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Arbeitsgruppe Datenbanken

Technical report

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Technical Report

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Abstract

Technological developments and changes in business process context pose new challenges for effective management of business processes. Business process modeling is one of the most important area in business process management. Business process modeling is used to graphically visualize the operations of a business process for a better understanding and different analyses. These new challenges are also investigated by researchers in business process modeling with different perspectives. In this report, we present active research areas of business process modeling. The active research areas and current challenges help us to outline future research directions in the business process modeling domain. Additionally, we also discuss the business process and detailed business process lifecycle from post execution perspective for a better understanding of business process context.

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1 Introduction

Management of business operations undergoes different trends. Specific terms have been coined to describe the focus of each trend like data oriented approaches (common in the seventies and eighties) and process oriented (in last two decades) [78]. In data oriented approaches, provision of IT support to business functions is a main focus of research, e.g., business data models and database systems. With the maturity of research on data oriented approaches, the focus shifted to higher levels where processes are in the main focus of research to provide services to customers. Methods focusing processes are proposed like process modeling techniques and process management systems, i.e., workflow management systems.

Recent technological developments open new horizons for products in different domains. These changes have an effect upon business process management research like satisfying the requirements of stakeholders in new domains. The effect of changes brings up several challenges in business process modeling domain as well. These challenges need to be addressed for better management of business processes. New methods and modeling languages are proposed to address these challenges.

Business process modeling is one of the most important methods in business process management. It is used for better understanding of business concerns and communication between stakeholders. Different benefits of business process models motivated researchers for effective usage of business process models in phases of the business process lifecycle [16]. Therefore, it is investigated by researchers in many directions. It is discussed under various topics related to business process lifecycle ranging from adaptation of information systems (communication, modeling the environment, development, and simulation) to business process analysis (improvement and reengineering).

Understanding a business process, its context, and techniques are a starting point for business process improvement. We provide several definitions of a business process from literature and discuss a meta model to understand business process context in Section 2. Business process modeling covers a wide area of research and state of the art in this domain is a challenging task. Several state of the art papers exist in the business process modeling domain, but they focus on certain aspects of a business process lifecycle like development and optimization [81].

The purpose of this report is to provide an overview of research in the business process modeling domain. Active research areas of business process modeling are discussed with different perspectives in Section 3. This state of the art helps us in identifying current challenges in the business process modeling domain and provides directions for future research. We briefly discuss the future research directions of business process modeling in Section 4. Section 5 summarizes presented work of this report.

2 Business Process Management

Customers' demands are fulfilled by enterprises which do business for several reasons like satisfying stakeholders (executives, employees, and customers), monetary gain, or increase in reputation. We restrict ourselves in this work to business processes in enterprises although business process management is also applicable to governmental institutions, cf. [24]. To maintain the competitive position in the market, enterprises provide new products and services. This trend of competitiveness triggers other enterprises to provide better services in order to keep or strengthen their position in the market. Executives set goals and objectives of enterprises which support the vision of a company. In order to achieve these goals and objectives, business operations are carried out in a specific way. This specific way is called business process and discussed in Section 2.1 by different researchers' viewpoints. Different techniques are used for management of a business process during its lifecycle and are discussed in detail in Section 2.2. Business process modeling is briefly introduced in Section 2.3 with two exemplary techniques.

2.1 Business Process Definitions

Being central part of organization's operations, different techniques are devised to manage processes like business process management [77, 85], business process reengineering (BPR) [27], or business process improvement (BPI) [28]. There are several definitions of a business process in the literature where authors define a business process in the scope of their management techniques. These definitions are a starting point for understanding the business process and its context for further research in business process management.

Hammer & Champy define business processes in the context of business process reengineering [27, p. 35] as follows:

> "A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer."

Similarly, Davenport defines business process from process innovation [18, p. 5] viewpoint as follows:

> "...a structured, measured set of activities designed to produce a specific output for a particular customer or market. It implies a strong emphasis on how work is done within an organization[...]. A process is thus a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs: a structure for action."

The above definitions focus on designing business processes with inputs and involved objects, hence outputs can be generated for potential customers. Business process reengineering and business process innovation are in response to a competitive and changing environment, where existing processes are no longer effective. Therefore, processes have to be redesigned from the scratch to address the demands of customers.

From the perspective of business process improvement (BPI), Harrington defines business processes in [28, p. 9]:

> "A business process consists of a group of logically related tasks that use the resources of the organization to provide defined results in support of the organization's objectives."

In this definition, the resources of organization and related tasks are focused to fulfill organization's objectives. The effective utilization of resources and structure of tasks are important for improvement in product and services. In BPI, specific goals are defined which are supposed to be achieved by process improvement like cost reduction or quality improvement and then these goals are propagated in concrete steps of the processes. Thus, attempts are made to improve existing processes in different aspects.

In [85, p. 5], Weske defines a business process from the management perspective with organizational resources as follows:

> "A business process consists of a set of activities that are performed in coordination in an organizational and technical environment."

This definition of business processes is related to the management perspective where organizational and technical resources are used for effective execution of business processes. This includes information systems, machines, and effective resource allocation. Several other definitions of business processes and their meta models are discussed in [24, 29]. Here, we describe a business process and its related context for discussion of business process lifecycle phases and research in business process modeling.

