not be available in a specific process modeling tool.

As a matter of fact, today a large number of modeling tools are available but they differ in the extent to which their constructs highlight different information associated with them. Additionally, these tools are also distinguished based on their expressiveness, flexibility, adoptability and usage complexity. Since, process engineer has very sound background

knowledge, he is responsible for the selection of suitable process modeling tool and then using specific process modeling tool to design a comprehensive process model. Once the comprehensive process model is developed, process engineer re-interact with process stakeholders for model validation. Process stakeholders now check whether the developed model fulfills their intended needs and purpose. They examine whether or not existing (i.e. as-is) as well as to-be processes are considered, processes flow is defined according to business rules, required information are flowing properly, resources are defined accordingly etc. Due to easily readable and understandable modeling notations of today's most of the process modeling tools, it is straightforward for process stakeholders to interpret and validate the developed process model.

5.2.3 Implementation Phase

This phase emphasizes the transformation of a process model to an executable process model. Main tasks that are performed in this phase include development and integration of required services to fulfill their operational needs for processes, design and deployment of organizational database, population of organizational resources within organizational database, development and management of required information systems to meet the informational needs. Key players within this phase are the process engineer, data experts and application developers. Within this phase, a process engineer interacts with developers and data experts to fulfill the operational and informational need of all the involved processes. Developers are responsible to develop applications or services that are required within these processes [Card09a]. Likewise, data experts are responsible for the development and overall management of information systems to meet the informational need of all the processes.

Initially, a process engineer proceeds for the transformation of process model to an executable code e.g. a BPMN process model is transformed into executable representation in BPEL. This transformation can be made manually or automatically, depending upon the selected process modeling tool. In fact, automatic transformation is preferable because it ensures the consistency between process model and executable model [Hari10]. Moreover, automatic transformation also reduces efforts as it does not require developing model from scratch. Finally, processes within the executable process model also need to be connected with the required applications or services.

Developers are responsible to provide support to fulfill the operational requirements of executable business processes. Indeed, required applications or services can be developed either from scratch, exposed from the existing systems, or even outsourced. In theory, it makes sense for developers to first develop all services only then these services can be composed into

processes. However, in the real world this is often not the case because developers probably do not have the luxury of time to develop the services first and only then start the processes [Hari10]. Even if they have enough time, it would be difficult to know which service will be required by which process. Therefore, it is appropriate that process engineer and developers should work in parallel.

Similarly, processes within the executable process model also used information systems e.g. databases, directories, repositories etc. Data experts are responsible to fulfill the informational needs of all the involved processes. They develop, deploy, and integrate required information systems for their processes within this phase. In addition to the informational need of processes, data experts are also responsible for the design and development of an organizational database that constitutes the society of process participants. They also populate the organizational elements and organizational relationship defined within the organizational database. This organizational database basically provides the foundation to a WfMS for the allocation of appropriate resources to their processes as defined through their assignment policy.

Thus, the ultimate objective of this phase is to make the process model ready for execution in all aspects however, processes are not actually executed in this phase.

5.2.4 Execution Phase

This is the phase in which process participants actually participate to execute their processes. A WfMS supports process orientation through the automated coordination of processes, data, applications and process participants. This orientation and coordination is based on the formal definition of the processes defined within the process model during process design phase.

In this phase, a workflow execution server creates workflow instances according to the formal definition of processes defined in process model. A Workflow execution engine also coordinates control flow by regulating the activation and execution of processes depending on the state of the overall process. Also, the activities within the workflow instance can have different states i.e. Created, Ready, Reserved, In-progress, Failed, Error or Completed. It subsequently manages the transition from one state to another state.

It also coordinates the data flow by transferring relevant data objects between processes, or between the workflow system and invoked applications or services. Moreover, the coordination of organizational resources takes place by the workflow management system that regulates the identification pending activities and notification of process participants about their pending activities. A workflow execution engine also manages the overall integrity

of workflow instances for example, if a process deadline is exceeded then the escalation procedure is triggered.

During the execution of process instances, a WfMS also supports continuous monitoring of running processes. During process execution, process monitoring deals for the analysis of running process instances. It enables process controllers to manipulate the behavior of current process instances and then react to the problems that arise during process enactment i.e. the length of work queues, the idle time of resources or the waiting time of pending activities.

All in all, a WfMS provides a comprehensive management support for the execution of business processes in a real time business environment and process participants are actually involved in performing their assigned tasks to achieve their overall objectives.

5.2.5 Evaluation Phase

Process evaluation phase completes the business process management cycle. During this phase, the execution of process instances is evaluated from an ex-post assessment perspective and the results from this evaluation then serve as the basis for process improvement.

To support evaluation, a workflow management system uses an audit trail because it holds a detailed and precise collection of data about operative process enactment. It contains detailed information about the behavior of the workflow system and the execution of workflow instances at run time. During the execution of business processes, workflow execution engine records detailed information about different events occurring during the execution of process instances. Traces of each instance are written to audit trail that records the behavior of each instance. This audit trail represents a detailed and precise collection of data for process evaluation. Therefore, it can be used for any specific evaluation purpose.

In this phase, a process controller uses workflow-based evaluation tools for the ex-post evaluation of process instances. In fact, a process evaluation tool focuses entirely on information contained in the audit trail and performs evaluation against some specific aspects. For example, different tools can use this audit trail information for the evaluation of some recovery functions, revisions, analysis and reengineering purposes. Similarly using process evaluation tool, adjustments to the process structure or its capacity adjustments for the identification of workflow participants (i.e. to reroute an activity to the performer of a previous activity) might be tested.

Within the evaluation phase, a process controller makes post-executional analysis of business processes and then uses the results of evaluation for future process improvements. Using an even log, AS-Is processes (existing processes) are evaluated to understand the current

situation of business processes. In case some discrepancies are observed between plan values and target values, the deficiencies in the business processes are investigated. Root causes of the problems are identified. The identified deficiencies are tried to be avoided in further executions. Thus, in this way processes are in a state of continuous improvement

5.3 Missing Link between Resource and Process

Since the modeling of business processes is well studied, the "link" between the organizational resource and the process is less well understood, and the current developments in the web services choreography area have mostly neglected the organizational aspect of workflow applications [Mueh04a].

Traditionally, during the design phase of a workflow application a process engineer designs both the process model that describes processes to be automated and the organization model that defines the society of organizational resources who carry out these processes. Usually, resources and workflow activities are linked simply through the role concept which is insufficient, especially for continuous resource improvement. Since, the role concept simply defines the functionality based resource class which is entirely used only in identifying a group of people having similar capabilities for authorization purpose and thus it cannot guide for checking the credibility of their link.

For assigning tasks in competitive business environments, merely use of role concept is not sufficient, especially in evaluating the resources' credibility for their success of business process performance. Since, without checking the credibility of the link, all the employees belonging to that role remain enacting the process even if some of them has poor process performance. Thus, as a result performance of a business process drags down.

Important questions in this scenario are: How to sufficiently fill the missing link between resource and process? How to properly manage credibility of the link? To achieve this objective, there is a need to first identify what is the missing ingredient of the link and how this missing ingredient can fill the gap towards managing the credibility of this link. For this purpose, we have developed a Process Resource Success (PRS) conceptual relationship model that helps in achieving this objective to fulfill the task assignment requirements of competitive business environment. Further, it not only allows for sufficiently defining the rationale of the link but also helps for developing a complete infrastructure and the methodology to realize continuous resource improvement.

Our PRS conceptual relationship model is shown in Figure 5.2 and it comprises three concepts and their interrelationships. In the model, a concept is represented with rectangle and name of the concept is described inside it. These concepts include a Process, a Resource

and a Goal. The interrelationships between these three concepts include Assign, Achieve and Demonstrate Business Success. These interrelationships among concepts are also shown by their linking arrow line. Fundamentals of these concepts and their interrelationships are based on the followings notions:

- Processes are "assigned" to organizational resources in order to execute them (link-1).
- Resources are responsible to "achieve" the goal (link-2).
- Achievement of a goal "demonstrates business success" thus validates the credibility of the link between resource and process (link-3).