Customer's demands and events in market enforce enterprise to provide new services or improve the existing ones for customer's satisfaction. This is due to the reason that old services are no longer efficient or do not fulfill new requirements. The changes in markets and customer demands have to be reflected in objectives of enterprise, processes, and correspondingly in the overall organization. Processes are governed by policies where inputs are transformed into outputs through actions performed by resources. Policies are defined by enterprises, markets (like standards), and government (e.g., environment friendly). Based on this description, a new abstract meta model of a business process and its context is represented in Fig. 1.

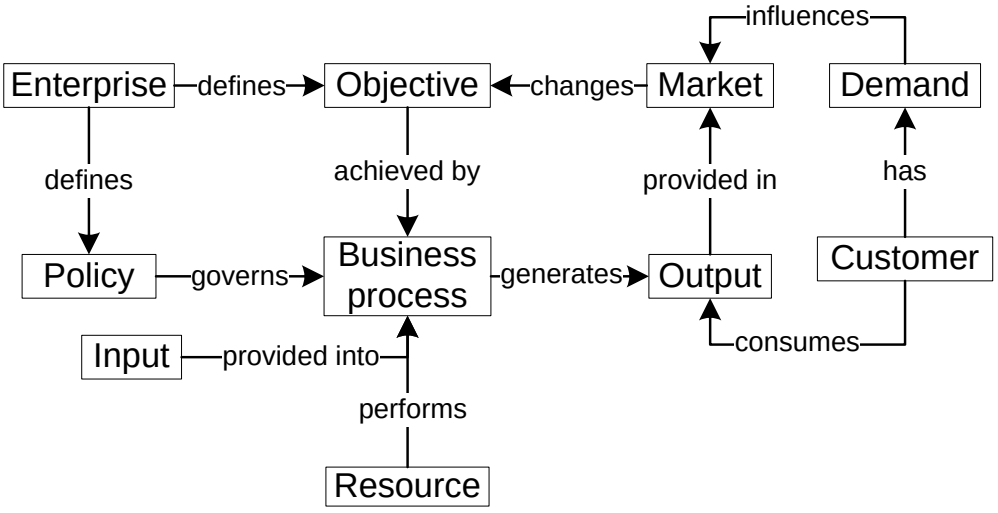

Figure 1: Business process meta model

We further elaborate the meta model of Fig. 1 to provide more details on involved elements of business processes and relation with management techniques. Customers demand products or services for consumption in their own context. The major changes in customer's demands and market have to be reflected in objectives of the enterprise. Changes in markets are because of certain events, for example, legislations imposed by government, new standards defined by groups of enterprises, or demands of certain items due to certain reasons like environmental conditions. Different aspects of such changes are addressed in research and we discuss them in Section 3.8 and Section 4.3. In Fig. 2, we show a meta model with more details of involved elements in business processes and its related techniques for management of business processes.

An objective of the enterprise is realized in processes which itself can be composed of different activities. Resources perform operations in these activities according to a specific set of rules to transform inputs into outputs. These specific sets of rules are defined by the enterprise in accordance with other policies. Inputs, activities, processes, rules, outputs, policies, and resources provide the operational view of a business process. Resources of business processes are further divided into different types, such as, humans, machines, and organizational structures. These different resources collaborate with one another to complete the execution of business processes. These details and management techniques are shown in the Fig. 2. Focusing particular entities of Fig. 2, different perspectives are provided in models such as control flow, cultural environment (employee's collaboration), and organizational perspective (resources usage, branches). Business processes are supported by workflow management systems which automate business processes [85, p. 50].

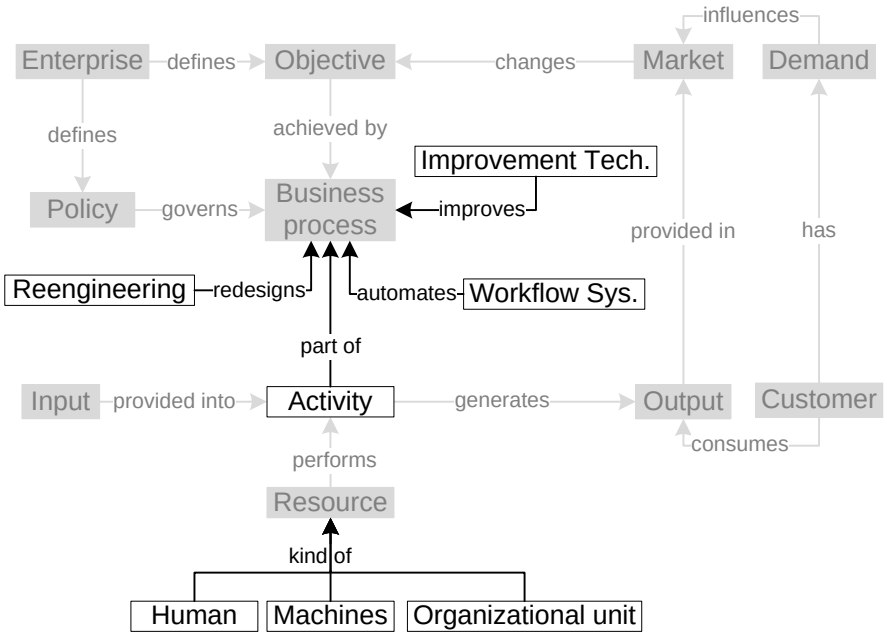

Figure 2: Business process context and management techniques

An efficient process step or an overall performance improvement requires evaluation of business processes after execution. Similarly, the feedback from customer and changes in market are also analysed to devise a strategy for improvement or redesign of business processes. We further discuss these concepts in the following subsection.

2.2 Business Process Lifecycle

Different techniques are used in a business process lifecycle for effective management of business processes. Business process management (BPM) is a cyclic methodology in which business processes are investigated in several perspectives during its phases. Business process lifecycle consists of several phases like plan, design, implement, execute, evaluate, analyse (post execution) and recommend. This business process lifecycle is recursive, which means that each phase can have similar phases during its lifecycle. The business process lifecycle with entry points of different business process management (BPM) techniques is shown in the Fig. 3. Entry points of business process management techniques (such as BPR or BPI) into phases depends on the context and usage of those techniques in enterprises. Activities carried out in business process management phases with respect to its techniques are briefly discussed as follows.

In the planning phase, analysts define which business processes are required to per-

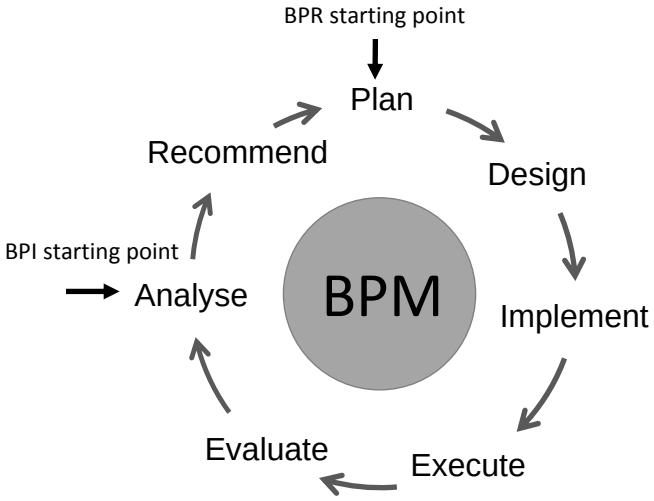

Figure 3: Business process management lifecycle

form in order to achieve the desired objectives, like providing products and services. In this phase, objectives and goals of a business process are described in detail. Therefore, processes are conceptualized in this phase and design characteristics are specified at an abstract level. The desired output of a business process is also defined in this phase.

From process improvement and change management perspective, a detailed plan is prepared about the changes to be carried out in business processes. These changes are due to process improvement or accommodating the new requirements. The scope and kind of changes are defined like which operations, organizational elements, and procedure should be changed. The target (TO-BE) design characteristics are provided to the design phase. Planning phase is also a starting point for the business process reengineering where processes are conceptualized from the scratch. However, the domain knowledge of experts and knowledge about previous processes creep back in.

In the design phase, different aspects of processes are considered in detail. Business processes are analysed in different perspectives like functional (which activities), behavioral (conditions, parallel, and iterations), organizational (where and by whom), and informational (requirements to perform) [16]. In this phase, different involved elements are explicitly specified like inputs, operations, conditions, flow of process, and resources. The target values of different objects are also specified for the evaluation phase. Therefore, a detailed design model is prepared for implementation phase.

From the process improvement and change management viewpoint, the target design characteristics are investigated in detail. The impact of changes on other objects is evaluated by analyzing it in different perspectives. Afterwards, the required changes and modifications are specified in the design model.

Once business processes are designed then these are implemented in an organization. The transformation from design to implementation is dependent on the description of language and granularity level of models. For efficiency, business processes are supported with information technology (IT). The implementation phase of business processes with IT can have similar phases of BP lifecycle because business needs and requirements have to be mapped into IT services to provide the IT support. Activities carried out for Business-IT alignment are further discussed in Section 3. Before execution, the enactment of processes is carried out. Enactment of processes means that resources are allocated to process operations and thus an execution environment is created.

Business processes are executed in order to fulfill the requests of customers (internal and external). Different instances are executed through a business process based on a defined event. Resources carry-out operations on inputs and transform the input into outputs. In this way, business processes are executed in enterprises. The execution of business processes is recorded with the help of information systems. Information systems are used for evaluation, analysis, and controlling of business processes. Controlling part is used to manage business process which includes measurement, monitoring and analysis of business process to make changes in real time.

After execution, the processes are evaluated for performance analysis. Customer and market demands are compared to the generated output. Different quantitative and qualitative measurements are made in this phase like statistics and process mining [75]. The actual values of objects are compared with the target values and the planned process behavior is compared with the actual behavior.

The post executional analysis of business processes uses the results of evaluation phase and analyse the performance of business processes in a broader context. The achievement of enterprise's objectives are analysed from customer, process and organizational performance aspects. In this phase, AS-IS process model is built from execution logs (data perspective) to understand the current execution of business processes. In case of discrepancies between plan and target values or behavior, the deficiencies in business processes are investigated. Different analyses are carried out to find root causes of problems identified in this phase. The post execution analysis of business processes is a starting point for business process improvement techniques.