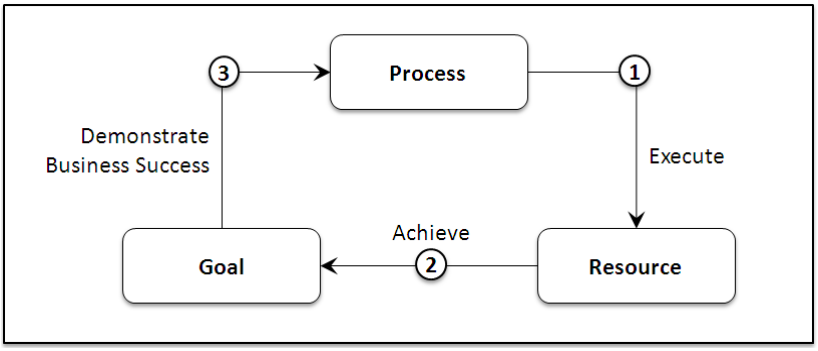


Figure 5.2: Process resource success conceptual relationship model

In our PRS conceptual relationship model, a goal concept is the fundamental element that is missing within the link between resource and process. Insertion of a goal between resource and process basically enables to create a closed-loop continuous evaluation mechanism. Based on goal achievement, success of business process performance can be validated thus it helps in validating the link credibility. It not only allows for the evaluation of resource towards success of business process performance but it also enables them for continuous improvement. As a matter of fact, this PRS relationship model gives only the conceptual foundation to perform this validation but it does not perform actual validation itself.

However, to perform this validation there is need to first define goals within the process model (we have defined it in Chapter 3). Furthermore, there is also need to introduce performance evaluation mechanism to evaluate goal achievement within the process layer (Chapter 4).

In fact, defining a goal within a process model and also providing a performance evaluation mechanism for goal evaluation and feedback is not at all enough to support continuous resource improvement. Rather, there is a need to define a precise and a comprehensive "methodology" that can explain the overall procedure of continuous resource

improvement along with different phases of a workflow lifecycle by addressing the important concerns such as:

- In addition to the normal functionalities of standard workflow lifecycle, what are the additional tasks that need to be performed in each phase?
- For each identified addition task, what are the different stake holders who are involved in performing these additional tasks?
- How different tools are used in performed different identified tasks?
- How additional tasks are distributed along different phases of a standard workflow lifecycle?

We call this methodology a workflow lifecycle support for continuous resource improvement and present it in the next section.

5.4 Workflow Lifecycle for Continuous Resource Improvement

Here, we explain our workflow lifecycle support for continuous resource improvement. We will explicitly focus on how the inclusion of a goal concept in process recipe is integrated into the standard workflow lifecycle. We will also show that continuous resource management means to consider goal modeling not as an add-on to the normal lifecycle but as an integral part of it thus influencing every phase of the lifecycle.

Since, goal is the central concept for our continuous resource improvement approach therefore we will highlight what are different stake holders that concern for overall goal management. A comprehensive view of different stake holders and their association with goal concept is shown in Figure 5.3. Main stake holders include Process Controller, Resources, Process Engineer and Data Expert. Their association with the goal concept for developing the overall methodology is described as follows:

- For proper resource management, goals are defined in competitive business environment and a process controller is responsible to “define” goals.
- For a process modeling tool, a goal is used as a “construct” and a process engineer uses a modeling tool to incorporate this construct into a process model.
- For performance evaluation mechanism, a goal is used as a “yardstick” to evaluate employees’ performance and a process controller uses a performance evaluation mechanism to evaluate employees’ performance.

- For the evaluation of employees' competencies against a goal, an operational database provides "data support" and a data expert is responsible for the management of an operational database.
- Organizational database provides basis for storing employees' "competency" profiles and a data expert is responsible for the overall management of organizational database.
- Resources are responsible to "achieve" the goal and achievement of a goal represents success of business process performance.

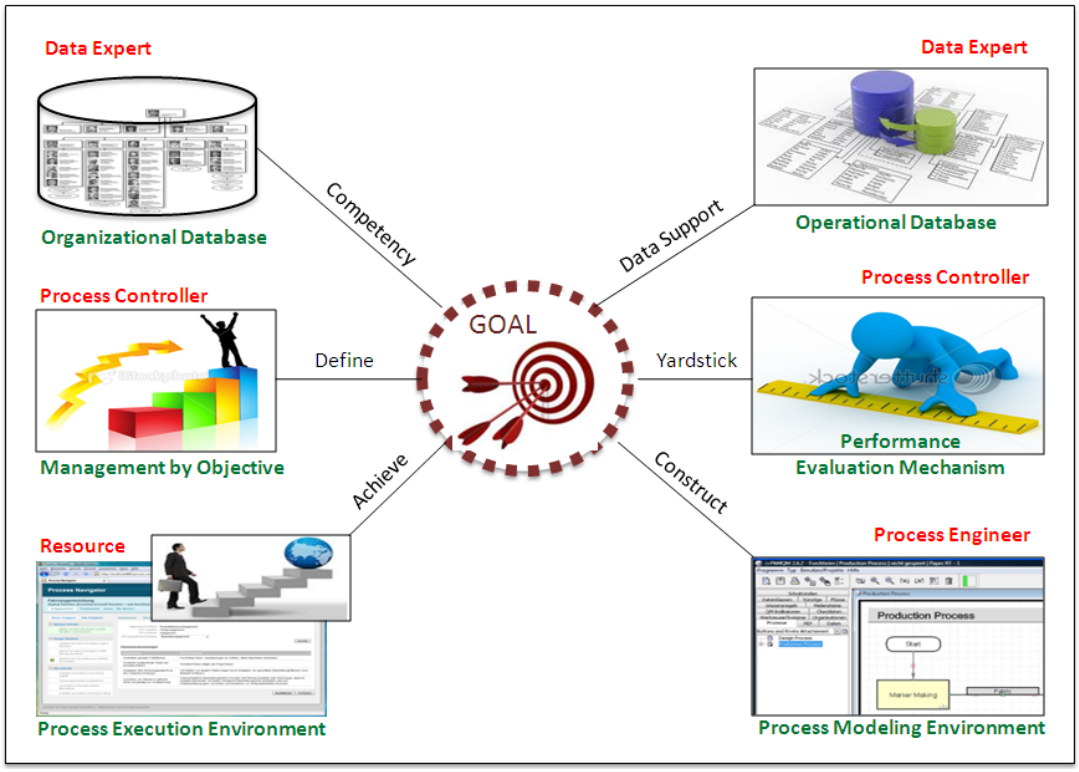


Figure 5.3: Goal stakeholders

5.4.1 Analysis Phase

In addition to the normal functionalities usually performed within the analysis phase of standard workflow lifecycle (Section 5.2), an additional functionality is also required in order to support continuous resource improvement. This additional functionality is the "analysis of the goals" that are usually assigned to employees in competitive business environments. Analysis of goals is important because goals not only motivate employees to concentrate on targets and focus on better process performance but also help them in improving their skills. Thus, in this

phase a process engineer is also asked to identify goals which should be reached and that will be later on used within the performance evaluation.

Specifically, analysis of goals needs to be performed in aligned with the normal tasks of the analysis phase. Process engineers, while analyzing the current environment of an organization with the aim to identify their existing processes as well as to-be processes also need to identify goals that are specific to their identified processes. Therefore, while they are interacting with process stake holders to develop an informal process model by focusing the five main perspectives of a process, they also need to get goal relevant information. Thus, as a result an informally sketched process model not only determines different process steps (functional perspective), their order of execution (behavioral perspective), participants who execute them (organizational perspective), tools or service (operational perspective) used to execute them, flow of data within these process steps (informational perspective) but also the description of goals that need to be achieved by their assigned resources.

Since, goals are defined through the mutual consensus of employers and employees (i.e. process controller and process participants) in align with their processes, therefore, a process engineer interacts with these people (employer and employees) to identify goals that are specific to their processes. Moreover, a process engineer is usually not very familiar with their business plans, metrics and company strategies, therefore these people can better assist him within this task. Process engineer identifies what data is used to measure the goal, what are different groups and what are group ranges and the ranks of different group. He also identify different factors what may influence the achievement of goal through the interactions with domain people because they know better these factor especially those employees who are actually involved in performing the tasks. All aspects or situations where performance of a single employee varies are identified and then are defined in terms of different perspectives of a process to constitute goal context definition. All goals relevant information that are identified are still specified informally because these information yet not constitute a concrete measurement and context infrastructure [Tal10].

5.4.2 Design Phase

This phase particularly concerns for the transformation of former informal process model (sketched in the previous phase) to a formal process model. Process engineer chooses a suitable process modeling tool and is responsible for the development of this formal process model. Traditionally, while modeling business process a process engineer focuses the functional, behavioral, informational, operational and organizational perspectives of a process

and then selects a suitable process modeling tool that facilitates appropriate constructs or notations to portray their required information within the model (Section 5.2.3).