The identified deficiencies are tried to be avoided in further executions. The purpose of this phase is to define the objective for planning phase in order to carryout the changes for improvement in subsequent phases. Therefore, in recommend phase the TO-BE concept is prepared. In this way, business processes are improved. For overall view of business process lifecycle, we summarize business process lifecycle phases in Table 1 with possible inputs, actions, and outputs.

Table 1: Business process lifecycle

Phase	**Activities**	**Input**	**Action**	**Output**
Plan	Process identification	Enterprise business objectives, change or improvement objective	Process identification, goal definition of BP, defining desired output, defining scope and kind of changes	Abstract BP description, design characteristics, plan for changes, To-Be design characteristics
Design	Detailed design of business process	Brief business process description, objectives, policies, org. info, output of plan phase	Defining inputs, procedure, rules, resource allocation, role mapping, and required changes	Detailed design model for implementation
Implement	IT implementation, simulation, and deployment	Output of design phase (detailed design model)	IT services, simulation, enactment and deployment of business process	Ready to execute environment
Execute	Execution	Defined event, instance execution request	Execution of business processes	Output result, product or service
Evaluate	Measure and monitor	Execution logs and other details	Taking Q&Q measurements, Comparison of plan and actual values	Statistics about performance of business objects
Analyse	AS-IS analysis, finding deficiencies	Performance statistics, execution details	AS-IS analysis, comparisons, mining, root cause analysis	Deficiencies, areas for improvement, new changes
Recommend	Defining change/ improvement objective	Deficiencies, areas for improvement or change	Defining the change or improvement objective	TO-BE concept and objective for changes

2.3 Business Process Modeling

Business process modeling is considered as the first and the most important step in BPM [77]. Business process modeling is used to visualize operations of a business process for better understanding and analysis. Being graphical nature of business process models, they are used as a medium of communication between stakeholders (e.g., executives, developers, and employees). Business process modeling has increased the ability to understand business processes and to make rational decisions for organizing activities in a traceable and understandable way [15].

Various elements and different stakeholders are involved in business processes. They have distinct demands and expectations from business process models. For example, executives want a holistic view of their enterprise, process owners require not only a holistic view but details of business processes. These details involve the structure of processes, operations carried out in these processes, and characteristics/attributes of involved objects. Similarly, the operational managers want further details of business processes and performance related information.

Representing all details of involved elements in one model will make the model very complex for comprehension. Therefore, different models are proposed in literature to fulfill the requirements of stakeholders in business process lifecycle. Depending on the purpose of modeling, business processes are represented at different levels of granularity and in different perspectives. In a perspective, particular details of processes are considered like organizational culture, organizational structure, functional perspective (operational details) as discussed in [16, 38]. This enables the stakeholders to focus on certain relationships and elements related to a business process. Some research work in business process modeling domain is discussed in Section 3.

Two approaches exist for modeling the business processes. One approach is a top-down approach and other is bottom-up. In a top-down approach, expert proposes the model that how business processes should be executed. It starts from an overall process, by considering it as a "black box" and then this "black box" is broken down into more details (like activities, tasks etc.) until all details are specified. In contrast to a top-down approach, the bottom-up approach starts documenting the details at a lower level, i.e., how the functions are executed at an operational level. After getting this information, functions are combined to make activities. Activities connecting other activities build processes. In this way, the whole business process model is built. Being started from lower level details, this approach gives you a detailed insight on processes and their executions. Mostly in business process improvement, the bottom-up approach is used as it helps to identify deficiencies in actual executions. The top-down approach is used for business process reengineering [12].

3 Research in Business Process Modeling

Continuous development in technologies and ever increasing demands of customers for efficiency and improvements in services keep business process modeling an important research area. This is due to the fact that business process models are used for easy communication and they provide insights about their processes with other management methods.

Several modeling methods, techniques, and hundreds tools exist for process modeling. Kettingler et. al. stopped at 72 methods and 144 tools for their comparative study in [26]. Similarly, one PhD student is reported to stop at a count of 3000 process modeling techniques [52]. Selection of a particular modeling technique is very important for success of a modeling goal.

The research work in business process modeling can be discussed with respect to changes in business domain and accommodating these changes in business processes during its lifecycle. Different modeling languages are devised to address the aspects of processes in different phases of BP lifecycle. One of the most important is to support business process with information technology. Therefore, most of the work in business process modeling domain is for Business-IT alignment. The steps carried out in Business-IT alignment are similar to the BP lifecycle phases as discussed in Section 2.2.

Different models are used in Business-IT alignment which fulfills different objectives of phases like communication, mapping business requirements to IT services, simulation, automation (workflow), controlling, analysis, and improvement. Table 2 shows the steps and corresponding models used for business-IT alignment. Models of one phase are transformed into other models to accommodate the needs of other phases. The issue of transformation of models is further discussed in Section 3.5.