To support continuous resource improvement, an additional functionality is required by the process engineer within the design phase. In this phase, process engineer is asked to integrate goal relevant information into the formal design. Basically, goal relevant information are informally collected during analysis phase. It usually comprises what a goal is all about, how it is measured, what are different success levels and how different success levels are distinguished.

In particular to goal modeling, he maps the informal description of a goal to a complete goal structure definition comprising of Goal Metric Definition, Goal Group Definition and Goal Context Definition (Chapter 3). Even most of the parameters of the Measurement Definition and Context Definition are set while modeling goals, some are still open – e.g. *data source* (table) and *goal query* cannot be specified yet. Since this information is related to the execution environment, completing this information is a part of the next phase.

Last but not least, the selection of a process modeling tool is important for the transformation of an informal process model to a formal process model because required construct may not be available prior e.g. goal. Process engineer is responsible to select a suitable process modeling tool that supports goal modeling such as i>PM [Pro05].

5.4.3 Implementation Phase

A process model formally defined in the design phase is still not executable. In this phase this formally defined process model is transformed into an executable process model. Key players within the implementation phase are process engineers, developers and data experts. Within this phase, process engineer is responsible to transform this model to an executable process through the collaboration of developers and data experts.

However to support continuous resource improvement, in addition to normal functionalities (Section 5.2.3) of this phase, some additional tasks also needs to be performed. These tasks include first, the preparation of operational database that is ultimately required to meet the information needed for goals evaluation; second, completion of some parameters such as data source and goal query within the goal definition. Because, goals are formally defined in the design phase, this operational database is referenced through a goal query, however, later to be used while evaluating employees' performance within the evaluation phase, but this operational database needs to be developed and integrated within this implementation phase.

Therefore, a process engineer interacts with a data expert in order to fill the open gaps in the Context and Measurement Definition of goal model. Data of the process log (artifacts of a workflow event log) and the application data store (e.g. fabric FaultTable) belong to two isolated data stores. Data within these data stores need to be integrated and transformed into a consistent operational database. Therefore, a data expert is asked to integrate both sources at least into a common view and create a consistent operational database. Only the operational database is created within this phase. Integration and transformation of event log data into this operation data store is done in the next phase.

5.4.4 Execution Phase

Normally, during the execution phase, individual process instances are derived from the process model and are coordinated by the process automation infrastructure. Process participants are notified about pending activities, and available resources are utilized. Artifacts of the single process instances are stored within the process log and application data stores. Continuous monitoring of running processes and the evaluation of completed processes is also supported.

In addition to the execution and monitoring of process instances, some additional activities need to be performed within this phase to support continuous resource management. It includes the integration of the individual instances of process log from audit trail with the corresponding instances of application data from application data stores and then updating them into the operational database.

In fact during process execution, a process log is stored in the audit trail and application data used within these process instances is stored in the operational data stores. Data expert is responsible to integrate these two data sources and populate them into an operational database. It is not a single short and one time activity, rather an operational database needs to be consistently updated. A Data expert is responsible to consistently update this operational database within this phase before the actual evaluation starts.

5.4.5 Evaluation Phase

The Process Evaluation phase completes the workflow lifecycle. In this phase, single workflow instances are evaluated from an ex-post perspective in order to draw conclusions for process improvements. The results of this evaluation are then used in another round of the lifecycle providing extended information to concerned people.

In particular to continuous resource improvement, a process controller is asked to perform analytical analysis of employees' performance to find out the root causes of poor

performance. For this purpose, he uses a performance evaluation tool i.e. the APE framework (Chapter 4) to perform this analysis. Analytical and quantitative analysis of employees' performance is made. Difference of success demand (i.e. goals) and success supply (i.e. competency profiles) is analyzed to determine employees potential and deficiencies. Results of an analysis are feedback not only to the organizational database but also to the assignment policies (Chapter 4). Thus, the objective of continuous resource improvement is achieved.

Now subsuming the last section, it is appropriate to summarize our continuous resource improvement methodology. We summarize the overview of our workflow lifecycle support for continuous resource improvement in Table 5.1. In this summary table, we highlight different phases of standard workflow lifecycle, workflow stakeholders (group of people or communities), main tasks that are performed by the stakeholder and the tools that are used to perform a specific task. In the table, we mention only additional tasks that are performed specific to continuous resource improvement. However, general overview of the standard workflow lifecycle is described in Section 5.2.

Phases	Stakeholders	Tasks	Tools
Analysis	Process engineer	Goal analysis	Manual
	Process controller & Process participants	Provide goal relevant information	
Design	Process engineer	Selects modeling tool Design goal	Process modeling tool that support goal modeling
	Process controller Process participants	Verify process model	Manual
Implementation	Process engineer	Process compilation Make process model ready for execution	Process compiler Process execution engine
	Developers	Develop application of performance evaluation	Application development tool
	Data expert	Design and development of competency driven organizational database	DBMS
	Data expert	Design and development of operational database	DBMS
Execution	Process participants	Perform their assigned tasks	Workflow application running on workflow execution engine
Evaluation	Process controller	Evaluate employees performance and provides feedback	Employees performance evaluation tool
	Process participants	Get performance feedback	

Table 5.1: Summary of continuous resource improvement methodology

CHAPTER 6

COMPETENCY DRIVEN DYNAMIC RESOURCE MANAGEMENT METHODOLOGY

Chapter 6: Competency Driven Dynamic Resource Management Methodology

In this chapter we present our fourth contribution i.e. the Competency-driven Dynamic Resource Management (CDRM) Methodology. It basically addresses the insufficiency of the work allocation mechanism of WfMSs since currently they do not have the ability to allocate work item to agents on the basis of history of their success of business process performance. We built our CDRM methodology on the notion of our success demand-and-supply model. This success demand-and-supply model basically explicates: "what success level is basically demanded from employees", that is defined through the goal concept; and "what success level is actually being provided by them", that is learned from execution history and is defined through "competency". Thus, in our CDRM Methodology assignment policy is defined **i**n terms of required competency as demanded by the goal definition as an additional constraint of its *Agent Selection* clause. Therefore, when a workflow execution engine resolves the policy it retrieves the list of only those agents who have good history of success of business process performance – thus allowing only successful employees (learned through history) remain enacting the process.

This chapter is organized into five sections. Initially in Section 6.1, we present the concerns of task assignment currently recognized in competitive business environment. Here, we will highlight how history based resource allocation is crucial for success of business process performance. Then in Section 6.2, we explain how history of agents' success of business process performance can be managed in terms of competency and give short background of competency management. Subsequently in Section 6.3, we will initially explain our success demand-and-supply model and then we describe the methodological architecture of our CRDM methodology that is built on the foundation of this success demand-and-supply model. Here, we will also overview different architectural components of our CDRM methodology and will justify their functionality towards achieving the overall objective. At the end, we finally describe our policy resolution mechanism to explain how our competency driven assignment policy is resolved in our process execution environment and how it retrieves the list of only those agents who have good history of success of business process performance – thus allowing only successful employees remain enacting the process.

6.1 Task Assignment Concerns

Workflow management systems are "organizationally aware" i.e. the distribution of work to workers is based on explicit models of an organizational structure and capabilities of workers. Unfortunately, most of the workflow management systems focus on the process dimension (i.e. control flow) and oversimplify the organizational dimension. Today's workflow management systems still offer work item to workers using rather primitive mechanisms. The importance of human resource involvement in the workflow applications has recently been pointed out by C. Moore [Moor02], who has identified the poor design of work assignment strategies as critical issues in workflow projects. Moreover, zur Muehlen [Mueh04a][Mueh04b] has also identified that the task assignment aspect of workflow technology is not well studied because still many WfMSs do not even support resource modeling (e.g. Kepler[Alt04], Taverna[Hul06], Triana [Tay06]), while others support only a role based distribution of work (e.g. OpenWFE [Ope11]).

For the successful application of workflow technology, it is crucial that there should be a good fit between the work practice and the task allocation mechanisms offered by the workflow management systems. In fact, employees' work history plays an important role because forthcoming tasks are assigned to workers usually on the basis of previous history of workers' work performance. Today's workflow management systems do not have the ability to allocate work items to resources on the basis of their previous history. Despite, history based resource allocation has recently been recognized as workflow resource pattern (History Based Allocation Pattern 9: WRP—HBA—9) [Russ07].