In planning phase, managers and experts discuss operations of enterprise which can be partially or fully automated. Models with graphical notations are often used for understanding and communication like Event-driven Process Chains (EPC) [63], Flow charts [30], Business Process Modeling Notation (BPMN) [8], and Use case diagrams [7]. Several variants of modeling languages are proposed for business-IT alignment like Unified Modeling Language (UML) diagrams [7] or Petri nets [50]. Simulation of business processes is carried out to validate and verify the business process design. Validation and enactment of business processes are discussed in Section 3.5 and Section 3.6 respectively. There is lack of business process model for evaluation, analysis, and recommendation phase of lifecycle which is discussed in Section 4. We further discuss the research work in business process modeling domain with challenges and researchers contributions to address those challenges in the following sections.

Table 2: Business process models for Business-IT alignment

Phase	**Activities**	**Stakeholders**	**Models**
Plan	Requirement elicitation	Managers, domain experts, IT manager	Flow chart, EPC, Use case, package
Design	Mapping requirements into technical services	Domain experts, IT team	DFD, ER diagram, UML Diagrams like class diagram
Implement	Coding, simulation, enactment, and deployment	IT team, managers	UML diagrams, BPMN, Petri nets
Execute	Execution, logging	IT team, employees	BPEL
Evaluate	Measurement and Monitoring	Process owners and Managers	Statistics
Analyse	Performance analysis, business analysis	Managers and process owners	Charts, key performance indicators
Recommend	Defining improvement objective	Managers, process owners, executives	BPMN, Flow chart

3.1 Devising Modeling Languages

New ideas (products) and technological developments increase demands of users towards business process models. These developments also expose the inabilities of modeling languages, and thus enforce researchers to incorporate the new concepts in modeling languages to fulfill their demands. Different new modeling languages are proposed and extended to satisfy the requirements of users.

Business process models are extended to represent the involved business elements with more details like legislations, risks, or involved roles. Similarly, successful modeling techniques of other domains are also applied in business process modeling like Petri nets [50] were applied in workflow management [67]. Several other extensions of Petri nets are also proposed to apply them more effectively in business process domain like Workflow nets [68], Object Oriented Petri nets [47], and Attributed Petri nets [21].

BPMN [8] are also devised to provide graphical notations for communication between business and technical users. The BPMN core set of elements focuses on the control perspective [49] while extended set of elements attempts to address other perspectives like organization (roles using swim lanes) [53].

3.2 Integration of Modeling Approaches

Most of the papers on comparison of business process modeling techniques suggest that a single technique of modeling is not sufficient and propagate the combination of modeling techniques [13, 17]. The reasons behind such motivations are to use the strong characteristics of modeling languages in phases. In [17], authors suggest to combine the graphical (flow charts) and tabular techniques to increase the understanding and improving the communication between stakeholders in business process models. In [20], authors maps and merge different modeling constructs of one language to another language for integration of process models for the purposes of system configurations. Similarly in [46], authors combine the object oriented and workflow modeling techniques for the purpose of business process reengineering.

However, integration of different models faces some problems like models at different level of details (coarse and fine granularities) and perspectives are mixed with one another [20]. This causes misunderstanding and confusion in minds of stakeholders. Despite these problems and challenges, integration of modeling approaches is still an interesting research topic and discussed with further details in few case studies like in a recent paper [13], where authors use flow charts([30]) and integrated definition modeling (IDEF0 [1]) language to model the business processes of a banking institution.

3.3 Integrated Framework

Different views and models are built to fulfill requirements of stakeholders. Mostly, these views or models are taken in fragmented parts and can not collaborate or efficiently used with one another [19]. Like models that are developed for a particular phase would not be reused or easily converted for usage into other phase. Similarly, when views are created "as needed" basis in the absence of an integrated framework, then consistency challenges arise as certain assumptions and dependencies are not explicit [9]. These issues support the misconception that process modeling is an overhead and less optimally used in enterprises [20].

The problems encountered in integration of modeling approaches can be addressed by the introduction of an integrated framework of modeling. Motivations for an integrated modeling framework are discussed in [9,10,19]. In [19], authors suggest the need of ERP-style integration of business process model to provide a consistent and coherent picture of enterprise operations from multiple perspectives. In comparison with fragmented parts of a model, the integrated framework ensures the sharing of consistent and common concepts through central repository [9]. The different views of models can be developed using a generic modeling language which is extendable by adding attributes

related to a particular perspective. In [9], authors provide an architectural framework to integrate and synchronized different views of a system. To decide which attributes should be included in a particular view, a matrix/scoring system is also proposed in [9], where weights are assigned to attributes for inclusion in a specific perspective or view.

Different enterprise modeling frameworks are proposed like CIM-OSA (Computer Integrated Manufacturing Open System Architecture) [36] and ARIS (Architecture of Integrated Information Systems) [62]. Research is carried out to effectively apply such frameworks in different scenarios of business process lifecycle. Different modeling languages are also used in such frameworks like in [86], authors use Petri nets in CIM-OSA framework for postal company processes.

3.4 Generic Modeling Language

Different modeling methods are also compared in literature [10,37] and then their strong characteristics are considered to build a generic modeling language to provide maximum benefits [37]. Generic modeling approaches can also be helpful to reuse the concepts introduced in one phase to other phases while maintaining the same notations and semantics for a common and standardize way between users. In [37], authors compare modeling approaches under six perspectives and then propagates to use their strong characteristics for devising a generic modeling method. Different views and perspectives can be built while using the same language.

Usage of generic modeling language for different purposes also poses some issues as it would not fulfill/satisfy all stakeholder demands at a time. Besides the attributes extension, modeling notations are also very critical in business process modeling. Different notational approaches are required for different modeling purposes and audiences [51]. For example, users feel convenient to use Gantt chart diagrams to manage the schedule rather than Petri nets or any other modeling notation. This issue can be resolved by generating models from a central repository using conventional modeling notations. Nevertheless, it requires a mapping function from one modeling concept to another.

3.5 Validation and Verification of Business Process Models

Business process models are investigated for validation and verification before execution. Validation of business processes refers whether business processes behave as expected whereas verification is concerned to check the model is free of logical errors [72]. Different modeling languages are evaluated in this aspect by various researchers. EPC

business models are investigated to check their structural correctness in [45, 69]. Petri nets are also used for validation and verification as they provide formal semantics and graphical notations for understanding business model. Different researchers contributed with the formalisms of Petri nets to check errors in a context of business domain [4, 70]. Different other formalism issues like OR formalism in business process models is discussed in [44]. Similarly, the notion of soundness is introduced in workflow nets [68] to check the correctness of models in business process domain. Other methods are proposed to transform one modeling language into other modeling languages for verification like EPC diagrams to Petri nets [34] or in [79, 80]. Similarly in [35], EPC diagrams are also transformed into UML Activity diagrams.

Business processes are also simulated before execution for validation and to check bottlenecks. Simulation of a business process provides a walk-through to the process where an analyst can see the behavior of business process [85] and identify possible errors. However, validation and verification techniques (like simulation) of business processes verify the syntactical and semantical correctness of a business process. This does not guarantee that their execution will also be correct in reality as discussed in process mining literature [71, 75]. Various studies in the field of process mining [71, 75] show that the execution of business processes in reality differs from the way it is designed or planned. This also holds in organizational projects where the way work is actually done is detached from the standard processes [10]. Similarly in [22], author argue to include different aspects like time and resources in business process simulations.

3.6 Enactment of Business Processes

Business process models are investigated for enactment of resources and execution of a business process. Execution of business processes are supported by workflow management systems. For this phase of business lifecycle, business process models are enhanced with technical information that facilitates the enactment of business processes [85]. In a recent survey on challenges of business process modeling [31], model-driven process execution is rated as the number one challenge in business process modeling domain. Different modeling languages are devised or extended for this purpose. Petri nets are also used for workflow management [68], and different extensions of Petri nets exists like workflow nets [68].

Modeling constructs of BPMN language are transformed into constructs for execution languages such as Business Process Execution Language (BPEL) [33]. In [43], authors proposed a method to transform graph oriented models into execution languages (BPEL). Similarly, in [49], authors claim to improve the transformation of BPMN notations into BPEL.

3.7 Comparative Surveys of Modeling languages

Several surveys [3, 31, 38, 54, 65, 81] and comparisons [17, 41, 55] are made to evaluate business process models in different phases of business process lifecycle. These surveys discuss the strengths and weaknesses of modeling languages empirically [31] and analytically [55]. In analytical surveys, Bunge-Wand-Weber model (BWW model [82–84]) is used for comparison, where constructs of modeling languages are evaluated for representation of concepts. In empirical surveys like [31], feedback from different stakeholders of business process models is incorporated and different issues and research challenges are identified. Such surveys are helpful for providing further directions to research in business process modeling, deciding which modeling language suits the best for certain phases (scenarios), and what are their strengths & weaknesses.

In [41], authors provide a comparative survey of different graphical and rule based modeling approaches. They define the criteria for comparative analysis like expressibility, flexibility, adaptability, and complexity. Moreover, they evaluate different modeling approaches against workflow patterns [76] because workflow patterns are used for functional comparison of processes. Their focus is towards the design and execution time issues. A comparison of modeling languages where a differentiation despite the control flow perspective is made still required.

Diagrammatic notations like flow charts are compared with tabular techniques like activity tables in [17]. The authors use the simplicity, flexibility, visibility, user involvement, and software support characteristics as criteria for the evaluation. A review of different process modeling techniques, their purpose and limitations are discussed in [3]. Similarly, several process modeling frameworks are surveyed in [10] where their purposes and key characteristics are mentioned.

In [25], authors evaluate different modeling language by comparing their support in different perspectives during business process lifecycle. Such evaluation of modeling languages provides a guideline in which situation or phases a particular modeling technique is best applicable. Similarly in [81], authors evaluate business process modeling languages for analysis and optimization of processes and provide a state of the art from this perspective.

3.8 Legislations & Environment

Enterprises have to follow the legislation rules and standards, that are set in the market. Recent legislations like the Sarbanes-Oxley Act (2002) attracted many researchers to accommodate the legislative aspects in business process models. Other researchers focus business process models to provide their support/benefits in order to conform with

these legislations. Business process models are enriched with annotations for better communication between domain experts and legislative officers, for example, control tags were introduced in [58]. Similarly a framework for aligning business processes with compliance is introduced in [57], where process models are also discussed with respect to compliance conformance.