The role of employees' work history is crucial particularly in employees' performance optimization. History preserves their experiences about their technical knowledge and skills that are being utilized in execution of their processes along with their results and outcomes. Normally, experience gain during the executions of daily tasks is easily lost. However, dynamic management and proper utilization of their work history results in improved operational process effectiveness, efficiency and reliability. Since through its proper utilization, it is possible to reduce the likelihood of human errors, increase productivity and quality, and the risk of work related disorders.

Employees' work history helps not only in deciding either to allocate or revoke work items but it also helps an organization towards achieving continuous improvement of its workers' capabilities [Bus95]. Therefore, if employees work history is proactively integrated and properly managed throughout the process management lifecycle – from analysis, design, implementation, execution and evaluation – then the people within the processes will respond

in a proactive manner rather than simply reacting to problems when they become out of range to manage.

To utilize work history it is also important to first decide: On which nominated factor history criteria should be used when determining who to distribute a specific work item? These criteria may include factors such as the worker that least recently executed the task, has executed it successfully the most times, has the shortest task turnaround time etc. Instead of having any static and fixed criteria, we rather believe in the organization's independence in defining these criteria that it normally consider and practice in determining its employees' success of business process performance. Therefore, we define goal in the process model for this purpose (Chapter 3).

Now, a very basic question arises: How to manage and utilize employees work history that is based on the criteria defined through a goal? Quite simple, employees' competencies must be considered because competency is the measure of "achieved success" of an employee toward accomplishing the goal of a business process and it is computed from the workflow execution history. Defining a goal allows an organization to define success criteria for its employees they commonly use in their work practice. Competency dynamically demonstrates employees' successes of a business process performance in accordance with their goal therefore it is true representative of their work history.

Currently, workflow management system only considers employees capabilities in terms of role when it assigns employees to processes. Because, its objective is to ensure that only authorized agents having the required capabilities should be assigned to processes. As a matter of fact, competency is more specific and dynamic than capability therefore, can preferably and accurately be used for the selection of employees to perform tasks according to the organizational expectation, defined through goals.

Our aim is to improve success of business process performance (in general) and to support continuous resource improvement (in particular). We have developed a methodology for the allocation of resources to work items on the basis of "history of agent' success of business process performance". Since, we recognize competency as achieved business success learned through history and have dynamically computed it using our APE framework (Chapter 4) we therefore name our methodology Competency-driven Dynamic Resource Management (CDRM) Methodology.

However, before going into details of our CDRM methodology it is important to first give a general overview how competency management is generally perceived.

6.2 Competency Management Background

Before going into details of what is competency and how it is generally managed, it is important to first disambiguate capability and competency. Capability is the skill to perform a particular task and is achieved through a certain education, knowledge or training whereas competency is the behavior towards achieving quantifiable level of performance against some performance standard. Therefore, capability is more general and not measurable, but in contrast, competency is more precise and measurable [Den2006].

The concept of competency management is well recognized by Sudbury [Sud03], David McClelland [Dav73] and Spencer [Spen93]. Sudbury [Sud03] defines competency as the ability of personnel to perform task according to expectation. He argues that competency management is crucial for competitive business environments because of the role that it plays in ensuring that tasks are carried out more adequately [Sud03]. According to him, competency implies not only the capabilities but also the knowledge, behavior, training, attitude and understanding towards specific task for achieving required performance standards to meet acceptable performance. Sudbury also presents competency management equation (Figure 6.1). Within his equation, he compares employees' competency with performance standard in a way that if employees competency is matched with the performance standard then employees' performance is acceptable or vice versa.

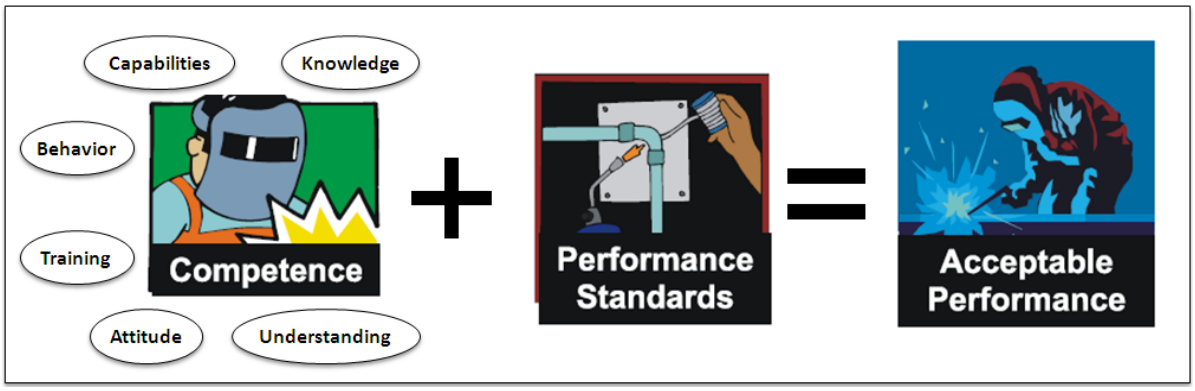


Figure 6.1: Competency management equation [Sud07]

David McClelland [Dav73] makes use of competency as a fundamental concept to classify human actors having similar capabilities. On the basis of employees' competencies, he then relates actors with the tasks that are being performed in the given environment.

Spencer [Spen93] also defines competency as the underlying characteristic of an individual that is causally related to criteria referenced effective task performance. By underlying characteristic, he means that the competency is part of a person and can be used to

deduce behavior. According to him, causally related means that a competency causes or can predict behavior and performance. Criteria referenced means that it is possible to quantify the level of a competency in task performance. This definition of competency implies a causal relation between purpose and result. The performance criteria (goals) are critical since a characteristic cannot be considered as competency because in the real world it does not predict something useful for purpose and result. According to Spencer competency management is concerned with the following guidelines:

- Identification of Competency Requirement: It concerns with the definition of criteria that is used to evaluate employees' competency by utilizing the history data.
- Competency Assessment: It aims for the evaluation of competency using evaluation criteria and history data.
- Materialization of Competency Profiles: It concerns to store the result of competency assessment.
- Competency Deployment: Utilization of competency profiles in task assignment.

How can these guidelines be opted by workflow management system to support history based resource allocation mechanism through competency management? Following considerations need to be taken into account:

- A WfMS must consider the design of performance standards (i.e. goals) during process design time so that it can be used as a criteria in evaluating their work history.
- The WfMS must consider providing tools or methods to evaluate employees' performance based on these performance standards in computing employees' competencies.
- The WfMS must consider providing competency storage space for storing employees' competency profiles.
- Finally, the WfMS must consider to provide the allocation mechanism to allocate only successful employees to their processes that are determined through their work history.

In the next section, we will explain how our CDRM methodology opt these guidelines to support the agents task assignment mechanism to on the basis of their history of achieved business success while utilizing their competencies.

6.3 CDRM Methodology

This section describes Competency-driven Dynamic Resource Management (CDRM). This methodology ultimately aims to dynamically allocate resources to their processes on the basis

of their history of achieved business success so that only successful employees remain enacting the processes.

CDRM Methodology is built on the foundation of our Success Demand-and-Supply Model (shown in Figure 6.2). This model comprises of two concepts that include goal and competency to help CDRM in understanding:

- **Success Demand:** What certain success level is actually required for a process? This success level is described by the goal concept and its achievement is demanded by all agents who are executing the certain process.
- **Success Supply:** What success level is in-fact provided by the agents? This success level is described by the term competency and is dynamically computed from process execution history.

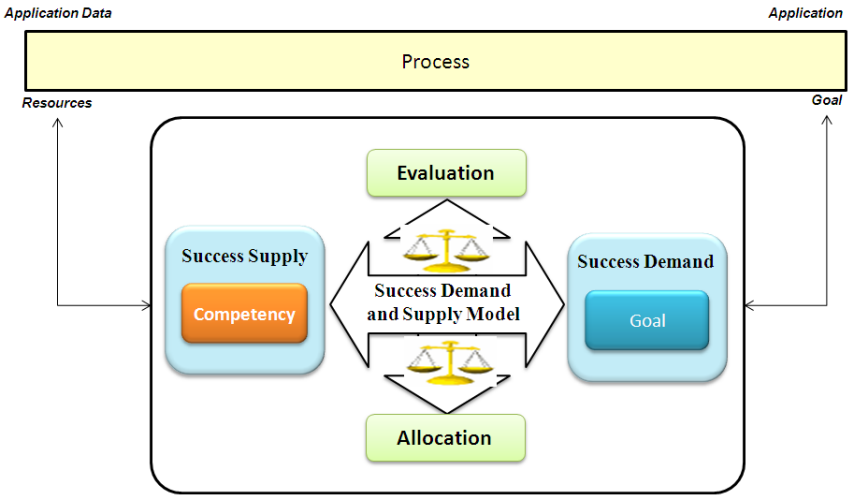


Figure 6.2: Success demand-and-supply model

Success demand and supply model also comprises two mechanisms that include Evaluation and Allocation.

- **Evaluation:** It concerns to use work history and goal definition to compute competencies.
- **Allocation:** It concerns for the allocation of successful employees to processes on the basis of their history of achieved business success.

We have built our CDRM methodology on the foundation of this success demand and supply model. Its methodological framework architecture is shown in Figure 6.3 that comprises following four main ingredients:

1. **Goal**: we defined a goal within our process modeling environment that defines success criteria for process performers. It serves as a yard stick for measuring employees'

competency profiles utilizing work history. In Section 6.3.1 we will explain how goal model is coordinated in our CDRM methodology.

2. **APE Framework**: Our performance evaluation mechanism that basically measure and consistently maintain employees' competency profiles. In Section 6.3.2 we will explain how our APE Framework coordinates this computation and consistently maintains employees' competency profiles.
3. **Competency Driven Organizational Model**: Our object oriented organizational model is flexible, extendable and general enough to store employees' competency profiles. It provided the basis for materialization of employees' competency profiles. In Section 6.3.3 we will explain how the structure of competency driven organizational database is differentiated from traditional organizational database and how employees' competency profiles are materialized into our competency driven organizational database.
4. **Competency Driven Assignment Policy**: Competency driven assignment policy in fact enforces the success demand-and-supply model whereas all others are supporting ingredients in our methodology. Indeed, it defines assignment policy in terms of a required competency (success supply) and matches it with the success level as demanded by goal definition (success demand) as an additional constraint. In Section 6.3.4, we will explain how a competency driven assignment policy defines this additional constraint.

The main ingredients of our CDRM methodology are mentioned with circle in Figure 6.3 (numbers in circles indicate the subsection numbers). In our CDRM methodology we have introduced the continuous resource improvement mechanism in a cyclical form. We will discuss how main ingredients of our CDRM methodology contribute to support continuous resource management in their respective section.

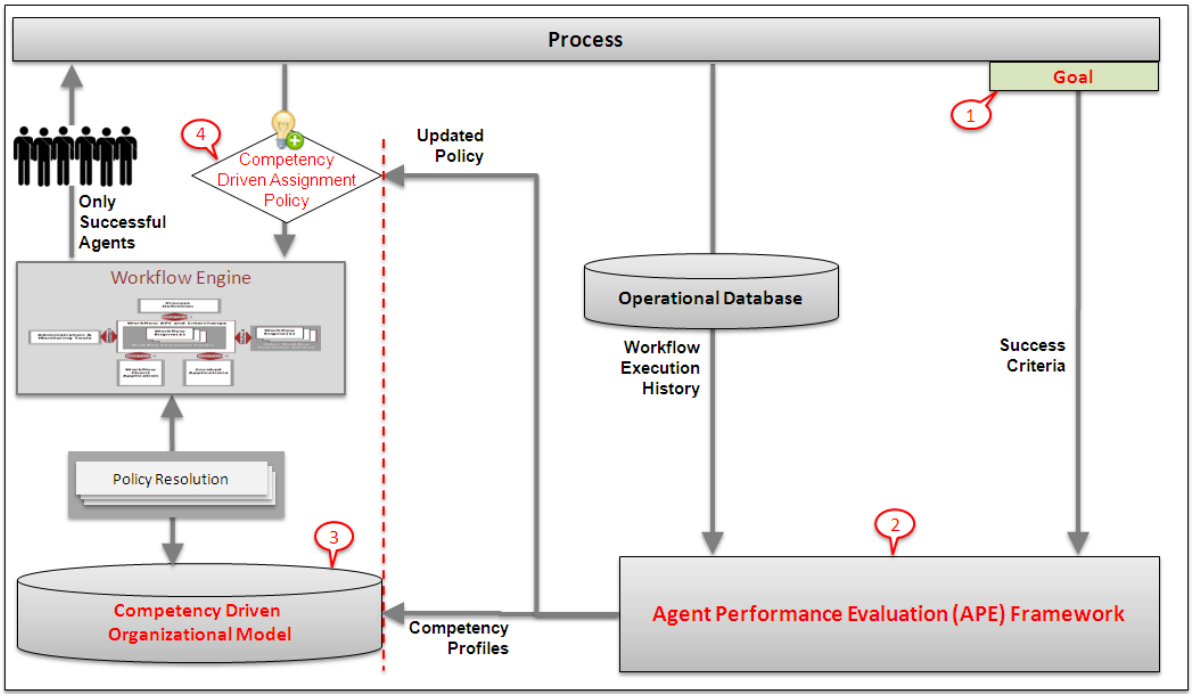


Figure 6.3: CDRM methodological framework architecture

6.3.1 Defining Goal

We model goal in our process modeling environment i>MP in align with the process and have provided a goal modeling support within the process model. Therefore, we refer to our Chapter 3 for detail about:

- How goals are actually set in real business environment between employees and employer as mutually agreed-upon achievable targets (Section 3.1).
- What are the prominent and often suggested guidelines for goal settings (Section 3.1).
- What is the goal model architecture and what are different parts of goal model and how these parts help in measuring employees' performance (Section 3.3).
- How this goal model architecture fits into the process meta model (Section 3.4).

Furthermore in Chapter 5, we have also given detailed continuous resource improvement support within workflow lifecycle. Within this lifecycle, we highlighted different activities concerning goal within different phases of workflow lifecycle such as:

- Goal Analysis
- Goal Design
- Management of Operation Database
- Goal Evaluation

In this section we do not want to give any further detail about goal modeling itself rather here we just highlight that a goal is the main ingredient of our CDRM methodology and its presence within the process model is critical because it provides success criteria that is used by our APE framework in measuring employees' competency profiles. Without a goal definition our CDRM methodology cannot distinguish successful agents because success of business process performance is defined through a goal. Furthermore, its availability within the process model supports continuous resource management because when success criteria is defined within the process model it can be used by the performance evaluation mechanism to evaluate and update agent competency profiles that are actually utilized during task assignments. Thus, a goal is an integral part of our CDRM methodology.

6.3.2 APE Framework

Basically, the APE framework is a performance evaluation mechanism that uses goal definition as a success criteria and operational database as a data source (that contains employees work history) to compute agent competency profiles. It aims to perform analytical analysis of employees' performance to determine who is performing a certain process how well and under what certain conditions. It also comprises many well tuned data mining algorithms that actually perform such analysis. It also feeds the result of evaluation back into organizational database.

We have already explained this framework in Chapter 4. Therefore, we refer to our Chapter 4 for detail about:

- What are the different components of APE Framework and what are the core functionalities of each component (Section 4.3)
- How data mining algorithm actually performs this analytical analysis and how these algorithms are tuned within the APE Framework (Section 4.3.3)
- How domain knowledge is delivered to data mining algorithms (Section 4.2)
- How agents competency profiles are actually computed within the framework (Section 4.3.3)
- How learning of analysis is fed back to organizational database and assignment policy (Section 4.3.4)

We also want to point out that it is also the main ingredient of our CDRM methodology and it presence within the process model is critical because it provides continuous evaluation (competency evaluation) and consistent feedback cycle for competency materialization within the process layer.

6.3.3 Competency Driven Organizational Database

Basically, an organizational database defines employees' society comprising of organizational entities (e.g. agents, departments) and relationships (e.g. play). For a workflow execution engine, it provides the basis for the selection of agents by using the agents' selection criteria defined in an assignment policy [Buss95]. Traditionally, an organizational database does not have any notion for employees' competency.

In contrast to traditionally defined organizational databases, in our CDRM methodology we deploy a competency driven organizational database that provides structure for the materialization of employees' competencies. The ultimate aim of structuring and materializing employees' competencies is to provide support for dynamic within our CDRM methodology so that when competency driven agent assignment policy is resolved, only successful agents are selected dynamically for process enactment.

In fact, in a competency driven organizational model, "Competency" is defined as an additional property of the organizational entity or relationship. Basically, an appropriate organizational entity or relationship is extended with an additional attribute named "Competency". For example, for the Cutting Process, the relationship "Play" is extended with a "Competency" attribute. It provides the structure for materialization of competency profiles for their associated agents and the roles they are responsible to play. An exemplary competency driven organizational model is shown in Figure 6.4 that defines the competency profiles for agents and the roles they play.