Context of business process is also modeled in business process models [61]. Context of business process includes customer demands, changes in markets, environmental conditions, and other involved elements of business processes. Such approaches are useful to build flexible business process models [48]. Flexible process modeling languages are devised to accept continuous changes in business domain into systems. One aspect of such changes is to adapt them in informations systems, which coined the term adaptive information systems.

3.9 Service Oriented Architecture and Modeling

Service Oriented Architecture (also referred as SOA) is an architectural approach which advocates a set of practices, disciplines, designs, and guidelines to use technologies to support business processes [64]. Business functionalities are implemented in a form of services and different services collaborate with one another to fulfill customer demands. Business process models are also investigated for SOA, for example, in [11] authors propose an approach for designing business processes in a service oriented way. A SOA based architecture framework is explained in [74], where different variants of business process modeling languages are discussed. Similarly, relation between workflow modeling and business processes for service composition is explained in [32]. Different concepts of modeling in service oriented lifecycle are discussed in [5].

A new modeling language is introduced in [6], that addresses challenges posed by nature of SOA like dynamicity and distributedness. In [56], authors attempt to bridge the business & IT gap in SOA domain by proposing a method to transform business process diagrams (BPMN) into UML service diagrams. ARIS framework [62] and EPCs are also investigated in [66] to devise a new modeling language for service oriented business process management. A business oriented perspective of service oriented architecture is discussed in [23].

3.10 Other Work in Business Process Modeling

Different other works exist to provide better modeling support in business process lifecycle. Business process modeling is also investigated to generate context based models.

In [14], authors build views of business process model based on the context where it is used. They develop a domain specific aspect language for this purpose and discuss it in the context of software development.

Inclusion & elimination of certain features in business process models is also investigated. In [22], authors discuss a feature based modeling approach where characteristics like time and cost are included. In [39], a method is proposed to build the business process models from employees task descriptions. A framework for selecting business process models in different phases is provided in [42], where different characteristics of modeling languages are discussed in different perspectives. We summarize the discussed research work of business process modeling domain in Table 3.

Table 3: Research in business process modeling

Category	Strength	Challenges	References
New/Extend Models	Better modeling support Business-IT alignment	New domains and technologies Isolated views	Petri nets [21, 47, 68], BPMN [8, 53]
Integration of models	Integrated views Strong characteristics usage	Combining different levels Consistency issues, updates	Integration attempts [17, 20, 46], examples [13]
Integrated Framework	coherent view of process Consistent models	Different modeling notation Costs	Integration framework literature [9, 10, 19], examples [36, 62]
Generic Modeling	Standard notation in enterprise Reuse of models	Lack of modeling construct abstract, general	Approaches [8, 10, 37]
Validation & Verification	Syntactic & semantic correctness Business process simulation	Require formalism No guarantee for reality	Petri nets related [4, 68, 70, 79], EPC based [45, 69, 80]
Enactment	Model driven process execution Automatic allocation of resources	Dependent on modeling constructs Models into execution language	References [33, 43, 49, 68]
Legislation & Environment	conformance to standards Understanding the context of BPs	Changes in legislations Require enrich representations	Legislations related [57, 58], context related [48, 61]
SOA & Models	Business service orientation	Rapid changes in technologies	References [5, 23, 32, 74], languages [6, 56, 66]
Comparative Surveys	Strengths & weaknesses of models Guidelines for model selection	Defining evaluation criteria Selection of evaluation technique	Comparisons [17, 25, 41, 55, 81], surveys [3, 31, 38, 54, 65, 81]

4 Research Directions

Continuous changes in business markets and technologies demand more functionalities within business process models. Different surveys indicate future research directions by stating current issues and challenges. In the following subsections, we provide some further interesting research topics for further investigation.

4.1 Inter Organizational Processes & Privacy Concerns

An increasing number of enterprises attempt to provide a full spectrum of services to consumers from a single point of service. This involves collaboration of different partners within business processes. Therefore, inter-organizational business process models are devised. In [55], authors found that current modeling language do not fully represent a collaboration perspective of different business partners and their contributions in business processes.

Collaboration between different enterprises and their process model poses the challenge of enterprises' privacy. Enterprises have to participate in processes at different stages that exhibits their process structures to other enterprises. Mostly this challenge is addressed by providing abstract models but these abstract models are of little usage because of less details. Some privacy preserving techniques should also be applied in business process modeling domain as these techniques are already under investigation in other domains such as in data mining [2].

4.2 Extension of Modeling Languages

In a recent survey of modeling techniques [55], authors find that only few modeling techniques represent business process environment. The absence of environment factors from models makes analyses difficult for analysts to understand execution of business processes and their performance. This is because of external factors (e.g., time, weather, market's condition, and employee's skills) which have a direct effect on business operations. How the environment elements can be represented in business models to make them context aware, and self adaptive as is an interesting question. Representing the context in models will be a step towards self adaptive models. Similarly, representation of environment in business process models would also help to understand an unexpected behavior of business processes in a real environment.

Introduction of new legislations and standards should also be incorporated in business process models. For example, a legislative officer may demand for the representa-

tion of environmental performance indicators and other business elements in a business process model for business process analysis.