Moreover, the extension of a competency attribute is not only specific for role based assignment within the "Play" relationship but even works equally well even for others mechanisms of agents assignments like direct, group or organizational relationships. An appropriate organizational element or relationship is extended depending upon the specific type of assignment and the organizational element or relationship where corresponding process participants are actually being defined. For example in case of direct assignment, competency attribute is extended within the organizational element namely "Agents".

Agents

Agent	Description	--
Amir	--	--
Rehman	--	--
Saqib	--	--
Tahir	--	--
Naveed	--	--
Shahid	--	--
--	--	--

Roles

Role	Description	--
Cutters	--	--
Sewers	--	--
Washer	--	--
Attacher	--	--
Trimmer	--	--
Presser	--	--
--	--	--

Play

Agent	Role	--	Competency
Amir	Cutters	--	1.30
Rehman	Cutters	--	2.08
Saqib	Cutters	--	1.47
Tahir	Cutters	--	3.51
Naila	Attacher	--	1.57
Arif	Trimmers	--	3.91
--	--	--	--

Groups

Groups	Description	--
Winners	--	--
--	--	--

--	--	
--	--	
--	--	

Departments

Department	Description	--
Production	--	--
--	--	--

Figure 6.4: Competency driven organizational database

An important consideration is the flexibility, extendibility and expressiveness of the organizational model of the WfMS to support the extension of a competency attribute within the organizational model. Some WfMSs offer only a restricted organizational model which is not extendable. Therefore, we are using an object oriented organizational meta model [Buss95] that is more general, flexible, extendible and more expressive than the organizational models of today's state of the art WfMSs such as Staffware [staf02], WebSphere [Web03], FLOWer [Flo04] and COSA [Tran03].

6.3.4 Competency Driven Assignment Policy

An Assignment policy specifies the agent selection criteria described in terms of organizational entities or relationships that are defined in the organizational database. Traditionally, neither assignment policy has any notion for defining organizational constraints in terms of competency nor organizational databases are structured to materialize these competencies.

In contrast to traditional assignment policy, our CDRM methodology offers competency driven assignment policy that describes agent selection criteria by adding an additional organizational constraint within the normal assignment policy. This additional constraint is defined in terms of required competency as demanded by the goal definition. It is simply

appended with existing constraints in the AGENT_SELECTION clause of the traditional assignment policy, as shown in Figure 6.5.

For example, for the Cutting Process, the AGENT_SELECTION clause of a traditional assignment policy merely restricts "agents who play cutter role" can execute the cutting process. As a result, all cutters are allowed to perform cutting, without focusing on "how successful they are performing their job". In contrast, our CDRM methodology appends the policy with an additional constraint like "competency < 2". When competency constraint is set according to the competency demand, as defined by the goal definition (i.e. cutting faults should be less than 2%), only successful agents are selected and continued with their processes.

This is the main component of our CDRM methodology where actual enforcement of success demand-and-supply model is applied. Within this constraint, the "Competency" attribute is referring to the organizational model where employees' competency profiles are consistently maintained by our APE Framework that basically represents "success supply" within the success demand and supply model. Similarly within this constraint, "<2.0" is specifically required competency level that is demanded by the goal definition that in fact represents "success demand" within the success demand and supply model.

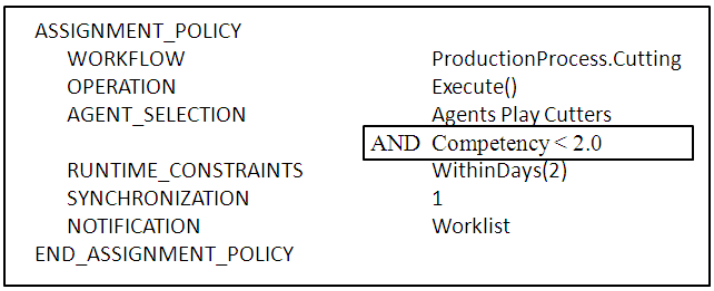


Figure 6.5: Competency driven assignment policy

Moreover, our CDRM methodology is not restricted only for role based assignment policy – instead it can be defined for any assignment mechanism like direct, group, organizational relationships etc. It is because competency based additional organizational constraint can simply be appended in the AGENT_SELECTION clause of any assignment policy, whatever are the assignment mechanisms. This flexibility boosts the adoptability of our methodology.

6.4 Policy Resolution

Here we explain the policy resolution mechanism in our process execution environment. Our processes are modeled in a process modeling tool i>PM [Pro05]. Processes are executed in our

process execution infrastructure called ProcessNavigator [Faer09] that is based on BPEL workflow engine [BPEL11a].The ProcessNavigator is an execution engine that manages and controls workflows that are ready for execution. Its policy resolution mechanism is shown in Figure 6.6.

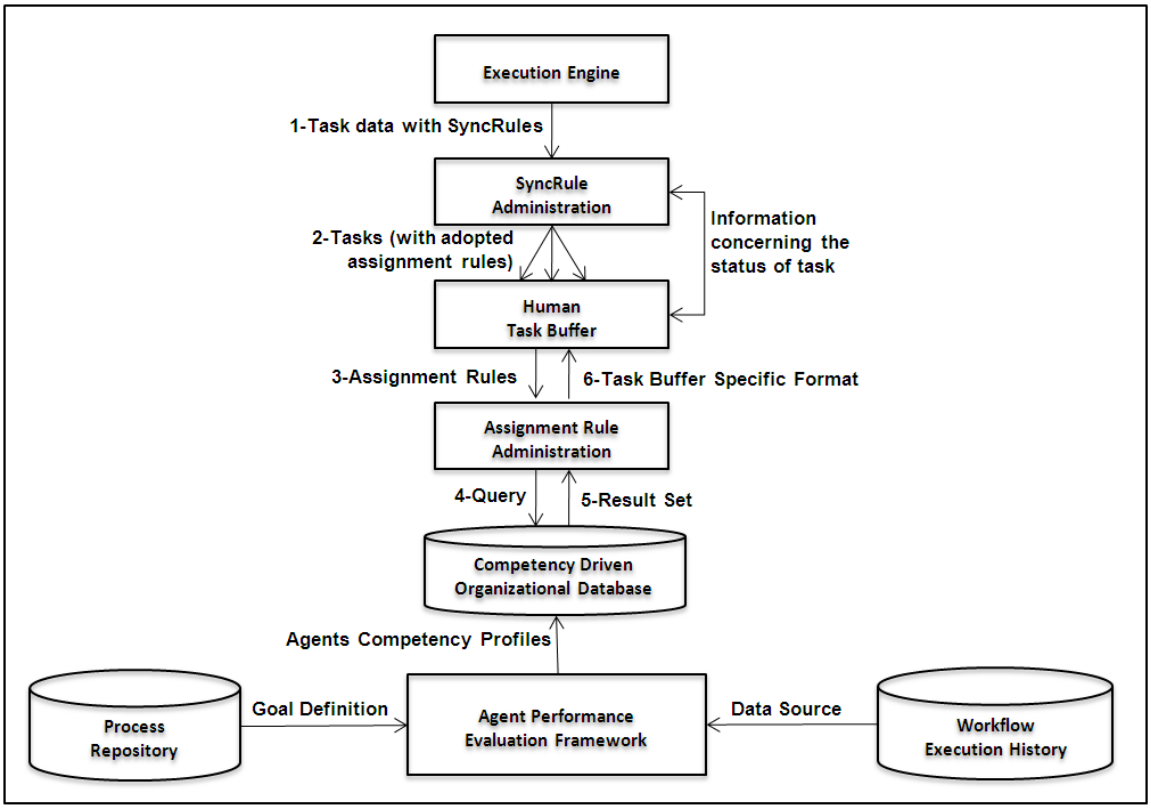


Figure 6.6: Policy resolution mechanism

Once the process is ready for execution, its task relevant data is forwarded to SyncRule Administration, where a synchronization policy is interposed (step-1 in Figure 6.6) for synchronization rules, if any such rule exists. When no synchronization rule is present, task relevant data is simply forwarded to Human Task Buffer (step-2). Human Task Buffer translates assignment policy into an executable query for the underlying system (step-3) by using template pool, mapping pool and element pool [Buss95]. These tools transform different constructs of assignment policy into its different clauses of a SELECT query.

The ProcessNavigator uses a relational DBMS as an underlying system to implement organizational database. This SQL query is then forwarded to a DBMS (step-4), that executes the SQL query and returns a result set. This result set contains the list of agents' names (step-5), who fulfill the conditions defined in the Agents_Selection clause of the assignment policy. In fact, this list of agents' names is not specific to the Human Task Buffer format. Assignment Rule

Administration then converts this result set i.e. list of agents that is specific to a format which is specific to Human Task Buffer (step-6). The Human Task Buffer then adds the task to the shared work list of all these employees (retrieved). An employee whose work history is credible selects the process in order to execute it. Human Task Buffer shifts this task in its private work list – who is then solely responsible for its successful execution. Thus through policy resolution mechanism, only successful employees continue with their processes.

CHAPTER 7

SUMMARY AND FUTURE PERSPECTIVES

7.1 Summary

The prime objective of the thesis is to provide proper resource management support for skill intensive applications of a workflow technology. It particularly focuses on providing technical support and methodological guidance that are crucial not only in assigning successful employees to their business processes but also in providing sufficient support for their continuous improvement. Thus, we address technical and methodological issues of resource management within the skill intensive applications of workflow technology.

In the beginning of Chapter 1, we initially presented the motivation of our thesis in terms of resource management within the context of WfMS and HRM domains. Then, we shortly described some fundamental concepts that are required to grasp the problem definition more convincingly. Subsequently, we illustrated the related issues and pointed out various requirements on the basis of our identified causes of poor resource management. Finally, we concluded the chapter by defining the focus of the thesis and summarizing our main contributions.

Chapter 2 was dedicated to related work where we presented current state of the art about the related approaches of our thesis. We divided the related approaches into four classes i.e. Business Process Modeling Languages, Performance Evaluation Mechanisms, Process Improvement Theories and Resource Allocation Mechanisms. Beside comprehensive survey of these approaches, we analyzed them on the basis of our identified issues and demonstrated that how they were responding to our derived requirements.

In Chapter 3, we presented goal modeling support within our i>PM process modeling environment. The ultimate objective for modeling goal was to incorporate employees' success criteria within the process model so that it can later be used to evaluate their success of business process performance by using our performance evaluation mechanism i.e. APE Framework. Since, we aimed for performing analytical analysis of employees' performance therefore we also incorporated Context Definition along with its Measurement Definition that provide not only performance measurement infrastructure but also support domain knowledge to data mining techniques that are essential in performing such analysis. We also demonstrated that how goal definition is customized into different levels of our POPM meta model hierarchy.

Chapter 4 presented APE Framework that performs analytical analysis of employees' performance. In this chapter, we initially demonstrated that why performing analytical analysis of employees' performance (in contrast to simple evaluation) is crucial for continuous resource development. Then, we described how goal model is useful for facilitating domain knowledge for data mining techniques that are integrated within the APE framework and how it

substitutes the personal involvement of data miners. Subsequently, we presented architecture of the APE framework and explained the functionality of different architectural components of APE framework. We justified that how different framework components use workflow execution history from operational database as a data source and goal definition not only as a success criteria but also as source of domain knowledge in performing analytical analysis of employees performance through the use of pre-tuned mining methods. Consequently, we explained that how these pre-tuned mining methods are triggered by the framework for computing agents' competency profiles and how these methods actually compute and feedback agent competency profiles into organizational database are illustrated. Finally, we also presented our experiments and experiences within a real world textile industry where we have shown that how APE framework meets our identified requirements.

Chapter 5 addressed the issue of insufficient methodological guidance for continuous resource improvement within standard process improvement lifecycle since the standard lifecycle only explains the utilization of resource along its different phases without giving any guidance how to improve them. Basically, this chapter was aimed for defining methodology in terms of workflow lifecycle support for continuous resource improvement. However before elaborating the methodology, it initially focused on how the link between resource and process is currently oddly defined and what its consequences are. Then, it proposed our process resource success (PRS) conceptual relationship model that enabled us for sufficiently validating the credibility of the link between resource and process. This PRS conceptual relationship model in fact guided us in distinguishing what is missing within this link (between resources and process) and how it is ultimately useful for supporting continuous resource improvement. Finally on the conceptual foundation of PRS relationship model, methodology was elaborated in terms of a set of basic tasks that need to be performed along different phases of standard workflow lifecycle to justify how these tasks provide sufficient guidance for performing continuous resource improvement. Indeed, this continuous resource improvement methodology precisely summarized different phases of standard workflow lifecycle, different workflow stakeholders (group of people or communities), their main tasks that are performed by them and different tools that are required in performing these tasks.

Chapter 6 highlighted the lack of WfMS task allocation mechanism for the allocation of resources to their processes on the basis of history of their success of business process performance. It proposed competency-driven dynamic resource management (CDRM) methodology that aims to allocate work item to only those agents who have good history of success of business process performance. Chapter started with the fundamental concerns of workflow' task allocation mechanisms. Subsequently, it presents our success demand-and-supply model to explicate what success level is basically demanded from employees and what

success level is actually being provided by them. Then on the foundation of this success demand and supply model we presented the architecture of our CDRM methodology. We also justified how the architectural components of our CDRM methodology collaborate for achieving its overall aim. At the end, we described our policy resolution mechanism to explain how our competency driven assignment policy is resolved in our process execution environment and how it retrieves the list of only those agents who have good history of success of business process performance – thus allowing only successful employees remain enacting the process.

7.2 Future Perspectives

We envisage the following future research directions as the key factors for the extension and enhancement of our research work

7.2.1 Process Analytical Modeling

Today process modeling languages such as BPMN, UML AD, EPC, IDEF 3, EEML URN etc, support only constructs that are used to describe different perspectives of a process such as functional, operational, behavioral, informational and organizational. Although these perspectives altogether define how processes are "executed" but they lack to define different constructs that can be used in "diagnosing" the process inefficiencies. Though, there is a need for introducing different modeling constructs within the process model that can be used in performing analysis of optimal execution of business processes. For example, process model defines only data produced and consumed by the process but the "data quality standards" are not modeled. Due to this lack of modeling data quality standards, process management poses data management related issues such as:

- Management of corrupt data transformation
- Validation of data transformation from source to sink
- Filtration of unwanted data received during transformation of data from source to sink
- Physical data transportation of data from source to sink

7.2.2 Process Centric Operational Intelligence

Business intelligence (BI) tools have long stood alone, taking data from business process and applying data mining techniques to provide useful knowledge or actions for decision makers. But simply taking only data silos misses part of picture because it lacks "context awareness" of

the business processes in which data was created. Context of a business process is important because when information are taken out of context lessens its value i.e. the results are, at best, limited, if not downright misleading. Process management technology though supports context awareness but lacks for supporting operational intelligence to optimize processes at runtime. Rather than having BI as an adjunct to an enterprise application of workflow technology, moving BI into processes will effectively optimize business processes at runtime. For example, when data quality standards are defined within the process, data mining techniques can be used in optimizing data management issues mentioned in Section 7.2.1.

7.2.3 Knowledge Discovery and Data Mining Modeling Framework

Traditionally, data mining is a data-driven trail-and-error process where data miner personally applies a data mining algorithm to extract some patterns or rules. These rules or patterns are then delivered to business people for making their useful business decisions. As a matter of fact, business people are unable to interpret these patterns or rules because they are defined in terms of technical significance of a mining algorithm. Business people feel confused by how they should care about these finding and what straightforward actions can be taken by them to support their business decision. To overcome this problem, data miners always need to transform the results of a mining algorithm into a form of an actionable knowledge that is understandable, actionable and deployable for business people. This transformation definitely requires some additional pre-processing and post-processing task to be performed personally. For advanced application of data mining, data miners even require to incorporate many alternate sequential or parallel algorithms to achieve this objective.

Data miners are currently looking for a framework to model pre-processing algorithms, core mining algorithms and post-processing algorithm for designing a complete mining application. This framework should not only allow them to transform the results of a mining algorithm into a form of an actionable knowledge that is understandable and deployable for business people. But In addition to that, framework should also enable them to define structure for many alternate sequential or parallel mining algorithms into a complete data mining application as well as allow them to formally define algorithms' input and output in terms of their rules or patterns they produced and consumed. Data miners expect a complete automated system that supports them in defining data mining applications in greatly promoting enterprise operational quality and productivity. We aim to utilize the knowledge and experience gained insight gain through process management domain to fulfill the framework requirement of data miners.