4.3 Adaptation and Customization of Modeling Languages

Different stakeholders are involved and each wants to view processes in his own domain like monitoring, control, and configuration. Context adaptive views or models are needed to be built based on user demands rather than models built earlier. Such views/-models can be further extended to provide better insights into processes. In [14], context adaptive models are built in software processes domain.

Model adaptation based on its usage by stakeholders can also be considered to provide maximum flexibility to end users. For example, the profile of end users can be maintained which stores personal preferences. Based on this profile, different models can be represented.

4.4 Analytical Modeling Language

Different process models are used for different modeling purposes and audiences as stated in [51]. Most of the modeling languages are designed for the development of information systems. These modeling languages are also used for post execution analysis of business processes. However, using these modeling languages for analyses of business processes is not appropriate, especially after execution, as these models are not designed for this purpose. Post execution analysis of business processes demands explicit representation of business elements with more details in the models. Therefore, an analytical modeling language is required which fulfills requirements of post execution analysis. Some of the characteristics of analytical modeling language are further discussed in [40].

Similarly, current business process models (and analyses) do not give directions about what exactly should be done to improve results and profits. In [73], authors demand that analysis of business processes should result the instructions or guidelines as in case of a navigation system. For example, for reaching a destination, directions like take 300m right and then 200m left are very helpful. Similarly, in case of business processes, what concrete steps should be taken to make improvements in business processes? How this can be achieved is a challenging task and needs further investigation. Business process analyses with descriptive graphical methods can answer such questions, and provide substantial results in business process improvement and optimization [19].

An analytical modeling language should define business processes precisely and

provide semantics for formalism. Important representational elements are needed to be provided for analysis even though formalism becomes complex and hard to define. Because enrichment of models will make their formalism complex, as issue of representation of models and its formalism is discussed in [54]. With the formal definition of enrich models, the analytical data can be automatically integrated in the business process models.

4.5 Structural Challenges of Business Process Models

Restrictions of most modeling languages are not compliant with business processes that occur in reality. For example, only a few modeling languages apply the structural restrictions on process models like workflow nets [68] where more than one input place is not allowed because of the complexity in its formalism, validation, and verification. Similarly, explicit representation of other involved elements is also often avoided. Due to this, business process models do not represent all required details of reality. In a real business process more than one starting place can occur and it requires all business elements to be represented explicitly. This question requires further investigation how reality should be represented in business process models.

Currently most of the structural deficiencies are investigated at a simulation level as described in the Section 3.5. However, investigations to find these deficiencies after process execution are very rare but important for analysis. For example, after an AND split (parallel construct), modeling language suggests that there should be AND join. In real business cases, sometimes this is not the case. How can we find such violations and deficiencies in real business processes executions?

Similarly, different other questions are still needed to be answered like how can weak structures in business process executions be identified? How they can be represented in business process models? The weak structure means that the path on which process execution often leads to failure or most of the time is consumed without significant contribution e.g., iterations. What are alternative paths to avoid failure structures and to use them for improvement and optimization? The best practices of carrying out business operations are also needed to be represented in business process models.

4.6 Discussion

Most of the issues discussed in earlier subsections can be resolved by introducing an integrated framework of modeling. A new integrated framework should be designed with consideration of these challenges. However, a new set of business process models (new

Table 4: Research directions and challenges

Categories	**Challenges**	**Possible resolutions**
Collaboration & Privacy	Improve collaboration between business partners, privacy concerns of business process models	Enrich representations and privacy preserving techniques [2]
Extension of Models	Representation of legislations and environment, new products, domains, and technologies	New business process models, enrich representations
Adaptation & Customization	Different requirements of stakeholders from models	Context adaptiveness [14], feature based model development [22]
Analytical Models	Models for analysis and improvement, representation of reality	Enrich representation, new business process models [40]
Structural Challenges	Structural limitations for formalism, Identifying deficiencies in models and execution of business processes	Graph reduction techniques [60], process mining [75]

models or extension of existing models) will be still required. A part of the centralized repository can store the information about legislations and environment. Business process models with extensions can show the impact of those legislations and environment elements on business objects and operations. Similarly, the central repository can be used to build the different modeling views for better insight into processes.

Business process models should be extended with enrich representation for better understanding and analysis regardless the complexity of formalism. The extended model should provide the clear communication between stakeholders and represent the reality. The issue of validation and verification using formal methods can be addressed by applying structural restrictions on a subset of enrich business process models. This subset can be achieved by applying graph reduction techniques on business process models as applied for analysis and identification of structural conflicts in business process models [59, 60]. In Table 4, we summarize the research direction with challenges and possible ways to resolve them.

5 Summary

In this report, we have discussed business process management with more details. We also provided a model for further explanation of business process context. We described business process lifecycle with more concrete details. We also discussed active research areas in business process modeling domain with a focus on analysis. However, we cannot exclude the possibility that some areas and modeling languages with analysis perspectives are not discussed in this paper. Therefore, we do not claim the completeness of our study. In this study, we also highlighted challenges in business process modeling and provided directions for further research in this domain.

Further research is needed to assess effects of business processes and context on enterprise operations. Changes in technology and context of business processes require a different set of models for phases of business process lifecycle. Therefore, a new set of models are required to address the current challenges of business process modeling.

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