APPENDIX

ABSTRACT PROCESS META META MODEL (APM^2M)

```
model APM2M {
      description = "Abstract Process Meta Meta Model of the
      Pespective Oriented Process Modeling (POPM) approach";
      modelURI = "model:/www.ai4.uni-bayreuth.de/models/POPM/1.0/APM2M";
      include "model:/www.ai4.uni-bayreuth.de/models/POPM/1.0/ER";
      include "model:/www.ai4.uni-bayreuth.de/models/POPM/1.0/Org";
      level M3 references ER.ER2 references Organisation.M2 {
      package APM2M {
      /* ------------------------------------------------------------
                  Package: Perspectives
                  Content: Definitions of perspectives
         ------------------------------------------------------------ */
      package Perspectives {
            import ER.ER2.ER.Entity;
            import ER.ER2.ER.Schema;
            import Organisation.M2.Roles.Role;

      /* ------------------------------------------------------------
          Concept: DataItem
          Content: Definition of data
          Data within a process model is defined in terms of a link
          into an ER model. A single data item corresponds with a
          single entity; however, an entity can be linked with
          others such that a complete hierarchy can be set up.
          Addtionally, the link into a data model can be enriched
          by a reference to the complete schema in which the
          referenced entity is defined. This allows matching
          algorithms to easily and quickly resolve schema
          information.
      ------------------------------------------------------------ */
      public concept DataItem diCounter 2 {
            attributes {
                  public concept Entity entity { multiplicity = one; }
                  public concept Schema schema;
                  }
            }
      /* ------------------------------------------------------------
          Concept: DataFlow
          Content: Definition a connection between two data items
          Data is produced and consumed within a process. A data
          flow establishes a link between two data items, thus
          allowing for specifying producer and consumer.
          Additionally, a transformation definition can be given
          as a string which defines what data are undergoing during
          the transport from the source to the sink.
      ------------------------------------------------------------ */
      public concept DataFlow diCounter 2 {
            attributes {
            public concept DataItem source { multiplicity = one; }
            public concept DataItem target { multiplicity = one; }
            public string transformationDefinition;
            public string annotation;
                        }
            }

      /* ------------------------------------------------------------
          Concept: OperationalPerspective
          Content: Definition of the operational perspective
```

```
        At the moment, the operational perspective is only defined
        by a service name and a list of consumed and produced
        data. A serviceName must be specified, whereas consumed
        and produced data are optional.
    ------------------------------------------------------------ */
    public concept OperationalPerspective diCounter 2 {
          attributes {
          public string serviceName { multiplicity = one; }
          public string serviceProvider;
          public string serviceUri;
          public string username;
          public string password;
          public concept DataItem producedItems
                { multiplicity =       zeroOrMore; }
          public concept DataItem consumedItems
                { multiplicity = zeroOrMore; }
                }
    }
    /* ------------------------------------------------------------
          Concept: FunctionalPerspective
          Content: Definitionof the functional perspective
          The functional perspective is defined by a string which is
          to be stored within the name attribute. An optional
          description can be additionally supplied within the
          descriptionOfFunction attribute.
    ------------------------------------------------------------ */
    public concept FunctionalPerspective diCounter 2 {
          attributes {
          public string name        { multiplicity = one; }
          public string descriptionOfFunction;
                }
    }

    /* ------------------------------------------------------------
          Concept: OrganizationalPerspective
          Content: Definitionof the organizational perspective
          The organizational perspective associates a role from an
          organizational model. This role is stored within the
          role attribute which is mandatory and cannot be left
          blank.
    ------------------------------------------------------------ */
    public concept OrganizationalPerspective diCounter 2 {
          attributes {
          public concept Role role { multiplicity = one; }
          }
    }

    /* ------------------------------------------------------------
          Concept: BehavioralPerspective
          Content: Definitionof the behavioral perspective
          The behavioral perspective is used for specifying the
          control flow in between steps of a process.
    ------------------------------------------------------------ */
    public concept BehavioralPerspective diCounter 2 {
          attributes {
                      public string annotation;
                      }
                }
```

```
/* ------------------------------------------------------------
Package: Goal
Content: Concepts specific to the goal perspective
------------------------------------------------------------ */
package Goal {
      public concept GoalPerspective diCounter 2 {
      attributes {
      public string name { multiplicity = one; }
      public string desc;
      public concept ContextDefinition context { multiplicity = one; }
      public         concept         MeasurementDefinition         measurement
             {multiplicity=one;}
            }
      }
      public concept ContextDefinition diCounter 2 {
      attributes {
      public concept DataDefinition dataDefinition  {multiplicity=one;}
      public concept OrganisationalDefinition organisationalDefinition
                  { multiplicity = one; }
      public concept OperationalDefinition operationalDefinition
                  { multiplicity = one; }
      public concept BehavioralDefinition behavioralDefinition
                  { multiplicity = one; }
            }
      }
      public concept DataDefinition diCounter 2 {
      attributes {
      public concept DataElementDefinition elements
                  { multiplicity = oneOrMore; }
            }
      }
      public concept DataElementDefinition diCounter 2 {
      attributes {
      public string name { multiplicity = one; }
      public string dataType { multiplicity = one; }
                  }
      }
      public concept OrganisationalDefinition diCounter 2 {
      attributes {
      public concept KeyAttribute keyAttributes
                  {multiplicity = oneOrMore; }
                  }
      }

      public concept OperationalDefinition diCounter 2 {
      attributes {
      public concept KeyAttribute keyAttributes
                  { multiplicity = oneOrMore; }
            }
      }
      public concept BehavioralDefinition diCounter 2 {
      attributes {
      public concept KeyAttribute keyAttributes
            { multiplicity = oneOrMore; }
            }
      }
      public concept KeyAttribute diCounter 2 {
      attributes {
```

```
      public string name { multiplicity = one; }
            }
      }
      public concept MeasurementDefinition diCounter 2 {
      attributes {
      public concept MetricDescription metricDescription
                  { multiplicity = one; }
      public concept GroupDefinition groupDefinition
                  { multiplicity = twoOrMore; }
            }
      }
      public concept MetricDescription diCounter 2 {
      attributes {
      public string metric           { multiplicity = one; }
      public string dataSource { multiplicity = one; }
      public string dataType         { multiplicity = one; }
      public string query            { multiplicity = one; }
            }
      }
      public concept GroupDefinition diCounter 2 {
      attributes {
      public string name             { multiplicity = one; }
      public string startValue { multiplicity = one; }
      public string endValue         { multiplicity = one; }
      public integer priority  { multiplicity = one; }
            }
      }
   }
}


import APM2M.M3.APM2M.Perspectives.DataItem;
import APM2M.M3.APM2M.Perspectives.BehavioralPerspective;
import APM2M.M3.APM2M.Perspectives.FunctionalPerspective;
import APM2M.M3.APM2M.Perspectives.OperationalPerspective;
import APM2M.M3.APM2M.Perspectives.OrganizationalPerspective;
import APM2M.M3.APM2M.Perspectives.Goal.GoalPerspective;



public abstract concept Node {
attributes {

// definition of input and output data
      public concept DataItem inputData       { multiplicity = zeroOrMore; }
      public concept DataItem outputData      { multiplicity = zeroOrMore; }

// definition of organizational, operational and functional perspectives
      public concept OrganizationalPerspective organizations
            { multiplicity = zeroOrMore; }
      public concept OperationalPerspective    operations
            { multiplicity = zeroOrMore; }
      public concept FunctionalPerspective     functions
            { multiplicity = zeroOrMore; }

//definition of incoming and outgoing control flows
      public concept BehavioralPerspective incomingControlFlows
```

```
            { multiplicity = zeroOrMore; }
      public concept BehavioralPerspective outgoingControlFlows
            { multiplicity = zeroOrMore; }

// definition of internal structure of a node (aggregation / composition)
      public concept Node innerContent        { multiplicity = zeroOrMore; }
      public concept GoalPerspective goals  { multiplicity = zeroOrMore; }
      }
      }

public concept NodeKind partitions Node {
      attributes {
      public boolean supportsIncomingData
            { default = false; enables = inputData; }
      public boolean supportsOutgoingData
            { default = false; enables = outputData; }
      public boolean supportsIncomingControlFlow
            { default = false; enables = incomingControlFlows; }
      public boolean supportsOutgoingControlFlow
            { default = false; enables = outgoingControlFlows; }
      public boolean supportsOrganizationalPerspective
            { default = false; enables = organizations; }
      public boolean supportsOperationalPerspective
            { default = false; enables = operations; }
      public boolean supportsFunctionalPerspective
            { default = false; enables = functions; }
      public boolean supportsAggregation
            { default = false; enables = innerContent; }
      public boolean supportsGoalPerspective
            { default = false; enables = goals; }
      }
    }
   }
  }
}
```

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